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Good communication always includes an effective transfer of knowledge. As the Chicago Sun-Times columnist Sydney J. Harris once pointed out, communication is not about giving out, but getting through.

Insightful teachers understand the distinction between giving out and getting through.

When my daughter Anica was in the fourth grade, she came home from school one day and described how her teacher, Mrs. De Leon, demonstrated to the class the importance of clear communication. Mrs. De Leon started by giving a lesson on writing clearly. Then she asked each pupil to take out a sheet of paper and pencil and write a set of instructions. “Tell me exactly how to make a peanut butter and jelly sandwich,” she said.

Mrs. De Leon collected the work. “Now we’ll see how well I can follow your directions,” she announced. She shuffled the papers and placed them neatly in a stack on her desk. Next, to the students’ amazement, she opened a drawer and pulled out in quick succession a loaf of bread, a jar of peanut butter, a squeeze bottle of grape jelly, a knife, and a roll of paper towels, all of which she arranged on the desktop next to the papers. Mrs. De Leon called each child, one by one, up to her desk. Reading aloud the student’s own instructions, she made each child a sandwich.

The children discovered, personally and graphically, how easily fragmented phrases and lapses in logic create confusion. One fourth grader got only a smear of peanut butter on her bread, and one just got jelly. One kid collected two pieces of bread alone. Another, to the gleeful howls of his classmates, had peanut butter spread across the palm of his hand. (“You put on the peanut butter,” the boy had written. “Put it on what?” Mrs. De Leon asked with a smile as she grasped his wrist.) Out of nineteen students, only three went back to their desks holding a complete sandwich of peanut butter and jelly correctly layered between two slices of bread.

Dental patients aren’t so different from those fourth graders. What do our patients really know about what we try to teach them? If we gave people a test, asking them to explain back to us what they understand about their treatment, how many would get only the peanut butter, or a lonely crust?

Mrs. De Leon’s demonstration suggests four lessons in communications for dentists. First, establish common ground. Don’t make too many assumptions about what people really grasp. For instance, my daughter Jillian used to take for granted that her friends all knew her dad is a dentist. When she was in the eighth grade, Jillian arrived at softball practice on a hot summer afternoon with gauze in her mouth. “My dad just pulled three of my teeth,” she explained. There was silence in the dugout. Then one of her teammates said, quietly, “When I get in trouble, my dad only puts me in time-out.”

Second, practice precise communication. Explain procedures slowly, and several times. Articulate each step: “Now I’m putting a ring around the tooth to keep the edge of the resin smooth and well formed.” Offer written handouts.

Third, administer a peanut butter and jelly sandwich test. Ask for feedback. See how much you can understand of what your patients explain about their own treatment. I am still surprised at how many people who have three or four crowns in their mouth don’t know what one is.

Fourth, write more than you think you need to in patient charts. Describe procedures precisely so others can understand. Update medical histories, chart existing restorations, and label radiographs. Don’t forget to record clear diagnoses and visible treatment plans. You never know when you’ll have to undergo the peanut butter and jelly sandwich test yourself.

Eric K. Curtis, DDS, MA, MAGD
Associate Editor
Managing Medical Emergencies in Your Practice

In the April AGD Podcast interview, Wes Blakeslee, DMD, FAGD, speaks with Catharine Goodson, DDS, about maintaining an emergency medication kit in the dental office. Dr. Goodson—an authority on emergency readiness for dental professionals—reviews the most common emergencies that occur in the dental practice, the typical contents of emergency medication kits, and the importance of ensuring your dental team is familiar with an established plan of action for emergency situations.
Discover and defend the middle ground

I found the March/April 2015 Ethics column, Case No. 11: Dear John, to be both enlightening and troubling. I dutifully followed the trail of bread crumbs to the destination chosen by the author: “the [doctor’s] professional ethics appear questionable in this case.” While a disclaimer was included that all of the information for this case study was provided from a letter reflecting a one-sided conversation, the overall tone of the article felt narrow and foreordained. If ethics can be defined as a way of systematizing, exploring, and discussing concepts of right and wrong conduct, ethical discussions feel incomplete if only the rightness or wrongness of an isolated decision or action is reported. Perhaps a more effective way to teach ethics might be to accurately describe contrast and allow readers to discover and defend their middle ground. While such a method would require an adjustment to how case studies generally are presented, attacks with “should” and “ought to” frequently paralyze openness to change and activate defense mechanisms.

Exposing that sentiment, I heartily applaud the idea that a general dentist is a valuable asset in the overall care of all patients. I further agree that the specialized care offered by general dentists might have positively impacted the outcomes described in the case reported. I echo concern that the introduction to the patient of the idea that he needed care from an additional specialist may have created a barrier to building trust with a general dentist, and may have confused the patient about where to go to next on his journey toward ideal health.

I do not feel the facts presented in this case study support the consideration of a refund for services rendered, although, should the assumptions made in the report prove to be factual, it is not unreasonable for the dentist to consider.

The self-referral of patients to specialists is a long-standing dilemma in health care. In medicine, more gateways seem to have been erected between primary care specialists and secondary or tertiary care specialists. Perhaps patients could be better assisted in receiving excellent comprehensive care in oral health if the dental profession considers and implements similar safeguards.

I thank the author for her treatment of such a thought-provoking topic.

David A. Keller, DDS, MBA, MAGD, ABGD, FACD
Vancouver, Washington

Response from Dr. Roucka

Thank you for your letter. Your points are well taken. The one-sidedness of the letter in this case is an element that I hoped would be thought provoking. The fact that we are having this dialogue leads me to believe I was successful in that regard.

A monetary refund for care or bad outcomes is a topic that frequently touches a nerve in conversation among health care providers. The fear that the issuing of a refund in such circumstances will be perceived as an admission of guilt is not unfounded or unprecedented. In some cases, however, refunds or account credits may be appropriate.

The major points I hoped to highlight in this dilemma are the dentist’s obligation to provide informed consent and practice within the standard of care as well as the dentist’s and patient’s duty to optimize the treatment outcome. When a patient self-refers to a specialist, treatment cannot be performed in a vacuum. The patient cannot be expected to know the implications of the lack of comprehensive care or noncompliance unless it is explained explicitly in language he/she understands. This responsibility ultimately falls on the dentist.

Hearing only one side of the story in this case complicates the matter, but the clues to the ultimate conclusion that was proposed are the following:

1. The language used in the letter was not appropriate for most lay people. There was a lot of dental jargon. If “informed consent” was obtained using the same level of jargon, then John probably did not fully understand what was being explained to him regarding the root canal itself, the long-term prognosis of the tooth, and the implications of not treating his periodontal disease. Admittedly, this is an assumption in this case based solely on the letter.

2. Should Dr. Huper have performed a root canal to completion for a patient with obvious periodontal disease and no general dentist? Dr. Huper had other options to relieve John’s pain. Perhaps a pulpectomy would have been more appropriate until a full treatment plan was developed.

3. The referral of John to a periodontist instead of a general dentist is also problematic in my opinion. John was in need of comprehensive care first and foremost, not immediate referral to another specialist. Perhaps if he had received comprehensive care, there would be no case to discuss here. Again, this is another assumption based on the contents of the letter.

If Dr. Huper had made the referral to a general dentist, had written the letter in language an average patient could understand, and performed emergency treatment only on tooth No. 2, and the outcome were the same, the conclusion of this case would have been much different from my perspective. He would have practiced within the standard of care.

Once again, I thank you for your thoughtful letter. Ethics is never black and white but occasionally, especially when it comes to important issues like informed consent and the standard of care, it is more black and white than gray.

P.S. I enjoyed your “trail of bread crumbs” analogy. Well put!
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The pros and cons of third molar extractions

Jane A. Soxman, DDS

The decision to recommend the extraction of third molars for teenaged patients requires consideration of the ramifications of the procedure. Before extraction is discussed for a particular patient, a panoramic radiograph should be obtained to determine the presence or congenital absence of third molars. In a study of American adolescents, 15% of the sample were missing at least 1 third molar, and 2% were congenitally missing all 4 third molars. Only 3/4 of patients have all 4 third molars. Tooth bud formation occurs at about 4-5 years of age, initial mineralization at 7-10 years, end crown mineralization at 12-15 years, and eruption at 17-21 years; root formation is completed at 18-25 years of age. The third molar may not be visualized radiographically until a child is about 10 years of age.

Pros
Extraction is typically recommended at ages 15-16 years or when tooth formation has progressed to a furcation. The risk of alveolar nerve damage is reduced if root formation is minimal. If the maxillary third molar is close to the floor of the sinus, extraction may be delayed, however, to avoid inadvertent perforation of the floor of the sinus and/or displacement of the tooth into the sinus.

In younger patients, the overlying bone may lift away with a curette, resulting in more rapid healing and reduced postoperative morbidity and pain because there is less surgical trauma. When postoperative outcomes were compared with the surgical difficulty, patients older than 21 years experienced prolonged recovery for lifestyle and oral function along with pain that lasted for almost 2 days longer than that experienced by younger patients. White & Proffit reported an association between the periodontal pathologies of third molars that affects adjacent, permanent second molars along with increased chances of pericoronitis and symptomatic periodontal inflammatory disease in an environment conducive to anaerobic bacteria. With partial eruption of an impacted mandibular third molar, food may become trapped under the operculum, or the opposing molar may injure the gingival tissue, resulting in pericoronitis. In a study by Garaas et al, 55% of subjects (average age of 25 years) had probing depths of 4 mm or more on the distal surfaces of the third molars.

Impacted mandibular third molars may result in attachment loss and periodontal defects on the distal surfaces of the mandibular second molar. Faria et al found that, prior to extraction, the average probing depth distal to the mandibular second molar was 5.70 mm. Twelve months after surgery, the probing depth was 3.77 mm. The distal surface of the second molar is difficult to floss, promoting caries and gingival inflammation. Jung & Cho found partially impacted mesioangular third molars resulted in a high incidence of both caries and periodontal bone loss affecting the adjacent second molar. Moreover, maxillary third molars often erupt with a buccal inclination, resulting in pain and inflammation caused by the trapping of the buccal mucosa between the maxillary and mandibular molars.

Histopathological studies have shown the presence of cystic changes in up to 50% of patients older than 20 years of age. In addition, early extraction avoids complications that may occur in patients with later health risk factors, such as history of bisphosphonate use, sexually transmitted diseases, chemotherapy, cardiac disease with valve replacements, hypertension, diabetes, or smoking, as well as complications associated with deeper impactions. Dry socket, or alveolar osteitis, occurs 3 times more frequently in females taking oral contraceptives. The presence of unerupted third molars creates a 2.5 times greater chance of an angle fracture of the mandible after a traumatic injury to the face.

The staggering cost of odontogenic infection is also cited as a reason for prophylactic removal of third molars. Fifty-five percent of odontogenic infections requiring hospitalization were caused by third molars. In a 2012 study, overall hospital costs were $749,382 with an average of $17,842 per person.

Cons
Stathopoulos et al found only 2.77% pathology in impacted third molars and concluded that extraction of asymptomatic third molars may not be justified. Kandasamy also reported that it is rare to find the development of cysts and tumors around impacted third molars and that removal may increase probing depth distal to the second molar.

Avoidance of mandibular incisor crowding is often a reason stated for prophylactic removal of third molars. However, studies have shown there is no proof of a causal relationship between third molars and lower incisor crowding. During extraction procedures, muscles and ligaments are stretched, and considerable force to the mandible may occur. The temporomandibular joint may be traumatized if the patient’s mouth is opened beyond the normal range of motion for an extended period of time. Huang & Rue found a 60% increased risk of temporomandibular disorder after third molar extraction in adolescents and young adults.

Complications associated with the risks of anesthesia due to loss of protective airway reflexes and adverse reactions to drugs must be considered as well.

Reaching a verdict
The space between the second molar and the ramus has been cited as the main etiologic factor determining the possibility for impaction. Extraction of premolars for orthodontic treatment may be deemed beneficial for the eruption of mandibular third molars. However, this theory has not proven to be the case. Although adequate retromolar space may be present, it is the inclination of the third molar that determines impaction.
Third molars may become upright during formation and eruption; overdiagnosis of impaction should be avoided. The roots of the mandibular third molars are not fully formed until 18-21 years of age. Once roots are developed, diagnosis of impaction is fairly reliable. To determine impending impaction, one line is drawn through the long axis of the third molar and another line is drawn tangent to the border of the corpus of the mandible. If the angle between the long axis of the mandibular third molar and the border of the mandible is <60 degrees, there is a strong possibility of impaction.16

The recommendation to extract third molars should be made after all parameters are considered. The clinician must be prepared to justify such a recommendation with evidence-based guidelines. If the patient was asymptomatic prior to elective extraction, the possibility of legal action is increased should perioperative or postoperative complications arise. Collaboration with other treating dentists, such as the orthodontist or oral surgeon, is mandatory. Once all of the pros and cons are discussed and acknowledged, the decision to periodically observe or to proceed with timely extraction can be made with the best interests of the patient in mind.

Author information
Dr. Soxman is a general practice residency seminar instructor, a national speaker for continuing dental education, and a diplomate of the American Board of Pediatric Dentistry. She maintains a private practice in Allison Park, Pennsylvania.

References

There is a clinical article on PEDIATRIC DENTISTRY in the online edition.

Clinical outcomes of indirect composite restorations for grossly mutilated primary molars: a clinical observation

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Early in my career, my goal in referring patients to specialists was for the patient to accept the reality that their problems required treatment involving another office and increased cost. Sometimes patients resisted these referrals as I had built good relationships with them and they didn't want to see another practitioner. I believed that I was explaining their conditions clearly and referring when they needed diagnostic or definitive care beyond my ability. I relied on these specialists to make treatment-planning decisions as they had residency training, confidence, and experience that I did not. I was impressed by their examination protocols and their judgments of which procedures would be appropriate and predictable. I used their referral slips to jot down names and treatment categories. Occasionally, patients would return to me a little confused as the specialist had mentioned new considerations for treatment that I hadn't discussed. I referred many patients to specialists, but only a few new patient referrals were sent to me (Fig. 1).

After 37 years of private practice and decades of continuing education, my concept of interdisciplinary dentistry has changed significantly. My practice—restorative dentistry in a fee-for-service setting—is focused on my interests and what I do best, and also allows me to spend extra time with patients. My current relationships with specialists mirror the changes I’ve made in my office. As a general dentist who limits his practice to restorative procedures, I make more referrals to specialists. I also have to demonstrate to these specialists why they should refer comprehensive-care patients to me and why my plan is indicated and predictable. Currently, approximately half of my new patients come from specialists, and many of these specialists are also my patients (Fig. 2).

Today, my goal when referring patients to a specialist is to ensure that they accept optimal care for long-term success. My responsibility is to diagnose and educate patients so that they know what the best treatment is and why that is preferable to any alternative plan. This approach benefits the specialists as they have highly informed patients who are oriented to the positive results provided by specialty care. I can then refine treatment plans with my specialist consults, coordinate all care, and solve occlusal and restorative problems for comfort, esthetics, and stability.

The specialist’s introduction to my office
All of my specialists have visited my office so that they have an in-depth understanding of my practice philosophy, technical dentistry, and treatment-planning protocol. I invite new specialists to my office for individual 2-hour meetings during which they have my undivided attention, similar to the setting of my new patient examinations. Over a casual lunch, the conversation starts with who they are, what influenced them to go into specialty practices, their practice philosophies, techniques and technologies used, and changes that they have made in their practices.

Once I understand who they are, I share my professional evolution and my philosophy of patient care. I show them PowerPoint presentations, videos, mounted diagnostic casts, preparation dies, and provisional restorations of my completed interdisciplinary cases so they can see how I practice. Patient care in my office is based on thorough examination and education followed by appropriate, conservative dentistry designed for long-term success. Using these interdisciplinary cases, I discuss each aspect of the 4 part examination with the specialist: preclinical interview, clinical examination, imaging, and occlusal analysis.

My relationships with new patients start with 90-minute comprehensive examinations; they don't first enter my practice via hygiene or emergency visits. My consistent experience is that patients have a very positive initial visit when there is enough time to examine and explain every problem, when they visualize their dental status, and when they learn how to predictably avoid future breakdown. Most patients comment on how unique this visit is and ask why their previous dentists did not allocate this time. My goals for the comprehensive examination are to gain a thorough understanding of the patient’s problem—as determined by both me and the patient—to foster in the patient an appreciation of my time and knowledge, and to create a complete record from which to develop a treatment plan for long-term stability with only routine maintenance.

The preclinical interview—the most important phase of the examination—is focused on learning who the patient is. This helps me communicate precisely what new patients need to know about future treatment decisions. It is critical to schedule enough time for patients to tell their stories and for them to know that they have been heard. Patients with extensive medical and/or dental histories or highly emotional personalities require...
this time. Conversely, patients who prefer a direct and concise approach need to have the examination proceed in a tightly organized way so that their time is respected. The dentist needs time to assess patients and to determine if their requests or limitations are appropriate for the office.

I conduct my clinical examination process in a co-diagnosis fashion in which I explain the significance of what we are seeing as the patient observes in a mirror. By asking questions and maintaining a dialogue, my objective is to involve patients so that they visualize and understand what is inside their mouths. I use these comprehensive treatment cases to show how each part of a clinical examination relates to the final result. The importance of occlusal analysis with diagnostic casts mounted in centric relation and computerized occlusal analysis is emphasized. I use photographs, radiographs, computed tomography, and magnetic resonance imaging in my diagnoses to convey how restoration is based on the global diagnosis.

Also, at the end of the examination, I educate patients about the details of oral hygiene so they can prevent recurrent problems. It is rare that patients attend to homecare properly. Educating patients on the details of homecare has a profound effect on how they value me and how they take care of themselves over the long term. Specialists need to know how I approach each aspect of patient care so that they can practice congruently. They need to have the same attention to detail and priority of education so that our patients understand optimal dentistry and request appropriate treatment.

**My visit to the specialist’s office**

My best learning experiences have involved spending time in my specialists’ offices. Initially, these visits were designed to learn who they were, what they were doing technically, and to assess whether I might want to specialize in the future. However, I began to recognize the importance of specialists’ interpersonal skills and how their staffs cared for patients. I began to consider whether my patients would fit into a particular specialist’s style of practice or if they would be better suited being seen by a different specialist.

Although continuing education courses and journals have helped me to understand more of what my specialists see and do, the conversations in their operatories during procedures have shown me in 3 dimensions what their concerns and limitations are for each procedure. These experiences have made me a better diagnostician and interdisciplinary team member. I can now tell patients what can be predictably accomplished and what decisions they should consider with each specialist. I have also gained an appreciation for the extensive time and effort my specialists expend during patient care. In some cases, this relationship has progressed to the point that I treat a patient during the same appointment (with restorative procedures) after specialist placement of implants, allowing every detail of the surgery to be discussed.

**Case workup and presentation to the specialist**

Interdisciplinary care requires communication and coordination of treatment planning prior to any procedure. Who a patient is as a person, as well as their concerns, should be the first things communicated to the specialist. I do this for all cases—whether a patient needs a single endodontic procedure or a complex orthodontic-periodontal-restorative treatment plan. A brief statement may contain all the relevant information in the former case; significantly more may be necessary in the latter. I note my experience with the patient and my examination data, the previous dental/endodontic history, and my diagnosis or difficulty in making the diagnosis. Any information that facilitates the specialist successfully meeting, diagnosing, or treating the patient is shared.

Roblee defined unidisciplinary therapy as diagnosis, treatment planning, therapy, and maintenance provided by 1 dentist. Its main deficiency is that the full scope of therapy may not be addressed. Multidisciplinary therapy involves multiple specialists but without an overall understanding of where various therapies fit into a comprehensive treatment plan. Interdisciplinary dentofacial therapy is characterized by regimented diagnostic, treatment planning, and therapeutic procedures with extensive communication between team members. Complex cases typically need restoration or occlusal equilibration to complete treatment. The restorative dentist can coordinate and sequence all specialist treatment so that these final steps are predictable for an optimal result.

The following simple checklist facilitates case discussion with multiple specialists. (1) Create a 1 page list of problems and solutions. Use the data from the 4 part examination detailed above to list the problems and show how they were defined and verified. Outline the proposed interdisciplinary treatment plan and why it is the most appropriate solution for the patient. (2) Specify what the specialist needs to do for each site to achieve these goals, eg, “erupt tooth No. 9 2.5 mm incisally and 1 mm facially.” This section would incorporate the results of my model surgery, diagnostic waxup, or computerized virtual workup. (3) Discuss the appropriateness, predictability, and alternatives to the recommended plan. Many times, the experience of the specialist can help determine a predictable and cost-effective procedure from several possible treatments. (4) Determine the sequence and cost of each phase of treatment. Patients need to know the approximate total time and cost of all aspects of treatment before deciding on their preferred solutions.

In my community, there is an overabundance of highly trained, ethical, and intelligent specialists. In some communities, specialists are not geographically available and unidisciplinary dentistry is required to avoid patient non-treatment. Dentists in this situation need to create relationships with the nearest specialists to learn as much as they can about their techniques, how these procedures may change their office routines, and where their limitations should be. Additionally, dentists in group practice may focus on 1 or 2 specialty procedures and treat patients accordingly.

Specialists have multiple advantages compared to general dentists practicing in a unidisciplinary style. They have completed residency training with extensive experience in clinical diagnosis and treatment, and should understand the relationships between their procedures and a comprehensive treatment plan. Residencies also give a strong scientific foundation for practice that is based on the dental literature. It is not possible to stay current in both the general dentistry and multispecialty literatures. Specialists practice a more narrow scope of procedures, and it is easier to develop expertise in a few compared to many procedures. They are trained to treat complications that a general dentist may not frequently encounter, thus improving
the overall quality of care. A higher volume of several procedures creates an economy of scale that makes it economically feasible to invest in equipment such as surgical microscopes, cone beam computed tomography, multiple implant systems, or piezoelectric handpieces, improving procedure predictability and quality. It is difficult to imagine a general dental office that has all the equipment and materials of an orthodontist, endodontist, periodontist, pedodontist, and oral surgeon.

Dental practice can be a continually positive, evolving professional lifestyle. It may take years of work to develop the scientific knowledge, technical ability, and people skills needed to find fulfillment in dentistry. Integral to providing patients with higher quality, durable, and predictable dentistry is recognizing the complexity of patient problems and developing an appropriate team to treat them. Relationships with specialists who enjoy teaching and appreciate the synergy of high-quality interdisciplinary care are fundamental to building a better practice.

Referrals to and from specialists are primarily based on developing personal relationships reflective of core values such as integrity and lifelong learning. The protocols discussed above will enhance the development of these professional relationships and improve the quality of patient care.

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**References**
A retrospective study on the use of a dental dressing to reduce dry socket incidence in smokers

James T. Murph Jr., DMD • Susan H. Jaques, DMD • Alexander N. Knoell, DMD • Geoffrey D. Archibald, DDS • Stan Yang, PhD

This study assessed the effectiveness of using an oxidized cellulose dental dressing in order to reduce the rate of alveolar osteitis after posterior tooth extraction in smokers. Dry socket incidences of heavy smokers from 4 independent dental clinics, which routinely used oxidized cellulose dental dressings to mitigate dry socket formation between March 2011 and December 2012, were compiled and evaluated. All extraction sites healed uneventfully except for those cases that developed dry sockets. Overall, 1.7% of male patients and 2.2% of female patients developed dry sockets. No conclusive relationship was found between the number of cigarettes smoked and dry socket formation among patients in this study. The results of this study were consistent with the view that gender, age, postextraction regimen, and multiple extractions affect dry socket formation. The results indicate that an oxidized cellulose dental dressing postextraction is a safe and effective method for mitigating dry socket formation among smokers.

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Exodontia: A retrospective study on the use of a dental dressing to reduce dry socket incidence in smokers

Materials and methods
This retrospective study compiled and analyzed the incidence of dry socket as recorded by 4 independent practitioners. These practitioners operated at their own clinics at separate locations in 3 different states (Minnesota, Tennessee, and South Carolina). Between March 2011 and December 2012, the practitioners routinely used oxidized regenerated cellulose dental dressings to control bleeding and mitigate dry socket formation for high-risk patients, such as (but not exclusively) those taking blood thinners and smokers. One practitioner began the use of the dental dressing early and produced the bulk of the data during the full length of the study period. The remaining 3 practitioners did not use the dressing until the last 8 months of the study period and produced significantly less data. To focus on high-risk scenarios with subsequent higher dry socket incidences, the data of all smoking patients, whose extractions involved only posterior teeth (the first premolar to the third molar)—regardless of the systemic health of the patients and independent of whether they had diseases such as blood clotting disorders, hypertension, or diabetes—were included in the study. Each practitioner used his/her own preferred extraction and postextraction regimen. All extractions were traumatic, and no dental implants were performed immediately or planned following extraction. The common link was the use of oxidized regenerated cellulose dental dressings to alleviate dry socket formation for all patients.

Two forms of BenaCel (plugs, 5 mm x 7 mm; sheets, 15 mm x 15 mm) were used by the practitioners. Both forms are made of the same material and exhibit the same performance, differing only in their configurations.34 Generally, sheets were used in third molar extractions and plugs were used in all other posterior sites, depending on the size of the extraction site and the doctor’s preference. According to the manufacturer’s product information, the dental dressing material should dissolve, transforming into a gelatinous material after contact with blood, and then be absorbed within 5 days.34 Depending upon the size of the extraction socket, 1-2 units of dental dressing were packed into the extraction site. The dental dressing was inserted into the apex of the extraction site without suture retention—unless the site was shallow or a surgical extraction was performed, in which case a crisscrossed suture was used to keep the dressing in the socket. A roll of wet sterile gauze was placed over the extraction site, and biting pressure was applied by the patient until the bleeding stopped.

In general, patients were instructed to refrain from smoking 1 day before extraction and for at least 1 day postextraction. Extractions were performed with patients under local anesthesia. Postextraction, 3 investigators curedt the sockets, while 1 investigator did not curette except when the site was infected. Patients were instructed to return for treatment if bleeding or excessive pain occurred.

If a patient returned, a diagnosis of dry socket was made based on the following criteria: a constant, radiating pain 3-4 days postoperatively, partial or total absence of a blood clot, and/or tenderness upon palpation.

Dry socket incidences were analyzed for the following variables: patient age, gender, number of packs of cigarettes smoked per day, and curetting status.

Results
The data of 472 patients (all smokers, with 707 posterior extractions performed) were used for this retrospective analysis. Of these procedures, 519 extractions (73%) were generated from 1 clinic, while 47 (7%), 64 (9%), and 77 (10%) extractions were collected from the remaining 3 clinics. The number of extractions reflects the experience and length of time the practitioners used the dressing during the study period and the demographic of the patient population for each clinic. Patients’ ages ranged from 11 to 86. The average ages of male and female patients were 39 and 41 years of age, respectively, with men being a larger proportion of the sample (61%). More than 85% of patients were between 21 and 60 years of age (Chart 1). Each patient’s smoking status was categorized by the number of packs smoked per day. On average, patients consumed 1.1 ± 0.4 packs of cigarettes each day, with a range of 0.5 to 3.0 packs per day. The majority of patients smoked 1 pack of cigarettes per day (Chart 2).
Second and third molar extractions constituted about 50% of all extractions (Chart 3). The remaining extractions included first molar, first premolar, and second premolar extraction sites. Overall, 71% of men and 68% of women received single extractions, and 22% of men and women received double extractions. The remaining patients had >2 extractions during the same visit.

Table 1 lists patient population, number of extractions, and the percentage of patients who developed dry sockets in accordance with the patients’ genders. A total of 10 dry sockets developed in 9 of 472 patients with 707 extractions. Four female and five male patients experienced dry sockets postextraction. One 33-year-old woman who smoked 1 pack of cigarettes per day had 2 dry sockets after multiple extractions from the same visit. Overall, 1.7% of men (1.1% of extractions) and 2.2% of women (1.9% of extractions) developed dry sockets.

Chart 4 shows the percentage of patients in each age bracket that developed dry sockets. The 4 women, who developed a total of 5 dry sockets, were between 33 and 42 years of age; of these women, 2 each were between 33 and 40 (4.7%) and between 41 and 42 (4.4%) years of age. Five dry sockets occurred in 5 men who were between 27 and 54 years of age; of these men, 2 each were between the ages of 41 and 50 (3.0%) and between 51 and 60 (5.1%). One man between the ages of 21 and 30 (1.25%) also developed a dry socket.

Chart 5 depicts the prevalence of dry sockets versus the number of packs of cigarettes smoked by patients per day. The dry socket prevalence ranged from 1.4% for 1 pack per day smokers to 6.3% for 1.5 packs per day smokers. The prevalences of dry sockets were 1.6% and 1.5%, respectively, for men and women who had single extractions, and 2.2% and 3.8%, respectively, for men and women who underwent 2 or more extractions during the same visit.

The number of extractions performed by each practitioner and the practitioner's postextraction regimen (curetting or non-curetting) along with the respective dry socket prevalences are listed in Table 2.

**Discussion**

This work is one of the earliest studies of the use of oxidized cellulose dental dressings to prevent dry socket formation in smokers. Although oxidized cellulose products such as Surgicel (Johnson & Johnson) have widely been used as hemostatic agents to control bleeding postextraction, there have been very few studies on the effectiveness of oxidized cellulose as a wound dressing to prevent or manage dry socket formation.33
Suleiman reported that the use of an oxidized cellulose dressing increased dry socket incidence. In contrast, the dressing used in the present study was found to be biocompatible and noninterfering with wound healing. The administration of the oxidized cellulose dental dressing was reported to be easy and nonintrusive to the practitioner’s regular routine. All study sites achieved hemostasis before patients were discharged from the clinics. Other than the cases of patients who developed dry sockets, postoperative healing was uneventful. There were no reported instances of swelling, discomfort, infection, or prolonged bleeding caused by the use of the dental dressing. The wound healing characteristics of oxidized cellulose dressings observed in this study were similar to the results of a preliminary retrospective study in which no postoperative bleeding, infections, or alveolitis were reported among 150 extractions from 118 patients, including both smokers and nonsmokers.

Dry socket incidence rates among smokers have been reported to range from 6.4% to 40.0% in mandibular third molar extractions and from 3.4% to 12.0% in general extractions, respectively. Dry socket incidence increases with increasing degrees of smoking, and patients who smoke immediately before or after tooth extraction have the highest incidence of dry socket formation. In the present study, approximately 90% of smokers smoked an average of 1 pack per day or more; these patients were considered “heavy” smokers. Despite emphatic instructions to refrain from smoking, the degree of patient compliance with these instructions could not be ascertained. It could be supposed that not all patients complied with the instructions, as some patients were observed smoking immediately after walking out of the clinics. Even so, the overall dry socket incidence rate for posterior extractions in smoking patients was 1.9%. Compared with the reported data in the literature, the relatively low incidence of dry sockets in this study support the hypothesis that oxidized cellulose dental dressings reduce dry socket incidence among smokers.

Female patients showed a slightly higher prevalence of dry sockets compared to male patients (2.2% versus 1.7%). The 4 women who developed dry sockets ranged in age between 33 and 42 years. Given the relatively low overall occurrence of dry sockets in the study, the concentration of dry socket patients in such a narrow age range was significant and suggested that adult, premenopausal female smokers are at an increased risk of developing dry sockets. The 5 men who developed dry sockets ranged in age from 27 to 54. There appeared to be an upward trend in dry socket prevalence among male smokers as age increased, with the older (51 to 60) age group exhibiting a higher dry socket prevalence (5.1%) than other age groups (Chart 4).

There was no trending effect on dry socket incidence with regard to the number of packs of cigarettes consumed per day. However, as approximately 80% of patients smoked 1 pack of cigarettes per day, it cannot be concluded that there is any relationship between the number of packs of cigarettes smoked and dry socket prevalence.

The practitioner who produced the most curette the socket postextraction, while the remaining 3 practitioners did. Both male and female patients showed a higher prevalence of dry socket formation if the postextraction treatment regimen involved curetting. In addition, multiple extractions also resulted in higher percentages of dry socket formation among both genders.

**Conclusion**

The findings of this retrospective study are consistent with those reported in the literature, in that a patient’s gender, age, and postextraction regimen—and along with practitioners’ experience—have been identified as factors affecting the prevalence of dry socket formation, even among smoking patients. While further studies are needed to substantiate the results derived from this retrospective study, it can be concluded that the use of the oxidized cellulose dental dressing appears to be safe and effective in reducing dry socket formation among smokers. Adult, premenopausal female smokers and older male smokers emerged as groups who are at higher risk of developing dry sockets. Multiple extractions in 1 visit and postextraction curetting also resulted in higher dry socket incidences. The overall results appeared to indicate that the use of oxidized cellulose is effective in reducing dry socket incidence regardless of the patient’s systemic health conditions and the practitioner’s treatment modality.

**Author information**

Dr. Murph is in private practice in Conway, South Carolina. Dr. Jaques is in private practice in Holly Hill, South Carolina. Dr. Knoell is in private practice in

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Henderson, Tennessee, and Dr. Archibald is in private practice in North Branch, Minnesota. Dr. Yang works for Unicare Biomedical, Inc., Laguna Hills, California.

Disclosure
Unicare Biomedical, Inc. manufactures and sells BenaCel oxidized cellulose dental dressing, which is largely used in this study. For their efforts, Unicare Biomedical provided BenaCel at a discounted price to the doctors to carry out their procedures and to provide data for this study. In no other way did Unicare Biomedical, Inc. influence the results or behaviors of the doctors involved in this study.

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Unicare Biomedical, Inc., Laguna Hills, CA 949.305.9600, www.unicarebiomedical.com

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What every dentist should know about artificial sweeteners and their effects

Zachary Aaron Starr • Judith A. Porter, DDS, EdD, FICD • Nasir Bashirelahi, PhD

Artificial sweeteners are a ubiquitous commodity on the market. The idea that people can consume a sweet food or beverage with “zero” calories seems too good to be true, and perhaps it is. The longevity and abundance of these products on the market necessitate the study of their mechanisms and their relationships to health and disease, including possible links to obesity, cardiovascular disease, and diabetes.

Today’s evidence-based practice of general dentistry demands a thorough understanding of the wide variety of artificial sweeteners and their physiological effects. Historically praised for their decreased cariogenic potential and caloric neutrality, artificial sweeteners have recently been linked to alterations in the gut microbiota that may generate glucose intolerance.1,2 Glucose intolerance can lead to obesity, Type 2 diabetes, and other expressions of metabolic syndromes. Clinicians must weigh the sweeteners’ benefits as sugar-free dietary options against these recently discovered risks.2

In 1879, Constantine Fahlberg discovered saccharin, which is 300 times sweeter than sucrose, but has a bitter aftertaste.3 Saccharin, like most artificial sweeteners, is not digested or absorbed and therefore provides no caloric contribution to the diet.4 In 1937, cyclamate was created but later banned in the United States due to its potentially carcinogenic properties.

Aspartame, an artificial sweetener composed of 2 amino acids (phenylalanine and aspartic acid), was discovered in 1965. Aspartame is 200 times sweeter than sucrose and lacks saccharin’s bitter aftertaste.5-7 Unlike other artificial sweeteners, aspartame is digested and absorbed and contributes 4 kcal per 1 g of aspartame. FDA guidelines limit daily aspartame intake to 50 mg/kg of body weight (192 oz for adults and 96 oz for children).4

Sucralose (marketed as Splenda), which is produced from sucrose, was discovered in 1979. Approved for use in food and drink in 1999, it is the most widely used artificial sweetener on the market today and is 600 times sweeter than its parent compound.6 Acesulfame potassium, another artificial sweetener which is 200 times sweeter than sucrose, was approved by the FDA for use in food in 1988.4 Neotame surfaced in 2002 and is the most potent artificial sweetener on the market to date—7000 times sweeter than sucrose.3 In terms of use in food products, aspartame and acesulfame potassium rank second and third, respectively, behind sucralose. Artificial sweeteners are most commonly found in carbonated beverages.3

It is worth noting the difference between artificial sweeteners (such as saccharin, sucralose, and aspartame) and sugar alcohols (such as xylitol and mannitol), which are found naturally in foods and plant products. Sugar alcohols provide minor caloric contributions when ingested, separating them from most artificial sweeteners.3

Digestion and absorption of carbohydrates

The breakdown of carbohydrates begins in the mouth with the mechanical processing of food via chewing and the addition of saliva to form a food bolus. Salivary amylase proteins begin the breakdown of starch and polymers of simple sugars into smaller chains of sugars.4 The bolus is then swallowed and driven from the mouth through the pharynx, esophagus, and stomach by peristaltic movements.5 In the stomach, sugars are not broken down but churned and mixed to form a mass known as chyme. Chyme passes to the duodenum, the first section of the small intestine, where it meets a secretion of sodium bicarbonate, a basic solution that neutralizes acid. Further along in the small intestine, enzymes break down the sugar disaccharides into their monosaccharide components; these are then absorbed through specialized cells in the villi and transported into the circulatory system.4

Glucose metabolism and satiation

Rising sugar levels in the bloodstream cause beta cells in the pancreas to release insulin into the blood. Insulin stimulates somatic cells to take up more glucose and hepatic cells to produce a storage product, glycogen, from available glucose.5,7 A homeostatic blood glucose level is considered to be approximately 90 mg per 100 ml. If blood glucose levels drop too low, the alpha cells of the pancreas release glucagon into the bloodstream, producing effects opposite to those of insulin. The opposing actions of these 2 hormones keep glucose levels in a stable range.4-7 In addition to insulin and glucagon, there are other signals—such as glycoproteins (such as GLP-1), hormones (such as leptin and ghrelin), and other metabolic products—that inform the body that it is satisfied and can stop eating.5-7 This state is known as satiation.

Satiation vs satiety

Satiation reflects the cumulative inhibitory feedback that the body has obtained food.3 This feedback comes from digestive, hormonal, cognitive, and sensory cues. When the body is sated, eating usually comes to an end. The time from when a person stops eating to the time of hunger is known as satiety.5 Satiety is variable in duration, depending on the person and the quantity and quality of food consumed. During satiety, the brain’s sensory and cognitive (perceptive) processes interact with the nutrients absorbed from the ingested food.3 Satiety stimulates negative feedback to keep the body in a...
state where it physiologically does not feel the need to eat, facilitating weight control. However, humans can override this inhibitory effect.

**Overeating and the reward pathway of the brain**

A learned brain response can overwhelm the body’s natural “off switch” to food consumption and thus cause overeating. Found in the mesolimbic dopamine pathway, this response acts as a reward system that causes people to eat after meals when they are not truly hungry. Exacerbated by stress, especially in those with belly fat, this reward system allows cues such as drugs, food, or sexual activity to increase dopamine signaling from the nerves of the ventral tegmental area (VTA) to the neurons in the ventral striatal area of the brain. This same pathway facilitates addiction to a specific substance or activity.

Additionally, the dopaminergic pathway can be modulated through different signals in the body, including food. Sweet or very tasty foods can stimulate dopamine release. According to a study performed by Lutter & Nestler, this dopaminergic response to food is thought to intensify the subject’s need for food rewards. This need is demonstrated by increased arousal of the VTA, psychomotor stimulation, and classical conditioning due to food-associated stimuli. Prolonged activation of the reward pathway contributes to intra-cellular adaptations that serve to maintain dopamine signaling homeostasis. Thus, when the reward pathway is activated for long periods of time, cells adapt in order to keep up with the increased dopamine levels being secreted in the brain.

The adaptations observed in the VTA neurons include inhibition of dopamine secretion, neuronal shrinkage, increased tyrosine hydroxylase activity, and increases in the cyclic adenosine monophosphate response element binding protein. These adaptations are thought to be what drives the heightened motivation to secure controlled substances in addicted patients. Similar adaptations have been noted in rodents exposed to very desirable foods for prolonged periods, suggesting that motivation to obtain food rewards can be changed by prolonged activation of the mesolimbic dopamine (reward) pathway in the brain. Humans may exhibit an addiction-like response to food by continually activating this reward center in the brain.

According to a 2010 study by Yang, there are two pathways to food reward: sensory (hedonic) and postprandial. The sensory pathway deals with the taste of food; sweet flavors are perceived by gustatory receptors. Recent research has shown that sweet taste receptors are found in not only the mouth but the entire digestive tract. Signals ascend from the gut to the thalamus, a relay station for sensory and motor signals, and then proceed to the gustatory cortex as well as the frontal lobe of the brain, where decision-making and expectation occur. The orbitofrontal cortex is also thought to be an integral part of the perception of rewards and punishment, resulting in adaptive learning. The mesolimbic dopamine system is then activated to provide a satisfied feeling after a pleasant taste. The second pathway to food reward, the postprandial branch, is dependent on the body’s metabolism of food.

**Artificial sweeteners and satiety**

Natural sweeteners (such as sugars and sugar alcohols) are metabolized and contribute calories to the body, activating the postprandial pathway. When non-nutritive sweeteners—such as saccharin, acesulfame potassium, and sucralose—are ingested, they cannot be digested by the body and therefore do not contribute calories to the diet. While aspartame is digested, its metabolites (aspartic acid, phenylalanine, and methanol) do not make the same contribution to the postprandial pathway. Thus, artificial sweeteners only activate the sensory (hedonic) portion of the food reward system.

This partial activation may contribute to an increased appetite by preparing the body for calories from a sweet flavor but not reinforcing that sweet flavor with activation of the postprandial pathway. According to Fernstrom et al, the amygdala—a part of the limbic system that contributes to the reward pathway—preferentially responds to beverages sweetened with low-calorie sweeteners versus natural sweeteners. Artificially sweetened beverages have also shown the ability to enhance appetite and elevate the preference for sweet flavors. Artificial sweeteners “trick” the body’s signals with a sweet taste but yield no energy. This results in no feeling of satiety. Satiety requires postabsorptive feedback, and artificial sweeteners are unable to provide the needed satisfaction. Activating only the hedonic portion of the food reward system may then cause overeating to compensate for this biological misconception, potentially continuing to activate the mesolimbic dopamine pathway in a vicious cycle.

**Artificial sweeteners and altered gut microflora**

Researchers have begun to look at the gut as a “microbial” organ due to the large number of microbial cells, which outnumber those of its human host. The gut’s resident microbial cells contribute a genome that is 100-150 times greater than that of the entire human genome. The resultant expression of these microbial genes has the power to affect host physiology. Thus, changes in gut microflora can lead to changes in host physiology. A 2014 article published in *General Dentistry* discusses the importance of maintaining a healthy microbiome with probiotics and the negative implications of antibiotic misuse. Other studies have demonstrated that the consumption of common artificial sweeteners can alter gut microflora in both animal and human models. Moreover, the diversity and quantity of gut microorganisms are regulated by diet.

Following human consumption of artificial sweeteners, researchers have noticed an overabundance of *Bacteroides* species and an underrepresentation of *Clostridiales* in some subjects. Similar microbiological patterns have been associated with obese and Type 2 diabetes subjects. These findings have led researchers to question whether our eating behaviors, including moods and cravings for specific foods, are also influenced by this resident microbial population. Alcock et al described a “metagenomic conflict” that pits microbes against hosts in a battle for survival in which both sides are influenced by selective evolutionary pressures. However, research remains inconclusive overall because each subject’s gut microflora response to diet—and specifically artificial sweeteners—is unique.
Association of cardiovascular disease with artificial sweeteners

The American Heart Association and the American Diabetes Association released the results of a National Health Survey that stated that people who consume 2 or more servings of artificially sweetened beverages per day had an associated increased risk for cardiovascular disease and chronic kidney disease. This finding was true when compared with people who drank ≤1 artificially sweetened beverage per month over an 11-12 year span.

Effect of artificial sweeteners on glycemic control

A 2009 statement from the American Heart Association and American Diabetes Association addressed glycemic control and artificial sweeteners. Because many health organizations recommend decreasing sugar consumption to promote glycemic control, many people are turning toward artificially sweetened beverages to give them the desired sweet flavor without the calories or spikes in blood glucose levels. However, after much research, the data are insufficient to determine if artificially sweetened beverages are the silver bullet they were intended to be. They appear to decrease sugar intake, but their negligible energy contribution may contribute to metabolic disturbances, especially if compensatory mechanisms are in place to acquire energy from other sources.

One theory posits that the use of non-nutritive sweeteners enhances appetite to the point that the calories and carbohydrates “saved” from drinking the artificially sweetened beverage are nullified due to increased caloric consumption after a sugar-free beverage or snack.

A study by Mattes & Popkin examined the effects of artificial sweeteners on appetite and food consumption. Eight plausible mechanisms for increased appetite and food consumption were evaluated, but the data collected proved insufficient to determine a causal relationship among the 3 variables. However, other studies found that sucralose ingestion did not stimulate the release of satiating glycoproteins (such as GLP-1) and did not reduce appetite. Furthermore, artificial sweeteners and Type 2 diabetes mellitus were examined in an attempt to prove a correlative relationship in at least 4 studies. While 2 studies showed no association, 2 other studies showed a significant correlation between artificial sweeteners and Type 2 diabetes.

Discussion

Food manufacturers have invested significant money and effort into the development of artificial sweeteners in an attempt to satisfy both the consumers’ addiction to sweetness and their avoidance of calories. The widespread use of these sweeteners has compelled researchers to investigate any possible harmful effects to the body. With the recent discovery of artificial sweeteners’ ability to influence gut microbiota, scientists are closer to establishing a link between artificial sweetener consumption and an increased risk for metabolic disease. In their efforts as clinicians to provide care in the most current evidence-based approach, dentists should share this information and provide personalized counseling to those patients who must monitor their glucose levels or are at high risk for caries. Simply telling patients to substitute sugar intake with artificial sweeteners could be deemed as malpractice and is not in line with current research. Instead, dentists should focus on other dietary suggestions, such as enjoying “sweet” foods in moderation, limiting “real” sugar consumption to meals, and avoiding long-term exposure to sugar throughout the day. It is the authors’ opinion that if patients desire sugar substitutes, dentists should emphasize consumption in moderation and a preference for sweeteners from natural sources.

Conclusion

Artificial sweeteners, seemingly harmless food additives, preferentially activate a reward pathway for sweet flavors. Activation of this pathway can cause compensatory overeating that may nullify the rationale for artificial sweetener use. Artificial sweeteners may also increase the risk for developing obesity, Type 2 diabetes, and other manifestations of metabolic disorders due to their ability to influence gut microflora, but more investigation needs to be done in order to determine causality.

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References

Kinetics of salivary pH after acidic beverage intake by patients undergoing orthodontic treatment

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Fabiana M.G. Franca, DDS, MS, PhD • Roberta T. Basting, DDS, MS, PhD

The saliva of patients undergoing orthodontic treatment with fixed appliances can potentially present a delay in the diluting, clearing, and buffering of dietary acids due to an increased number of retention areas. The aim of this clinical trial was to compare salivary pH kinetics of patients with and without orthodontic treatment, following the intake of an acidic beverage. Twenty participants undergoing orthodontic treatment and 20 control counterparts had their saliva assessed for flow rate, pH, and buffering capacity. There was no significant difference between salivary parameters in participants with or without an orthodontic appliance. Salivary pH recovery following acidic beverage intake was slower in the orthodontic subjects compared to controls. Patients with fixed orthodontic appliances, therefore, seem to be at higher risk of dental erosion, suggesting that dietary advice and preventive care need to be implemented during orthodontic treatment.

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Key words: dental erosion, saliva, pH, acidic beverage, orthodontic patients

The risk of developing carious lesions during orthodontic treatment with fixed appliances is high.1-4 Such risk is related to the presence of brackets, arch wires, and other orthodontic appliances that hinder appropriate oral hygiene.5-7

Considering that orthodontic treatment is usually performed on children and adolescents, who are generally the major consumers of soft drinks and fruit juices, there is concern about the potential of such beverages to increase the risk of dental erosion in patients undergoing orthodontic treatment.8 This concern increases when one considers the growing body of evidence that correlates soft drink intake with dental erosion.9-11 A clinical study by Prietsch et al reported severe dental erosion around orthodontic brackets as a result of the high intake of an acidic soft drink.12

The pathology of dental erosion involves interplay among chemical, biological, and behavioral factors and entails the progressive and irreversible dissolution of the outer layer of the dental tissues and demineralization of the underlying surface.13,14 Among the chemical factors, pH, titratable acidity, and calcium-chelating properties influence the erosive potential of acidic beverages.15 Saliva is the principal biological factor, which acts by diluting, clearing, and buffering acids and providing electrolytes.16 These protective functions are especially important, as the erosiveness of acidic beverages is time-dependent; saliva provides intraoral pH recovery after acidic insults, thus playing a crucial role in controlling the erosive process.17-21 Thus, an understanding of the kinetics of salivary pH following acidic beverage intake would provide a valuable insight into the physiopathology of dental erosion.

Although some studies have measured salivary pH after exposure to acidic beverages or solutions, none have yet monitored the salivary pH of patients undergoing orthodontic treatment with fixed appliances.18,20,22-27 In these patients, the diluting, clearing, and buffering actions of saliva may be delayed due to an increased number of retention areas. Based on this rationale, the aim of this clinical trial was to evaluate the salivary pH kinetics of patients undergoing orthodontic treatment after sipping an acidic beverage.

Materials and methods

Study outline

This randomized, controlled study followed a combination of parallel-arm and crossover designs. Twenty participants undergoing orthodontic treatment with metallic, fixed appliances in both arches and 20 not undergoing orthodontic treatment were included. All participants had their unstimulated and stimulated whole saliva evaluated for flow rate, pH, and buffering capacity. Half of the participants of each group were then instructed to sip but not swallow 15 ml of orange juice, then switch to distilled water with 5% sucrose added. The remaining participants performed the reverse sequence. The pH of the saliva-beverage mixture was assessed at 15 points in time.

Subjects and ethical aspects

The protocols were reviewed and approved by the Sao Leopoldo Mandic Institute and Dental Research Center ethics committee (No. 2011/0418). Written, informed consent to the protocols was obtained from each participant. Volunteers were eligible if they exhibited good conditions of oral hygiene and normal flow rates of stimulated saliva. Volunteers for the group of patients undergoing orthodontic treatment were eligible if they were wearing metallic fixed appliances in both dental arches. Volunteers were excluded if they presented with tooth wear lesions, active caries, extensive direct restorations, indirect restorations, periodontal disease, or reflux disease. Subjects were further excluded if they were wearing removable orthodontic appliances, were taking regular medications, or had any systemic diseases. Smokers and patients suffering from alcoholism, in addition to pregnant and/or breastfeeding women, were also excluded.

Flow rate, pH, and buffering capacity of saliva

Two days prior to commencing, each participant was required to use only the toothpaste and soft-bristle toothbrush provided for the study, refraining from using any other oral product.
Saliva was collected between 8:30 and 11:30 am. All subjects abstained from eating, drinking, or performing any oral hygiene for 2 hours prior to collection. Once seated upright in a chair, the subjects relaxed for 5 minutes and were instructed during the collection to make as few movements as possible, including swallowing. All subjects contributed 1 sample each of unstimulated and stimulated whole saliva. Before the collection, disposable cups were weighed on an electronic scale (ASF11, Marte Cientifica).

For unstimulated saliva, subjects were instructed to sit with their heads slightly down and drain their saliva into 1 of the pre-weighed disposable cups as passively as possible. After 5 minutes of collection, the disposable cup was reweighed. The flow rate was calculated in g/minute, which is effectively equivalent to ml/minute. After collection, the unstimulated saliva was also evaluated for pH, measured using a 3 mm diameter calomel microelectrode (Accumet EW-55500-45, Cole-Parmer) connected to a digital pH meter (W3B, Bel Equipamentos Analiticos LTDA). Salivary buffering capacity was measured as follows. The collected saliva was mixed by inverting the covered disposable cup 5 times, and 1 ml of saliva was then transferred to 3 ml of a 5 mM HCl solution. The mixture was then vortexed for 5 seconds, and the disposable cup was uncovered to allow CO2 to escape; after 5 minutes, the pH of the saliva/HCl mixture was measured using the Accumet EW-55500-45.

After the collection of the unstimulated saliva, subjects were instructed to chew for 30 seconds on a 5 x 5 cm2 piece of paraffin. The saliva produced during this time was then swallowed before the collection was started. Chewing was resumed for 5 minutes, with saliva spat out at short intervals into pre-weighed disposable cups. Samples of stimulated saliva were also measured for flow rate, pH, and buffering capacity.

### Monitoring of salivary pH
Half of the orthodontic subjects and half of the controls were randomly assigned to initially sip 15 ml of orange juice (Fast Fruit Gourmet, GlobalFruit) with a pH of 3.6 and high buffering capacity. The orange juice was at room temperature and kept in the mouth for 10 seconds after which volunteers spat out the orange juice/saliva mixture into disposable screw-capped plastic tubes. Samples of this mixture were collected at 14 time points following the first spitting: 15, 30, 45, 60, 90, 120, 150, 180, 240, 270, 300, 360, and 420 seconds. In total, the orange juice/saliva mixture was spat out 15 times: at 10 seconds after sipping, then every 15 seconds up to 1 minute, next every 30 seconds up to 5 minutes, and finally at 6 and 7 minutes. The participants were asked not to swallow during the time span covered. The pH of each of the 15 samples was measured immediately after spitting, using the calomel microelectrode.

The remaining subjects sipped distilled water with 5% sucrose added (pH 5.8), following exactly the same procedures as described above. Following a 1-day washout period, volunteers switched to sip the other beverage. Thus, half of the participants performed the sequence of orange juice first, switching to distilled water with 5% sucrose added (pH 6.1), while the remainder performed the reverse sequence.

### Statistical analysis
A Student’s t test was applied to assess differences in salivary parameters between participants undergoing orthodontic treatment and those not undergoing orthodontic treatment.

The pH values of the saliva samples collected at the different time intervals were evaluated with a 3-way ANOVA for repeated measurements and with Tukey’s test. The significance level was set at 5%. Statistical calculations were performed using SPSS version 20 software (SPSS, Inc.).

### Results
The Student’s t test demonstrated no significant difference in salivary parameters in either the orthodontic subjects or the controls (Table 1).

Three-way ANOVA of repeated measurements demonstrated a significant interaction between metallic fixed orthodontic appliances and time after sipping ($P < 0.001$). Tukey’s test demonstrated that when subjects sipped water, the salivary pH values in the orthodontic subjects did not differ from those measured in the controls, regardless of the time interval.

For the control subjects, sipping orange juice kept salivary pH significantly lower than sipping the distilled water with

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**Table 1. Salivary parameters measured for control and orthodontic subjects in the study.**

<table>
<thead>
<tr>
<th>Salivary parameters</th>
<th>Subjects</th>
<th>Control (SD)</th>
<th>Orthodontic (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate (ml/min)</td>
<td>Unstimulated</td>
<td>0.60 (0.47)</td>
<td>0.41 (0.28)</td>
<td>0.51 (0.40)*</td>
</tr>
<tr>
<td></td>
<td>Stimulated</td>
<td>1.45 (0.62)</td>
<td>1.59 (0.54)</td>
<td>1.52 (0.58)*</td>
</tr>
<tr>
<td>pH</td>
<td>Unstimulated</td>
<td>6.63 (0.39)</td>
<td>6.70 (0.20)</td>
<td>6.66 (0.31)*</td>
</tr>
<tr>
<td></td>
<td>Stimulated</td>
<td>7.18 (0.23)</td>
<td>7.05 (0.25)</td>
<td>7.12 (0.25)*</td>
</tr>
<tr>
<td>Buffering capacity</td>
<td>Unstimulated</td>
<td>3.57 (1.16)</td>
<td>2.98 (0.37)</td>
<td>3.29 (0.91)*</td>
</tr>
<tr>
<td>(pH)</td>
<td>Stimulated</td>
<td>4.53 (1.18)</td>
<td>4.69 (0.94)</td>
<td>4.61 (1.06)*</td>
</tr>
</tbody>
</table>

Means followed by different lowercase superscript letters denote significant differences between unstimulated and stimulated saliva for each salivary parameter. Abbreviation: SD, standard deviation.
5% sucrose added for up to 60 seconds, during which the salivary pH was below the critical value for enamel (pH 5.5) for 30 seconds. For the orthodontic subjects, sipping orange juice kept salivary pH significantly lower than sipping the distilled water with 5% sucrose added for up to 210 seconds, during which time the salivary pH was below the critical value for enamel for 60 seconds (Table 2).

The Chart depicts the kinetics of salivary pH of the orthodontic and control groups according to the beverage sipped. Salivary pH presented a significant exponential drop, followed by a pH rise to the basal salivary pH values, and was succeeded by a leveling off as a result of orange juice sipping.

Discussion

This trial was designed to test whether the presence of metallic, fixed, orthodontic appliances would retard salivary pH recovery following acidic beverage intake. Orange juice was the beverage of choice as it presents a high buffering capacity, causing saliva to require longer periods of time to neutralize it than other beverages.28-30 In addition, the erosive capacity of orange juice has previously been demonstrated.31 Distilled water with 5% sucrose added was used as the control beverage instead of plain water. This experimental component was an attempt to calibrate the potential gustatory stimulation of saliva provided by both beverages, since orange juice typically has around 5% sucrose occurring naturally.32

Although salivary parameters did not differ between the orthodontic and control subjects, after sipping orange juice, the presence of the orthodontic appliances doubled the time during which salivary pH was below the critical pH for enamel. For the control subjects, the pH remained below 5.5 for 30 seconds, while the salivary pH remained below 5.5 for 60 seconds for the orthodontic subjects. This increase may be attributed to the presence of brackets and arch wires, which create more retentive areas and thereby reduce the effectiveness of saliva in clearing and diluting acids. In addition, fixed orthodontic appliances may potentially preclude the friction exerted by soft tissues, which are known to displace soft drinks adhered to enamel.33

The current results showed that salivary pH substantially dropped in the first 15 seconds for both the orthodontic and control subjects. These 2 curves, however, deviated from one another over time, as the control subjects demonstrated faster recoveries of their salivary pH values. In fact, after 60 seconds, the salivary pH after sipping orange juice did not differ from that after sipping distilled water with 5% sucrose added. Conversely, among the orthodontic subjects, at 210 seconds the salivary pH—as a consequence of orange juice intake—remained significantly lower than that observed for distilled water with 5% sucrose added. Therefore, among the orthodontic subjects, not only was the salivary pH below the critical value for enamel for twice the amount of time when sipping orange juice, it remained significantly lower for 3.5 times longer in comparison to the scenario in which distilled water with 5% sucrose added was sipped.

In this study, salivary pH was monitored using a microelectrode in samples of beverage/saliva mixture spat out into containers. The major advantage of this methodology was the possibility of measuring salivary pH within short time intervals in low saliva volumes and in a very simple manner. In some studies, pH electrodes were held in vacuum-formed splints.20,23,24 The main drawback of such splints is that they can increase salivary flow rate and, therefore, salivary buffering capacity.24 In other studies, intraoral pH was recorded using the microtouch method in which electrode tips are placed on the tooth surface.10,25-27 However, despite the fact that there were no splints, the electrode tips had to be repositioned at different sites within the oral cavity.25 Therefore, using the microtouch method somewhat hinders data acquisition when used within short time periods, such as those in which acidic beverages are kept in the mouth.20,26 In addition, with the microtouch method, a salt bridge needs to be established between a reference electrode and the subject’s finger.27 Another method found in the literature for measuring salivary pH refers to the

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Distilled water with 5% sucrose added</th>
<th>Orange juice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control (SD)</td>
<td>Orthodontic (SD)</td>
</tr>
<tr>
<td>0</td>
<td>6.30 (0.58)a</td>
<td>6.38 (0.43)a</td>
</tr>
<tr>
<td>15</td>
<td>6.65 (0.74)a</td>
<td>6.72 (0.29)a</td>
</tr>
<tr>
<td>30</td>
<td>6.73 (0.80)a</td>
<td>6.71 (0.26)a</td>
</tr>
<tr>
<td>45</td>
<td>6.66 (0.72)a</td>
<td>6.68 (0.34)a</td>
</tr>
<tr>
<td>60</td>
<td>6.66 (0.80)a</td>
<td>6.63 (0.30)a</td>
</tr>
<tr>
<td>90</td>
<td>6.66 (0.65)a</td>
<td>6.60 (0.34)a</td>
</tr>
<tr>
<td>120</td>
<td>6.63 (0.52)a</td>
<td>6.56 (0.39)a</td>
</tr>
<tr>
<td>150</td>
<td>6.56 (0.58)a</td>
<td>6.55 (0.36)a</td>
</tr>
<tr>
<td>180</td>
<td>6.58 (0.48)a</td>
<td>6.50 (0.41)a</td>
</tr>
<tr>
<td>210</td>
<td>6.58 (0.37)a</td>
<td>6.48 (0.43)a</td>
</tr>
<tr>
<td>240</td>
<td>6.63 (0.43)a</td>
<td>6.48 (0.39)a</td>
</tr>
<tr>
<td>270</td>
<td>6.53 (0.37)a</td>
<td>6.46 (0.45)a</td>
</tr>
<tr>
<td>300</td>
<td>6.52 (0.37)a</td>
<td>6.48 (0.41)a</td>
</tr>
<tr>
<td>360</td>
<td>6.54 (0.32)a</td>
<td>6.47 (0.42)a</td>
</tr>
<tr>
<td>420</td>
<td>6.55 (0.27)a</td>
<td>6.49 (0.46)a</td>
</tr>
</tbody>
</table>

Means followed by different lowercase superscript letters denote significant differences within a row. *pH value in relation to critical pH of enamel. ¥pH value in relation to critical pH of dentin. Abbreviation: SD, standard deviation.
usage of telemetry systems from which continuous readings are taken. The main drawback of such telemetric measurements is the requirement of skin reference electrodes, which need to be attached to a subject’s arm. It is important to note that the pH recorded when analyzing the orange juice/saliva mixture in this study reflected the overall pH of the oral cavity and not the values of site-specific locations, which may retain acids distinctively. Therefore, it is possible that acids may be retained longer on dental surfaces than in total saliva, which would create a more problematic erosive scenario, especially in fixed orthodontic patients. In addition, under real-life conditions, not only would one sip be taken but rather repeated sips, therefore increasing the contact time between the beverages and the oral tissues.

Conclusion

Based on the current findings, salivary pH recovery after acidic beverage intake was found to be slow in patients undergoing orthodontic treatment with fixed appliances, potentially placing them at higher risk of dental erosion. Therefore, dietary advice and preventive care should be directed toward patients undergoing orthodontic treatment.

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Disclaimer

The authors have no financial, economic, commercial, and/or professional interests related to topics presented in this article.

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Manufacturers
Bel Equipamentos Analiticos LTDA, Piracicaba, Brazil 19.3435.3534, www.beleng.com.br
Cole-Parmer, Vernon Hills, IL 800.323.4340, www.coleparmer.com
GlobalFruit, Visconde do Rio Branco, Minas Gerais, Brazil 55.32.3551.8200, www.globalfruit.com.br
Marte Cientifica, Sao Paulo, Brazil 55.11.3411.4500, www.marte.com.br
SPSS, Inc., Chicago, IL 312.651.3000, www.spss.com
Fiber posts are widely used to restore endodontically treated teeth. Glass fiber posts are biocompatible, do not corrode, and offer the most favorable optical properties for reproducing the natural aspect of the restored tooth. Resin cements have been widely used for luting fiber posts due to their enhanced mechanical properties. Several factors play a role in the intraradicular bonding of resin-based materials. The peculiar histological characteristics of root dentin, the presence of endodontic smear layers (created either by endodontic instruments or modified by irrigants), and adverse geometric factors—such as the extremely high cavity configuration (C-factor) and the difficult to achieve direct irradiation by light in deep regions of the root canal—are consistent factors that negatively affect the bonding of glass fiber posts to root canal dentin. In addition, the type of bonding system used, the luting cement, and its cure may interfere with hybrid layer formation along the root canal walls, thus affecting post retention. This hybridization is critical in the apical third of the post space due to the difficulty in establishing adhesion in this area.

Traditional resin cements with chemical or dual activation are commonly used to overcome problems in supplying the necessary irradiation of light into the root canal. However, alternative adhesive strategies—such as luting systems with self-etching adhesives—are generally applied on dry dentin and do not require the additional step of rinsing with phosphoric acid, thus eliminating the problem of dentin wetness control. Compared to the traditional resin cements, self-etching adhesives require no previous treatment of the dental substrate, since the stages of acid etching and adhesive system application have been eliminated. The bonding mechanism of self-adhesive cements is based on micromechanical retention and chemical adhesion.

When self-adhesive cements are bonded to dentin, there is a rapid change in pH (ranging from 2.0 to 2.4) that causes an early activation of the matrix metalloproteinase (MMP), along with increased collagenolytic activity (approaching maximum levels). During dentin demineralization, latent MMP is denatured as more proteases are exposed. As a result, collagen fibrils that are not completely protected by resin monomers during dentin hybridization become highly susceptible to hydrolytic degradation.

Chlorhexidine (CHX) has been shown to have an inhibitory effect on endogenous collagenolytic activity in dentin. Although CHX diminishes the loss of bond strength over time, not much is known about the influence of a CHX solution—when applied prior to the cementation of indirect restorations—on the integrity of the bonded interface formed by self-adhesive cements to root dentin.

In 2009, Hiraishi et al speculated that the deterioration of the bonding efficacy of commercial self-adhesive luting cements might be related to the presence of moisture contamination on the dentin surface. Hence, it is of interest to examine the influence of different luting systems and the effect of 2% CHX on the nanoleakage at the cement-dentin interface.

### Materials and methods

Thirty bovine roots were stored for 7 days in a saturated thymol solution at 5°C for disinfection and used within 1 week postextraction. The roots’ inclusion criteria were completely formed apices, without excessive root curvature, and root canals with a diameter smaller than the diameter of a Largo No. 5 bur (DENTSPLY Maillefer), cut to the length of 17 mm. Teeth were divided into 6 experimental groups (n = 3) and restored with different cementation techniques (Table 1).

### Endodontic treatment

For endodontic treatment, a step-back preparation technique was used with stainless steel K-files and Gates-Glidden burs (No. 3-5) (Miltex, Inc.) at the working length; the roots were irrigated with distilled water after every change of instrument. Roots were dried with paper points and filled with gutta percha cones (DENTSPLY Maillefer) using the lateral condensation technique. The roots were stored in distilled water at 37°C.

### The aim of this in vitro study was to evaluate the nanoleakage of fiber posts luted using different adhesive strategies and to investigate the effect of 2% chlorhexidine (CHX) on nanoleakage at the resin-dentin interfaces of self-adhesive cements. The self-adhesive and etch-and-rinse adhesive groups tested demonstrated similar results with regard to nanoleakage. Pretreatment with CHX promoted an adequate seal at the resin-dentin interface for self-adhesive cements.

**Keywords:** nanoleakage, self-adhesive cement, chlorhexidine, fiber post

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**Post luting procedures**

The next step involved the removal of the gutta percha, leaving at least 5 mm of the endodontic filling at the apex of each canal. The post spaces were prepared to a distance of 10 mm from the cemento-enamel junction, using a No. 4 Largo drill (DENTSPLY Maillefer). The roots were separated randomly into 6 experimental groups (n = 3) according to the luting system used: Group 1, Scotchbond Multi-Purpose Plus (3M ESPE) chemical cure etch-and-rinse adhesive + RelyX ARC dual-cured cement (3M ESPE); Group 2, Clearfil SE Bond (Kuraray America, Inc.) self-etching adhesive + ED Primer (Kuraray America, Inc.) dual cure + Panavia F dual-cured cement (Kuraray America, Inc.); Group 3, Clearfil SE Bond’s physical cure + Panavia F; Group 4, Scotchbond Multi-Purpose Plus physical cure + RelyX ARC; Group 5, RelyX U100 self-adhesive cement (3M ESPE); Group 6, RelyX Unicem (3M ESPE) self-adhesive cement.

The glass fiber posts (Reforpost, Angelus Industria de Produtos Odontologicos S/A) were cleaned with 70% alcohol for 1 minute, then dried. Afterward, a silane coupling agent (Silano Angelus, Angelus Industria de Produtos Odontologicos S/A) was applied on each post surface for 1 minute; then, the posts in each of the 6 groups were luted following their respective manufacturer’s instructions (Table 2). The materials were manipulated and inserted into the canal with a Centrix syringe with a metallic tip (Centrix, DFL Industria e Comercio). RelyX Unicem was applied with a capsule and elongation tip provided by the manufacturer. For activation purposes, the dual-cure cements and adhesive systems were cured from the top of the post with a halogen curing light unit (Optilux 501, Kerr Corporation) at 600 mW/cm². To simulate clinical conditions, a wax protection barrier was applied to the external surface of the roots to prevent the passage of light.

**CHX**

To evaluate the effect of CHX in the self-adhesive cements, the prepared root canals were randomly divided into 4 subgroups: Subgroup A, RelyX Unicem; Subgroup B, 2% CHX + RelyX Unicem; Subgroup C, RelyX U100; Subgroup D, 2% CHX + RelyX U100. Prior to cementing the root canals, Subgroups B and D were irrigated with 2% CHX digluconate solution for 1 minute; the excess was dried with absorbent paper points. The luting procedures of the fiberglass posts with self-adhesive cements were performed as described previously.

**Nanoleakage test**

After cementation procedures were performed, the restored roots were stored in relative humidity for 24 hours at 37°C. Using an Isomet 1000 digital cutting machine (Buehler), the roots were sectioned perpendicular to the long axis.

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**Table 1. Luting system, adhesive strategies, and mode of cure used in each group in the study.**

<table>
<thead>
<tr>
<th>Luting system, adhesive strategies, and mode of cure</th>
<th>Composition</th>
</tr>
</thead>
</table>
| 1 Scotchbond Multi-Purpose Plus adhesive system, etch-and-rinse, chemical cure | Upper:
Activator: ethyl, alcohol, benzene sulfonic acid, sodium salt
Primer: water, hydroxyethyl methacrylate (HEMA), Vitrebond copolymer
Catalyst: bisphenol A diglycidyl methacrylate (bis-GMA), HEMA, benzoyl peroxide |
Rely X ARC resin cement, dual cure | Silane-treated ceramic, triethylene-glycoldimethacrylate (TEGDMA), Bis-GMA, silane-treated silica, functionalized dimethacrylate polymer |
| 2 ED Primer, self-etching, self-cure | Primer A: HEMA, N-methacryloyl 5-aminosalicylic acid (5-NMSA), methacryloyloxycetyl dihydrogen phosphate (MDP), water, accelerator
Primer B: HEMA, 5-NMSA, water, initiator, accelerator |
| Clearfil SE Bond adhesive system, self-etching, dual cure | Primer: HEMA, MDP, hydrophilic aliphatic dimethacrylate, dimethylaminopropylmethacrylate, water, accelerators, dyes
Bond: Bis-GMA, HEMA, MDP, hydrophobic aliphatic dimethacrylate, colloidal silica, dimethacrylate polymer, initiators, accelerators |
| Panavia F resin cement, dual cure | Paste A: dimethacrylate, MDP, barium glass powder, sodium fluoride, silica
Paste B: dimethacrylate, MDP, barium glass powder, sodium fluoride, silica, benzoyl peroxide, amine, sodium aromatic sulfonate |
| 3 Clearfil SE Bond adhesive system, self-etching, physical cure | Primer: HEMA, MDP, hydrophilic aliphatic dimethacrylate, dimethylaminopropylmethacrylate, water, accelerators, dyes.
Bond: Bis-GMA, HEMA, MDP, hydrophobic aliphatic dimethacrylate, colloidal silica, dimethacrylate polymer, initiators, accelerators |
| Panavia F resin cement, dual cure | Paste A: dimethacrylate, MDP, barium glass powder, sodium fluoride, silica
Paste B: dimethacrylate, MDP, barium glass powder, sodium fluoride, silica, benzoyl peroxide, amine, sodium aromatic sulfonate |
| 4 Scotchbond Multi-Purpose Plus adhesive system, etch-and-rinse, physical cure | Activator: ethyl, alcohol, benzene sulfonic acid, sodium salt
Primer: water, HEMA, Vitrebond copolymer
Catalyst: Bis-GMA, HEMA, benzoyl peroxide |
| Rely X ARC resin cement, dual cure | Silane-treated ceramic, TEGDMA, Bis-GMA, silane-treated silica, functionalized dimethacrylate polymer |
| 5 RelyX U100 resin cement, self-adhesive, dual cure | Glass powder, methacrylated phosphoric acid esters, TEGDMA, silane-treated silica, sodium persulfate, glass powder, substituted dimethacrylate, silane-treated silica, sodium p-toluene sulfinate, calcium hydroxide |
| 6 RelyX Unicem, resin cement, self-adhesive, dual cure | Powder: glass powder, silica, calcium hydroxide, substitute pyrimidine, peroxy compound, pigment, initiator
Liquid: methacrylated phosphoric ester, dimethacrylate, stabilizer, initiator |
The first slice (1 mm thick) of each root was discarded. The samples were cleaned with 10% liquid phosphoric acid for 10 seconds, washed, and submitted to ultrasound for 10 minutes. Next, each specimen was immersed in a 50% ammoniac silver nitrate solution for 24 hours in dark conditions at 37°C. The specimens were then thoroughly rinsed in distilled water for 2 minutes and immersed in a photo-developing solution for 8 hours (Kodak Developer D-76, Eastman Kodak Company) under fluorescent light, in order to reduce silver ions to metallic silver grains along the bonded interface, adhesive resin, and cement polymeric structure. Next, the stained specimens were embedded in a polystyrene resin and wet-polished sequentially with aluminum oxide papers (600, 1200, and 2000 grit) and finished with a diamond paste of decreasing grain using a metallographic polisher (PL02, Arotec SA). After each step of the polishing procedure, the specimens were immersed in distilled water and placed in ultrasonic baths (Ultrasone D 1440, Odontobras) for 10 minutes.

The specimens were dried with absorbent papers and immersed in a solution of 50% phosphoric acid for 10 seconds, followed by rinsing in distilled water. For deproteinization, a 10% solution of sodium hypochlorite was used for 10 minutes. The specimens were then rinsed, dried at room temperature for 2 hours, and dehydrated with ethanol (at increasing concentrations of 25%, 50%, 75%, 90%, and 100%), for 10 minutes each. The specimens were carbon-coated (SCD-050 Sputter Coater, Leica Microsystems) and analyzed in a scanning electron microscope (SEM) (JEOL Ltd.) at 15 kV. The images of silver-infiltrated specimens were taken in order to calculate the marked area using the computer software Image Tool 3.0 (University of Texas, Health Science Center at San Antonio). The integrity of the interface in each third was then expressed as the percentage of the continuous (gap-free) interface. The percentage of the continuous interface along the entire cement-radicular dentin interface was also calculated.

**Statistical analysis**

Data were analyzed using ANOVA followed by Tukey’s test at a 5% level of significance ($P = 0.05$).

Statistical analysis of the data obtained in the nanoleakage test was performed according to a casual split-plot design, in which the factors under study were the cements, the plot, and the root third; Tukey’s test was applied.

**Results**

**Nanoleakage evaluation**

ANOVA indicated statistically significant differences between the different luting cements, the plot, and the root third; Tukey’s test was applied.

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**Table 2. Bonding procedures used in the study.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Dentin pretreatment</th>
<th>Resin cement application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Etch-and-rinse</td>
<td>Apply etch (37% phosphoric acid) for 15 seconds. Rinse with water and dry with paper points. Apply primer. Dry with gentle airflow for evaporation of solvent (5 seconds). Apply adhesive (Scotchbond Multi-Purpose). After each application, remove excess with paper points. Light cure for 10 seconds.</td>
<td>Dispense Rely X Arc cement onto mixing pad and mix for 30 seconds. Apply mixed paste with aid of Centrix syringe and seat post in root canal. Remove excess cement. Light cure for 40 seconds.</td>
</tr>
<tr>
<td>2 Self-etching</td>
<td>Clearfil SE Bond: Actively apply primer for 20 seconds. Dry with gentle airflow for evaporation of solvent. Apply adhesive (Clearfil SE Bond). Dry with gentle airflow for 3 seconds. After each application, remove excess with paper points. Light cure for 10 seconds. ED Primer: Mix 1 drop each of Primers ED-A and ED-B. Apply mixture to root canal; leave in place for 60 seconds. Remove excess primer with paper points. Dry with gentle airflow.</td>
<td>Mix Panavia F paste A and paste B for 20 seconds. Apply mixed paste with aid of Centrix syringe and seat post in root canal. Remove excess cement. Light cure for 40 seconds.</td>
</tr>
<tr>
<td>3 Self-etching</td>
<td>Actively apply primer for 20 seconds. Dry with gentle airflow for evaporation of solvent. Apply adhesive (Clearfil SE Bond). Dry with gentle airflow for 3 seconds. After each application, remove excess with paper points. Light cure for 10 seconds.</td>
<td>Mix Panavia F paste A and paste B for 20 seconds. Apply mixed paste with aid of Centrix syringe and seat post in root canal. Remove excess cement. Light cure for 40 seconds.</td>
</tr>
<tr>
<td>4 Etch-and-rinse</td>
<td>Apply etchant (37% phosphoric acid) for 15 seconds. Rinse with water and dry with paper points. Apply Scotchbond Multi-Purpose activator and gently agitate for 5 seconds. Apply catalyst. After each application, remove excess with paper points. Light cure for 40 seconds.</td>
<td>Dispense Rely X ARC cement onto a mixing pad and mix for 30 seconds. Apply mixed paste with aid of Centrix syringe and seat post in root canal. Remove excess cement. Light cure for 40 seconds.</td>
</tr>
</tbody>
</table>
systems and between interactions of luting systems and root thirds. The results of Tukey’s test are presented in Table 3.

Group 3 presented greater nanoleakage in the apical third, with statistically significant differences between the middle and cervical thirds (Fig. 1A). A statistically significant difference was also found in the apical thirds of the other groups.

The resin tags formed inside the dentinal tubule by the specimens in Group 3 were short and/or not very pronounced (Fig. 1B). A lower mean nanoleakage percentage was achieved by the Group 1 specimens in the apical third, but it did not differ significantly from the other remaining groups (Fig. 2A). It was also possible to observe extensive resin tag formation inside the dentinal tubules in Group 1 specimens (Fig. 2B).

In the specimens of Groups 5 and 6, the SEM images showed no formation of a hybrid layer at the adhesive interface of these cements. This was also true with Subgroups B and D which were pretreated with CHX. All the specimens of self-adhesive cement presented nanoleakage (Fig. 3 and 4).

**Nanoleakage evaluation for CHX**

ANOVA indicated statistically significant differences between the self-adhesive cements not pretreated with CHX and the self-adhesive cements treated with CHX. No difference was observed among the root thirds of the CHX groups. The results of Tukey’s test are presented in Table 4.

**Discussion**

Fiber posts can be cemented using conventional dual-cure resin-based cements in combination with etch-and-rinse or self-etch adhesives, or by using the recently formulated self-adhesive cements that allow simultaneous bonding between the root dentin and the post. Due to the large variety of products and the intrinsic difficulties of bonding within the endodontic space, the use of an adequate luting strategy is particularly important as it directly affects the quality of the tooth-luting interface.13,20

When the nanoleakage patterns between the root dentin and the luting system were evaluated, a better quality, thicker hybrid layer with long resin tags in the dentinal tubules could be observed for Group 1 at the apical thirds (Fig. 5). With the exception of Group 3, there were no statistically significant differences for the other groups. A 3-step etch-and-rinse adhesive system increases the interfacial adaptation of dual-cure luting cements because it increases

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**Table 3. Mean nanoleakage percentage and standard deviation (SD) for the luting systems and the root thirds.**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>17.56 (2.28)</td>
<td>17.52 (1.12)</td>
<td>23.64 (2.17)</td>
<td>21.85 (2.18)</td>
<td>13.32 (0.71)</td>
<td>23.26 (2.65)</td>
</tr>
<tr>
<td>Middle</td>
<td>15.49 (1.99)</td>
<td>24.09 (4.25)</td>
<td>23.02 (3.36)</td>
<td>20.88 (3.86)</td>
<td>15.79 (4.04)</td>
<td>21.07 (7.64)</td>
</tr>
<tr>
<td>Apical</td>
<td>12.23 (3.89)</td>
<td>22.65 (2.07)</td>
<td>37.11 (1.13)</td>
<td>20.42 (7.30)</td>
<td>16.43 (3.18)</td>
<td>20.43 (5.30)</td>
</tr>
</tbody>
</table>

Data with same superscript letters (uppercase for rows, lowercase for columns) are not significantly different (P < 0.05).

Groups: Group 1, Scotchbond Multi-Purpose Plus chemical cure + RelyX ARC; Group 2, Clearfil SE Bond + ED Prime dual cure + Panavia F; Group 3, Clearfil SE Bond physical cure + Panavia F; Group 4, Scotchbond Multi-Purpose Plus physical cure + RelyX ARC; Group 5, RelyX U100; Group 6, RelyX Unicem.
adhesive penetration into the dentinal tubules, forming long resin tags in the tubules that are opened by acid etching, thereby improving the pattern of dentin hybridization.21 However, during the post space preparation, a thick smear layer was created on the root canal walls (mainly in the apical third) which, due to the root’s anatomical configuration, favors the accumulation of debris in the apical region. In this sense, the dentin pretreatment with the use of phosphoric acid in the etch-and-rinse technique may have been the determining factor in the lower nanoleakage percentage at the apical third in Group 1 compared to Group 3 (P < 0.0001). It is possible that the self-etch adhesive used in Group 3 (Clearfil SE Bond) was not acidic enough to etch the dentin surface and dissolve the thick root dentin smear layer accumulated in the apical region.

On the other hand, specimens of Group 2 (self-etching adhesive strategy) showed values in the apical third similar to the ones found in Group 1 (etch-and-rinse adhesive strategy). Group 2 incorporated the dual-cured Panavia F cement with the self-etching Clearfil SE Bond and the self-etching and self-curing ED Primer. The use of Clearfil SE Bond without the ED Primer in Group 3 may have contributed to poor infiltration of the resin cement-dentin interface due to possible incompatibility with the dual-cured Panavia F resin cement. After photoactivation of Clearfil SE Bond, a nonpolymerized resin layer (with a pH of 1.35) remained on the top of the polymerized adhesive resin layer due to an oxygen interaction.22,23 The acid resin monomers—caused by oxygen inhibition in the nonpolymerized adhesive residual layer—react with the tertiary amine of the resin cement.24 Moreover, these adhesives promote a permeable hybrid layer, allowing water diffusion from the dentin and forming water droplets along the adhesive resin-cement interface, which may have contributed to the significant interfacial nanoleakage demonstrated in the apical third of the specimens of Group 3.25 The further application of the ED Primer in Group 2 of this study probably helped eliminate the inherent incompatibility between the self-etch adhesive Clearfil

### Table 4. Mean nanoleakage (%) and standard deviation (SD) for the self-adhesive cements pretreated with chlorhexidine (CHX).

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean % (SD)</th>
<th>Tukey’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>RelyX Unicem with CHX</td>
<td>9.17 (2.47)</td>
<td>a</td>
</tr>
<tr>
<td>RelyX U100 with CHX</td>
<td>9.27 (3.16)</td>
<td>a</td>
</tr>
<tr>
<td>RelyX U100 without CHX</td>
<td>15.18 (2.96)</td>
<td>b</td>
</tr>
<tr>
<td>RelyX Unicem without CHX</td>
<td>21.59 (5.00)</td>
<td>c</td>
</tr>
</tbody>
</table>

Data with same lowercase letters are not significantly different (P < 0.05).
The multifunctional, phosphoric acid-modified, methacrylate monomers of RelyX U100 (pH <2) demineralize root dentin as well as infiltrate the substrate and react with the hydroxyapatite of hard tissues. The micromechanical retention associated with the chemical adhesion to hydroxyapatite provides self-adhesiveness to the RelyX U100 cement. This chemical interaction produces water, which accelerates neutralization of phosphoric-acid methacrylate, basic fillers, and hydroxyapatite. The system likely gained water resistance, and, although water and buffering of the smear layer may have reduced demineralization capacity, the effectiveness of the RelyX U100 cement was not compromised.

The analysis of the results of the effect of 2% CHX pretreatment on the adhesive interface quality of self-adhesive resin cements showed significantly lower nanoleakage on the tooth-luting interfaces that were pretreated with CHX prior to luting with self-adhesive systems. The decreased nanoleakage results of the self-adhesive cements results can be explained by the increase in the dentin surface energy, and the interaction between the dentin surface and the resin cement is strongly dependent upon the equilibrium of high surface energy and high wettability.

In addition, self-adhesive cements do not require acid etching. Thus, when CHX is applied to smear-covered dentin surfaces, it can partially remove the smear layer and even expose some underlying dentinal tubules. CHX has cationic properties, thereby enabling it to bind to phosphorated groups in apatite, and thus producing a strong affinity for tooth surfaces.

This study assessed the interfacial nanoleakage of fiber posts after 24 hours of water storage. The results showed that the extension of silver nitrate deposition along the bonded interface of fiber posts was significantly influenced by the luting system. However, the study findings do not indicate with certainty that any of the 3 investigated adhesive approaches is better than the others. It is possible that a longer storage time and/or thermal cycling in future studies would give different results. Nevertheless, according to the results observed in this study, the self-etching approach may offer less favorable adhesion to root canal dentin in comparison with etch-and-rinse or self-adhesive approaches.

Based on these findings, clinicians should be aware that, although in the majority of clinical investigations fiber posts are cemented using dual-cured resin cements with etch-and-rinse adhesives, the number of clinical steps in these procedures might favor the occurrence of errors. Scientists and manufacturers have been continuously challenged to simplify clinical procedures. The self-adhesive cements require no technique-sensitive steps and should therefore be considered as an interesting alternative for luting of intracanal posts because they also present a satisfactory performance, as indicated in the results of the laboratory nanoleakage test in this study. Regarding the effect of dentin pretreatment with CHX, in addition to the inhibitory effects of CHX on dentin proteases, the application of CHX appears to promote an adequate seal at the resin cement-dentin interface.

Conclusion

Within the limitations of this study, it was possible to conclude that Group 3 (Clearfil SE Bond + Panavia F) group showed higher nanoleakage patterns in the apical third compared to the other groups; the specimens of the self-adhesive strategies groups (Groups 5 and 6) demonstrated similar results as compared to the conventional etch-and-rinse adhesive strategies; and in CHX-treated adhesive interfaces of self-adhesive luting cements, reduced uptake of silver particles was observed.

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References


The 15 questions for this exercise are based on the article, *Nanoleakage of fiber posts luted with different adhesive strategies and the effect of chlorhexidine on the interface of dentin and self-adhesive cements*, on pages 31-37. This exercise was developed by Kim Capehart, DDS, MBA, PhD(c), in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing this exercise will enable you to:
- identify the characteristics of fiber posts and dentin using various adhesive strategies;
- identify the effects of various luting systems and chlorhexidine (CHX) in dentin; and
- recognize the advantages of the various luting systems used for luting fiber posts.

### Questions

1. All of the following are consistent problems that affect the bonding of glass fiber posts to root canal dentin except one. Which is the exception?
   - A. adverse geometric factors
   - B. peculiar histological characteristics of root dentin
   - C. presence of accessory canals
   - D. difficulty in achieving direct irradiation by light in deep regions of the root canal

2. Hybrid layer formation is critical in the ______ of the post space.
   - A. entire length
   - B. coronal third
   - C. middle third
   - D. apical third

3. The pH range that occurs immediately after mixing self-adhesive cements is _______.
   - A. 1.5-1.9
   - B. 2.0-2.4
   - C. 2.5-2.9
   - D. 3.0-3.4

4. CHX has been shown to have (an) _______ effect on the endogenous collagenolytic activity in dentin.
   - A. no
   - B. unknown
   - C. inhibitory
   - D. unrestrictive

5. All of the following were inclusion criteria of the bovine roots except one. Which is the exception?
   - A. multiple canals
   - B. completely formed apices
   - C. no excessive curvature
   - D. roots with tight canals

6. After the storage of the roots, the gutta percha was removed and at least ___ mm of endodontic filling was left at the apex of each canal.
   - A. 1
   - B. 3
   - C. 5
   - D. 7

7. The glass fiber posts were cleaned with _____ % alcohol for 1 minute followed by drying.
   - A. 60
   - B. 70
   - C. 80
   - D. 90

8. The specimens were carbon-coated and analyzed by a scanning electron microscope at _____ kV.
   - A. 10
   - B. 15
   - C. 20
   - D. 25

9. Data were analyzed using ANOVA followed by ______ test at a 5% level of significance.
   - A. Fisher's LSD
   - B. Student Newman-Keuls (SNK)
   - C. Cronbach's alpha
   - D. Tukey's

10. The resin tags formed inside the dentinal tubules by Group 3 specimens were short and/or not very pronounced. A lower mean nanoleakage percentage was achieved by the Group 1 specimens in the apical third.
    - A. Both statements are true.
    - B. The first statement is true; the second is false.
    - C. The first statement is false; the second is true.
    - D. Both statements are false.

11. The acid resin monomers in the nonpolymerized adhesive residual layer react with the ______ amine of the resin cement.
    - A. primary
    - B. secondary
    - C. tertiary
    - D. quaternary

12. RelyX Unicem has a chemical interaction with hydroxyapatite that may be based on the chelation of the _______ ions.
    - A. magnesium
    - B. phosphorus
    - C. calcium
    - D. oxygen

13. Cationic properties of _______ enable the binding of phosphorated groups in apatite, producing a strong affinity for the tooth surface.
    - A. phosphoric acid
    - B. hydroxyapatite
    - C. CHX
    - D. modified methacrylate monomers

14. The group consisting of Clearfil SE Bond combined with _______ showed higher nanoleakage patterns in the apical third compared to other groups.
    - A. RelyX Unicem
    - B. ED Primer
    - C. CHX
    - D. Panavia F

15. CHX-treated adhesive interfaces of self-adhesive luting cements reduced the uptake of _______ particles.
    - A. hydroxyapatite
    - B. calcium
    - C. magnesium
    - D. silver

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**Answer form is on the inside back cover. Answers for this exercise must be received by April 30, 2016.**
Computer Designed/Fabricated Crowns

Microcomputed tomography marginal fit evaluation of computer-aided design/computer-aided manufacturing crowns with different methods of virtual model acquisition

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This in vitro study used microcomputed tomography to evaluate the marginal fit of crowns fabricated using a chairside computer-aided design/computer-aided manufacturing (CAD/CAM) system with different methods of virtual model acquisition. Crowns were fabricated to fit in a cast containing a single human premolar. Four methods of virtual model acquisition were used: Group 1 (control), digital impressioning of a typodont; Group 2, digital impressioning of a powdered typodont; Group 3, digital impressioning of a regular impression; and Group 4, digital impressioning of a master cast. Statistically significant differences were found between the marginal gap of Group 2 and the other groups (P < 0.05); no differences were found among Groups 1, 3, and 4. The results showed that crowns fabricated using the chairside CAD/CAM system exhibited significantly smaller vertical misfit when a thin layer of powder was applied over the typodont before digital impressioning.

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Ceramic crowns can be produced using different techniques, including computer-aided design/computer-aided manufacturing (CAD/CAM) procedures, available in dental practices, laboratories, and production centers.1 The major advantage of this technology when compared to conventional fixed prostheses is the reduction of both chair and laboratory time.2

A new CAD/CAM material, Lava Ultimate Restorative (3M ESPE), is a resin nanoceramic block that reportedly achieves superior esthetic results and can be used in chairside CAD/CAM systems (E4D, E4D Technologies LLC).3-5 These blocks are made of nanoceramic particles embedded in a highly cured resin matrix; therefore, glaze firing is not recommended, as it would melt the restoration. This nanoceramic material only needs to be subjected to a polishing process before fixation, thus enabling intra- or extraoral adjustments.3

An important issue to consider regarding the clinical success of an all-ceramic restoration is the marginal fit.6-8 There is currently no consensus regarding a defined clinically acceptable marginal fit. Some studies have shown that a marginal fit ≤120 µm is clinically acceptable, whereas others have recommended ≤100 µm or ≤75 µm.9-14 The survival of ceramic inlays is also fundamentally dependent on durable bonding.15

Stereomicroscopy, scanning electron microscopy, optical microscope and microcomputed tomography (µCT) are methods used to evaluate marginal fit.7,11,16-26 Stereomicroscope techniques require a transverse section of the sample to measure the marginal gap, but this procedure can cause sample deformations.13 Analyses involving a scanning electron microscope can be inaccurate, considering the overlap, depending on the positioning of the sample.22 The µCT system can be relatively expensive; however, it is a nondestructive method.24-27 This 3-dimensional (3D) system also provides detailed high-resolution imaging, allowing an internal view of the sample.28,29

To date, there has been little research on the marginal fit of resin nanoceramic crowns captured using the E4D chairside CAD/CAM system.3 In this study, µCT was used to evaluate the marginal fit of crowns. The null hypothesis of this study was that different methods of virtual model acquisition would not influence the marginal fit of resin nanoceramic crowns.

Materials and methods
Sample preparation
A human mandibular left first premolar and adjacent teeth were fastened to a typodont model and prepared by an experienced operator for an all-ceramic crown. This procedure was approved by the Federal University of Uberlandia Ethics Committee (381/06). A standard set of diamond burs (1014, 3145, 3098, and 3098F, KG Sorensen) was used. The preparation was free of undercuts, the angles were rounded, and the walls were tapered 6 degrees to the occlusal surface. The margins were prepared with shoulders and rounded axiogingival line angles.30

Restoration fabrication
The 4 experimental groups were based on different methods for acquiring the virtual models. All groups used Lava Ultimate Restorative and were designated as Group 1 (control), digital impressioning of a typodont; Group 2, digital impressioning of a typodont with a thin layer of titanium dioxide powder; Group 3, digital impressioning of a regular impression; and Group 4, digital impressioning of a master cast.

The same scanning technology (E4D laser scanner, E4D Technologies LLC) was used for the 4 groups. For the control group (Group 1), 5 digital impressions were made of the prepared tooth fastened to a typodont. For Group 2, 5 digital impressions of the prepared tooth were made, but not before a thin layer of...
powder (ES-CAD Spray, Henry Schein Dental) was applied. For Group 3, 5 regular impressions with heavy and light vinyl polysiloxane impression material (Imprint 3 Quick Step, 3M ESPE) were taken from the prepared tooth. For Group 4, 5 regular impressions with Imprint 3 Quick Step were made to obtain 5 stone dies with type V dental stone (Die-Keen Green, Heraeus Kulzer). For all 4 groups, the same operator made all the impressions at room temperature and obtained all the stone dies.

The crowns were designed for all 4 groups using E4D DentaLogic software (version 2.0, E4D Technologies LLC) with luting space and an adhesive gap set to 10 µm. Finally, an E4D mill (E4D Technologies LLC) was used for CAM processing of the designed crowns. The same experienced operator made all the crowns.

Measuring procedures
No adjustments were made to the ceramic crowns before marginal fit measurements. The prepared tooth was removed, and each crown was fixed to the same tooth using silicone material (Fit Checker, GC America, Inc.). To acquire images for marginal fit measurements, all specimens were scanned using µCT (SCANCO CT40, SCANCO Medical AG). Imaging was performed at 70 kVp and 112 µA with a resolution of 1024 x 1024 pixels. Pixel size and slice width were both 8 µm, and the scan time was approximately 1 hour. A total of 630 2-dimensional images were acquired for each specimen. Transaxial images of the crown and prepared tooth were captured first.

Thirteen images from the sagittal set and 13 images from the coronal set (Fig. 1 and 2) were selected to illustrate sample extension in 2 different planes. The 13 selected images were evenly distributed between the first and last images that contained the cervical margin. For each image, 2 measurements of horizontal fit and 2 measurements of vertical fit were performed at 400X magnification using CTAn processing software (version 1.12.0.0, Skyscan, Bruker microCT). For vertical fit, measurements were taken from the external crown margin to the most external point of the tooth (Fig. 3). For horizontal fit, measurements were taken from the most external point at the prepared margin of the tooth to the crown margin (Fig. 4). The marginal fit was measured at 52 sites for each specimen, according to the method used by Groten et al.20

Statistical analyses
Statistical analyses were performed with Sigma Plot statistical software (version 12.0, Systat Software, Inc.). A 1-way ANOVA test was performed to determine the significance among groups, followed by the Tukey test ($\alpha = 0.05$) for post hoc comparisons. Vertical marginal fits were grouped according to the following values from previous studies: $<75$ µm, 75-100 µm, 100-120 µm, and $>120$ µm. The maximum acceptable vertical misfit was set to 75 µm.32,33 In addition, horizontal misfit values were placed into 3 categories: underextended, equally extended, and overextended.31,33

Results
With the exception of Group 4, the majority of vertical misfit values for the crowns were $<75$ µm (Table). Chart 1 shows the vertical misfit (µm) and standard deviation (SD) for each group. The mean vertical misfits (SD) were Group 1, 66.5 (29.97); Group 2, 34.9 (6.67); Group 3, 59.7 (17.45); and Group 4, 92.34 (21.51). Statistically significant differences in vertical fit between Group 2 and the other groups were detected ($P = .042$), but no difference was detected among Groups 1, 3, and 4, which exhibited low vertical misfit values. Horizontal misfit values (defined as underextended, equally extended, or overextended) were also calculated for each group: Group 1, 83.1%; Group 2, 93.7%; Group 3, 75.4%, and Group 4, 84.6% (Chart 2).

Discussion
The null hypothesis—that a different method of virtual model acquisition does not affect the marginal fit of resin nanoceramic crowns—was rejected. Data from this study revealed statistically significant differences in marginal fit when resin nanoceramic crowns were produced with different methods.
Results concerning vertical misfit favored the digital impressioning of Group 2. This may be due to the powder applied to the surface eliminating any reflection and shine that may have affected the scanner. Although the results revealed a statistically significant difference between Groups 1 and 2, the E4D manufacturer recommends an intraoral digital impression without powder application. Digital impressioning of the typodont with powder could result in lower misfit values. The present study suggests that the upper limit of acceptable misfit should be 75 µm.

Results of the horizontal misfit comparisons favored the digital impression of Group 3. This may be due to the way 3D scanners convert the optical data to a 3D model, based on the distance from the scanner’s sensor tip to the object. The margin surface of Group 3 was the nearest to the scanner sensor tip of all groups tested. Restorations with significant horizontal misfit can facilitate the retention of food and bacterial plaque. This makes a patient’s hygiene more difficult to maintain, leading to periodontal problems and possible caries that may reduce restoration longevity. Nevertheless, a horizontal misfit could be reduced by adjusting the crown or tooth. This adjustment is not possible with a vertical misfit.

Five different impressions were made to generate 5 virtual models, eliminating the effect of variation associated with preparation. This revealed marginal fit discrepancies that specifically resulted from different digital impression methods. Previous in vitro studies have used different numbers of specimens per group. In the present study, 52 measurements were performed per sample. While other studies have used magnifications of 250X, the present study analyzed at 400X magnification. The clinical cementation process could damage the master die, thus increasing the marginal discrepancy, and a cross-section may be necessary before the measurements are taken.

The clinical cementation process could damage the master die, thus increasing the marginal discrepancy, and a cross-section may be necessary before the measurements are taken.
Long-term clinical data are required to verify the relative efficacy and importance of these techniques. Within the limitations of this study, the crowns manufactured by the E4D chairside CAD/CAM process exhibited significantly smaller vertical misfit when a thin layer of powder was applied over the tryptodon before digital impressioning. Further studies should be performed using different types of dental stone to understand their influence on vertical misfit.

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Disclaimer
The authors have no financial, economic, commercial, and/or professional interests related to topics presented in this article.

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The effect of using propylene glycol as a vehicle on the microhardness of mineral trioxide aggregate

Amin Salem Milani, DDS, MSc • Alireza Banifatemeh, DDS • Saeed Rahimi, DDS, MSc • Mohammad Asghari Jafarabadi, PhD

While it has been proven that the handling properties of mineral trioxide aggregate (MTA) are improved upon mixing it with propylene glycol (PG), this study sought to evaluate how PG affects the microhardness of MTA in terms of setting quality. MTA was mixed with different proportions of distilled water (DW) and PG to prepare 5 groups (n = 30). The DW/PG percent proportions used in Groups 1-5 were 100/0, 80/20, 50/50, 20/80, and 0/100, respectively. The mixed MTA was condensed into acrylic molds. Half of the samples of each group were evaluated on Day 4, the other half on Day 28. The results indicated that PG reduces the microhardness of MTA, thus adversely affecting its setting process. Group 2 (80% DW/20% PG) best improved the handling of MTA without a significant reduction in setting quality.

Materials and methods

Specimen preparation

MTA was mixed with DW and PG in different proportions to create 5 different groups (n = 30). Group 1 samples used 100% DW, Group 2 samples combined 80% DW and 20% PG, Group 3 samples combined 50% DW and 50% PG, Group 4 samples mixed 20% DW with 80% PG, and Group 5 samples used 100% PG. The DW/PG ratios were determined to MTA by volume, and the powder/liquid ratio was the same for all groups (1 g MTA powder/0.4 ml liquid).

Using an amalgam carrier, the samples were packed incrementally into acrylic resin molds (5 mm diameter x 4 mm height). The extruded material was removed with a No. 11 scalpel to provide a flat MTA surface flush with the end of the molds. The samples were covered by an oasis.
sponge soaked in synthetic tissue fluid. Half of the samples in each group were incubated at 37°C and 95% humidity for 4 days and the remainder for 28 days. After incubation, the surface of each sample was wet polished using minimal hand pressure and various silicon carbide–based sandpapers (300, 600, 1200, and 2400 grit). The polished samples were cleaned gently with DW to remove surface debris; at that point, the surfaces were dried immediately using an oil-free air spray.

**Microhardness test**
The Vickers hardness test was performed using a microhardness tester with a square base, pyramid-shaped indenter. A load of 300 g was applied for 10 seconds; at that point, the microhardness values (kgf/mm²) appeared on the digital readout of the tester. For each specimen, the microhardness was measured on 3 separate locations (no closer than 1 mm to each other or to the sample periphery). The mean microhardness value was calculated and recorded.

**Statistical analysis**
The data were statistically analyzed using SPSS software (Version 16, IBM Corporation). Due to the heterogeneity of variances (Levene test; P > 0.05), the Welch robust test was used to compare the mean hardness values among groups, followed by the Games-Howell post hoc test for pairwise comparison. Within each group, a paired samples t test was used to assess the different microhardness values at Day 4 and Day 28. Values of P < 0.05 were considered significant.

**Results**
Group 5 was excluded from this study, as the 100% PG prevented the MTA from setting, making it impossible to measure microhardness. The mean microhardness (kgf/mm²) values for the other experimental groups are summarized in the Table. The results of the Welch robust test revealed significant differences among 4 groups at both Day 4 and Day 28 (P = 0.000). In addition, the Games-Howell post hoc test showed that all pairwise comparisons between groups were significant (P < 0.05). The microhardness in Group 1 (100% DW) was significantly higher than in other groups (P < 0.05), and there was a corresponding significant decrease in microhardness as the proportion of PG to DW increased (P < 0.05). The microhardness at Day 28 was significantly higher for Groups 1 and 2 (P < 0.05). By contrast, the microhardness in Group 4 was significantly lower at Day 28 compared to Day 4 (P < 0.05). Group 3 samples showed no difference in microhardness between 4 and 28 days (P > 0.05).

**Discussion**
Mixing MTA powder with PG alone or with a PG/DW mixture alters its consistency and improves handling. This study sought to evaluate the effect of PG on the microhardness of MTA as a criterion for the setting quality. Microhardness is not a fundamental material property; rather, it represents an arbitrary quantity that is used to provide a relative idea of other physical properties, such as yield strength, tensile strength, and modulus of elasticity; in addition, it is used as an indicator of MTA setting. The results of the present study showed that adding PG reduced MTA microhardness.

Adequate hydration is a factor that has a direct effect on MTA's setting reaction. The literature has shown that any environmental factor that affects the hydration of MTA has the potential to change its physical properties. Therefore, the decrease in microhardness that resulted from the addition of PG may be explained by the reduced percentage of DW in the liquid. The hygroscopic property of PG means it is likely to absorb more water from the mixed MTA and further reduce the amount of DW available for hydration. Duarte et al evaluated the effect of different DW/PG ratios on pH and calcium ion release as an indicator of MTA's hydration process. Adding PG increased the pH and calcium ion release during the initial setting phase; however, both decreased consistently over time and, after 24 hours, there was no significant difference compared to samples treated with 100% DW. Duarte et al concluded that adding PG reduced the amount of water in the mixture without affecting the hydration process. This conclusion appears to contrast with the findings of the present study. The authors of the present study propose that evaluating pH and calcium ion release is not suitable as a single criterion for the setting quality of MTA. Alterations of other MTA properties (such as microhardness) should also be considered as another indicator of the setting process. An animal study found that MTA pastes prepared with either DW or PG had similar biocompatibility. Therefore, the authors of the present study conclude that although PG may have a negative effect on the setting process, the effect is not so great as to influence its biocompatibility.

Another finding in this study was the increasing surface microhardness of MTA with DW over time, corroborating the findings reported in previous studies. This increased hardness value indicates that MTA is likely to continue to set and gain hardness over time. However, in the present study, adding PG to DW reduced this trend, in that the hardness did not increase over time in Group 3 (P > 0.05), and the hardness in the Group 4 samples actually decreased.

### Table. Mean and standard deviation (SD) of Vickers surface microhardness (kgf/mm²) in experimental groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>1 (100% DW)</th>
<th>2 (80% DW/20% PG)</th>
<th>3 (50% DW/50% PG)</th>
<th>4 (20% DW/80% PG)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 4</td>
<td>11.6 (3.5)</td>
<td>5.5 (1.5)</td>
<td>4.2 (0.9)</td>
<td>2.8 (0.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Day 28</td>
<td>28.6 (10.7)</td>
<td>7.8 (2.6)</td>
<td>4.8 (1.6)</td>
<td>2.0 (0.6)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Abbreviations: DW, distilled water; PG, propylene glycol.

*Note: The P values in the right column are related to the difference of hardness among different groups at each time point; however, the P values in the 3rd row are related to the differences in hardness of each group at 2 time points. For example, 0.019 in the 3rd row means that the hardness of MTA with 80% DW/20% PG is greater at day 28 than day 4.*
by Day 28. The mechanism for decreased microhardness is unclear, and further investigation is warranted. It seems that 20% PG combined with 80% DW had the least adverse effect on this increasing hardness trend over time compared to higher PG concentrations.

Present data show that acidity, reduced humidity, greater condensation pressure, and contact with fetal bovine serum or blood during setting have an adverse effect on the setting process and reduce MTA microhardness. Different mechanisms have been proposed for these findings. Kim et al suggested that the proteins in fetal bovine serum interfere with the setting reaction of MTA and reduce hard-

The exact mechanism of how PG affects MTA microhardness is unclear. Future studies might consider using scanning electron microscopic analysis and energy dispersive X-ray spectroscopy to characterize the surface of MTA mixed with PG and thus elucidate the underlying mechanism. A previous study showed that PG increases the setting time of MTA. Other studies are underway to control this adverse effect of PG on the setting time of MTA by incorporating accelerants; however, additional study is needed to determine the effects these PG accelerants will have on the different properties of MTA.

Conclusion
Based on the results of this study, it was concluded that PG reduces the surface microhardness of MTA and is likely to have an adverse effect on its setting process. A mixture of 80% DW and 20% PG is recommended to improve MTA handling.

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By Day 28, the mechanism for decreased microhardness is unclear, and further investigation is warranted. It seems that 20% PG combined with 80% DW had the least adverse effect on this increasing hardness trend over time compared to higher PG concentrations.

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Clinical performance of topical sodium fluoride when supplementing carbamide peroxide at-home bleaching gel

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Patricia Rondon Pleffken, DDS, MS, PhD  •  Marcia Carneiro Valera, DDS, MS, PhD

This clinical study evaluated the use of 0.11% topical sodium fluoride (SF) desensitizing agent to treat tooth sensitivity during a nightguard tooth whitening procedure. Thirty-two subjects bleached their teeth with 10% carbamide peroxide (CP) gel using an at-home bleaching technique with custom trays. During bleaching treatment, subjects were divided into 2 groups (n = 16). The subjects in Group 1 received a topical gel containing 0.11% SF; the subjects in Group 2 received a placebo gel (PG). Each subject was instructed to place the gel in his/her bleaching tray for 30 min every day following bleaching treatment.

Results showed the use of SF did not affect the whitening efficacy of the 10% CP gel. Subjects who received the PG had significantly higher tooth sensitivity when compared with subjects who received SF (P < 0.00). The use of daily 0.11% SF after 10% CP bleaching gel reduced tooth sensitivity during the bleaching treatment.

Key words: dental bleaching, carbamide peroxide, fluoride, tooth sensitivity

A t-home tooth bleaching has been greatly successful in dentistry. The current agents used for bleaching procedures are hydrogen peroxide or carbamide peroxide (CP) in a variety of concentrations. Tooth sensitivity is the most common side effect associated with at-home bleaching techniques. Clinical studies of at-home bleaching treatments report tooth sensitivity in 9%-100% of subjects. One of several etiological factors associated with this complication is the low pH of bleaching materials, which may produce an acid-etch effect on dentin, consequently removing minerals from the teeth. Other factors in tooth sensitivity due to at-home bleaching are the low levels of water content within the bleaching materials and the anhydrous materials used to dry the teeth.

To decrease tooth sensitivity, the best solution during at-home tooth bleaching is to reduce either the frequency or duration of bleaching applications. Also, the use of topical fluorides or desensitizing pastes after the bleaching session may reduce tooth sensitivity. Topical fluoride advantages include being noninvasive, cost-effective, and easy to apply, and it can be used either in-office or at-home techniques, depending on the concentration of the solution.

Most investigators have studied the use of fluorides and other desensitizing agents (such as potassium nitrate) in order to effectively manage tooth sensitivity. The purpose of this clinical study is to evaluate the use of topical fluoride on tooth sensitivity during a nightguard tooth whitening procedure. The null hypothesis tested was that the use of topical fluoride would not affect tooth sensitivity during at-home tooth bleaching.

Materials and methods
This study was submitted to and approved by the Ethical Committee in Research of Sao Jose dos Campos School of Dentistry, Sao Paulo State University, Brazil (Protocol No. 039/2009-PH/CEP). All subjects read and signed informed consent forms.

Subject selection
Thirty-two volunteer subjects (19 women and 13 men) with a mean age of 24.8 years participated in this study. Inclusion criteria were teeth that were minimally A2-shaded and good general health. Exclusion criteria were restorations in anterior teeth, tooth sensitivity, pregnancy/breastfeeding, smoking, active caries, previous bleaching treatments, and/or subjects who were <17 years of age.

Bleaching procedure
The subjects received a complete oral prophylaxis using rubber cups with pumice then rinsing with water/air spray for 30 seconds.

Initial shades
All subjects were evaluated for initial (baseline) shades with 3 calibrated examiners (85% inter-rater reliability). Shades were assessed using a shade guide (Vita Lumin Vacuum, VITA Zahnfabrik) to record the shades of the anterior teeth from the left to the right canines.

Bleaching product
The home bleaching was accomplished with a 10% CP gel (Bioformula Farmacia de Manipulacao) that was manufactured specifically for this study. In this formulation, the bleaching agent did not contain desensitizing agents.

Bleaching trays
Alginate impressions (Jeltrate, DENTSPLY International) of both dental arches of each subject were taken to obtain stone casts, which were then cut into horseshoe shapes. Custom-fabricated bleaching trays of ethyl vinyl acetate (FGM Produtos Odontologicos) were formed for each subject using a vacuum machine (Bio-Art Equipamentos Odontologicos Ltda). The bleaching trays did not have reservoirs and were trimmed 1 mm above the gingival margin without contacting the gingival tissue. All subjects received a syringe with 10% carbamide peroxide gel and were instructed on how to load the bleaching
trays. The subjects received verbal and written instructions regarding the bleaching procedure. All subjects employed the bleaching product by filling both the maxillary and mandibular trays for 14 consecutive nights in an 8 hour regimen. However, if a subject experienced tooth sensitivity, he or she had the option to discontinue the treatment at any time.

During the bleaching treatment, subjects were divided into 2 groups (n = 16). Group 1 subjects received a gel containing an 0.11% sodium fluoride (SF) desensitizing agent (Bioformula Farmacia de Manipulacao); Group 2 subjects received a placebo gel (PG) (Bioformula Farmacia de Manipulacao). Each subject was instructed to apply the gel in his/her bleaching tray for 10 minutes every day following the bleaching treatment.

Tooth sensitivity
After applying the SF or PG, the subjects were instructed to record (on a visual scale from 0 to 10) the degree of sensitivity perceived during the whitening treatments: Grade 0, absence of sensitivity; Grades 1-3, slight sensitivity not necessitating suspension of treatment; Grades 4-6, moderate sensitivity that forced suspension of treatment for 1 day; Grades 7-9, severe sensitivity that led to complete suspension of treatment. The subjects scored their sensibilities every day after applying either the desensitizing agent or the placebo. The degree of sensitivity was calculated as the mean of the treatment days.

Final shades
The bleaching outcomes were evaluated with the Vita Lumin Vacuum shade guide 30 days after the onset of treatment using the same 3 calibrated examiners from the earlier visual evaluation. The shade changes were obtained by Vita shade tabs ranging from 1 (B1) to 16 (C4) (Table 1).7

Statistical analysis
The data collected from each treatment group for changes in tooth sensitivity were submitted to a Wilcoxon signed-rank test. The data collected regarding the changes in tooth shades were submitted to a statistical test with a 5% level of significance.

Results
Tooth sensitivity
All 32 participants completed the study. The data (mean score and standard deviations) collected regarding the changes in tooth sensitivity are presented in Table 2. A significant statistical difference in tooth sensitivity was detected when Group 1 and Group 2 were compared (P < 0.00). Group 2 (placebo gel) demonstrated statistically higher tooth sensitivity than Group 1 (SF gel). The Chart describes the comparison of tooth sensitivity during the 14 days of bleaching treatment for Groups 1 and 2.

Tooth shade
Table 3 presents the data collected for changes in tooth shade. It was noted that the 10% CP bleaching gel did significantly whiten teeth.

Discussion
The first null hypothesis was rejected, because there was a significant reduction in tooth sensitivity for subjects in Group 1 compared to Group 2. SF is a compound that—when in contact with mineralized tooth structures—apparently causes

### Table 1. Conversion of Vita Classical Shade Guide tabs to numeric values.

<table>
<thead>
<tr>
<th>Tab</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1</td>
</tr>
<tr>
<td>A1</td>
<td>2</td>
</tr>
<tr>
<td>B2</td>
<td>3</td>
</tr>
<tr>
<td>A2</td>
<td>5</td>
</tr>
<tr>
<td>C1</td>
<td>6</td>
</tr>
<tr>
<td>C2</td>
<td>7</td>
</tr>
<tr>
<td>B3</td>
<td>10</td>
</tr>
<tr>
<td>C3</td>
<td>11</td>
</tr>
<tr>
<td>A3</td>
<td>15</td>
</tr>
<tr>
<td>D3</td>
<td>10</td>
</tr>
<tr>
<td>A3.5</td>
<td>12</td>
</tr>
<tr>
<td>C4</td>
<td>16</td>
</tr>
</tbody>
</table>

### Table 2. Mean score and standard deviation (SD) of tooth sensitivity and results of the Wilcoxon signed-rank test.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean score (SD) of tooth sensitivity</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (SF)</td>
<td>0.84 (0.62)</td>
<td>&lt;0.00*</td>
</tr>
<tr>
<td>2 (PG)</td>
<td>1.39 (0.28)</td>
<td>&lt;0.00*</td>
</tr>
</tbody>
</table>

*Indicates statistical significance. Abbreviation: SF, sodium fluoride; PG, placebo gel.
reductions in the diameters of the dentinal tubules by precipitating calcium fluoride crystals. The speculated mode of action is the formation of a calcified barrier blocking the tubule openings, consequently decreasing tooth sensitivity. The results of this present study were consistent with the findings of Tam, Alonso de la Pena & Balboa Cabrita, and Haywood et al, who observed decreases of tooth sensitivity when desensitizing agents such as fluoride were used after at-home bleaching treatments with 10% CP bleaching gel.

This study also corroborated the findings of Armenio et al, who observed that using 1.23% SF for 4 minutes a day after bleaching with 16% CP reduced the intensity of tooth sensitivity.

The Chart depicts a significant reduction in tooth sensitivity for Group 1 on Day 3. Calcium fluoride is an unstable compound, providing a short period of desensitizing effect, indicating the necessity of regular daily applications after at-home tooth bleaching to reduce tooth sensitivity.

The typical duration of daily exposure to fluorides (mouthrinses, dentifrices, pastes, and gels) in contact with teeth is a few minutes at most. In this study, the duration of daily exposure to SF after a bleaching treatment was 10 minutes. Therefore, at least 10 minutes are necessary to achieve satisfactory tooth desensitization after an at-home bleaching treatment with SF.

Some studies have shown that bleaching agents can cause changes in the surface morphology of enamel, including such negative effects as demineralization, erosion, wear, roughness, mineral content loss, and reduction in enamel microhardness. Additionally, cleaning one’s teeth with toothbrushing and/or using abrasive toothpastes after a bleaching treatment can enhance the phenomena of erosion and wear.

Therefore, toothbrushing immediately following the use of topical fluoride after a bleaching treatment should be avoided, in order to prevent erosion of the enamel surface. Also, the use of daily SF therapy increases enamel hardness and may reverse the demineralizing effect of the bleaching agent on the enamel surface, potentially preventing the loss of mineral content.

For changes in tooth shade, this study demonstrated that 10% CP bleaching gel did significantly whiten teeth for Groups 1 and 2 (P < 0.00). Both treatment groups in this study produced equivalent color changes, and these results suggested that topical fluoride therapy after at-home tooth bleaching did not significantly affect the bleaching efficacy within the parameters of this study. These results are in agreement with other studies, which found that various desensitizing agents (such as fluoride) did not affect the efficacy of the bleaching treatment.

The current trend of incorporating desensitizing agents in the bleaching agent has shown promising results in reducing tooth sensitivity and enamel remineralization without affecting the efficiency of the bleaching. A major advantage of this new technique is the reduced time required, as there is no need to apply the agent before or after a bleaching procedure, reducing the risk of noncooperation by the patient.

This study indicated that the 10-minute application of 0.11% SF gel as a desensitizing agent could be very helpful in decreasing tooth sensitivity; it also did not significantly affect the bleaching efficacy of the 10% CP bleaching gel. Reducing tooth sensitivity improves patient comfort during bleaching procedures. Further research should be conducted to determine whether the 0.11% SF gel would exhibit this same effect when different concentrations of CP and/or hydrogen peroxide are used.

Table 3. Means and standard deviations (SDs) of subjective evaluation of tooth shades and results of the statistical t test.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (SD) initial shade</th>
<th>Mean (SD) final shade</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (SF)</td>
<td>5.48 (3.60)</td>
<td>2.87 (1.82)</td>
<td>6.35</td>
<td>&lt;0.00*</td>
</tr>
<tr>
<td>2 (PG)</td>
<td>5.10 (2.95)</td>
<td>2.73 (1.58)</td>
<td>6.92</td>
<td>&lt;0.00*</td>
</tr>
</tbody>
</table>

*Indicates statistical significance. Abbreviations: SF, sodium fluoride; PG, placebo gel.

Conclusion

The application of 0.11% topical SF gel after a 10% CP bleaching gel treatment reduced tooth sensitivity during a 2 week at-home bleaching treatment.

Author information

Drs. Barcellos, Batista, da Silva, and Plefken received their PhDs from the Sao Jose dos Campos School of Dentistry, Universidade Estadual Paulista, Brazil, where Dr. Valera is an associate professor, Restorative Dentistry Department.

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55.16.3371.6502, www.bioart.com.br

Bioformula Farmacia de Manipulacao, Sao Jose dos Campos, Brazil

DENTSPLY International, York, PA
800.877.0020, www.dentsply.com

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A new nanohybrid composite activated by sonic energy has been recently introduced as a single-step, bulk-fill restorative material. The purpose of this study was to compare the physical properties of this new composite to various other composite restorative materials marketed for posterior or bulk-fill placement. The following physical properties were examined: depth of cure, volumetric shrinkage, flexural strength, flexural modulus, fracture toughness, and percent porosity. A mean and standard deviation were determined per group. One-way ANOVA and Tukey’s post hoc tests were performed per property ($\alpha = 0.05$). Percent porosity was evaluated with a Kruskal-Wallis/Mann-Whitney test ($\alpha = 0.005$). Significant differences were found between groups ($P < 0.001$) per test type. Compared to the other composite restorative materials, the new nanohybrid composite showed low shrinkage and percent porosity, moderate fracture toughness and flexural modulus, and high flexural strength. However, it also demonstrated a relatively reduced depth of cure compared to the other composites.

C omposite resin was first introduced in the 1960’s as an alternative to acrylic resins for esthetic dental restorations.1 Initially these materials performed poorly, but increased popularity and demand for esthetic restorations have driven continued improvement in strength, wear resistance, handling, and esthetics.2 For many years, composite resin restorations have been considered an acceptable treatment choice for anterior applications. Recent advances in composite resin mechanical properties and improved adhesive systems have broadened the application of these materials to include the restoration of posterior teeth.3 However, it is still generally accepted that posterior composite resin restorations have limitations and that there is no one ideal material available.4

A volumetric shrinkage occurs when a composite resin material is cured.1 The shrinkage is the result of conversion of monomer molecules into a more dense polymer network, which leads to bulk contraction.5 In vivo studies have demonstrated the percentage of marginal gaps in a composite resin restoration may vary between 14% and 54% depending on the materials and technique.6 The resulting marginal gap may provide a site for recurrent caries; this is cited as the most common cause of failure for composite resins.7 In spite of significant advances in composite resin composition, there has not been an equivalent decrease in microleakage and gap formation.8

Another concern regarding composite resin is the depth of cure during placement. When composite resin is applied as a single bulk layer, there may be a low degree of polymerization at the depth of deeper cavity preparations due to attenuation of the light.1 An insufficient degree of curing affects the composite resin’s chemical properties and may lead to the erosion of possible irritant, allergic, or toxic components from the material.9 Uncured composite resin at the base of a restoration may also cause microleakage with resulting pulpal sensitivity, staining, and recurrent caries.10 Additionally, incomplete curing is associated with a reduction in the mechanical properties of the material.11

Historically, composite resin restorations have been advocated for use in areas of minimal stress.10 However, increased demand has led to a greater use of these restorations on posterior teeth, where considerable mechanical challenges occur during function.12 To withstand these stresses, the modification of filler particle size and morphology has resulted in improved mechanical properties.13 Heavily filled composite resins have improved mechanical strength, fracture properties, and wear resistance.4 However, as the maximum filler volume is about 70%, overloading can result in poor handling characteristics and technical difficulties, such as decreased wettability.14 Filler content not only directly determines the mechanical properties of composite resin but also allows for a reduction in monomer content; improves handling properties; and influences wear resistance, translucency, opalescence, radiopacity, intrinsic surface roughness, and polishability.15

Another clinical aspect of concern regarding composite resins is their handling characteristics. The ability of a composite material to flow may play a major role in the ultimate success of a restoration.16 However, in many Class II cavity preparations, it is difficult to obtain proper contour and adequate proximal contacts because the composite resin is not packable.17 The desire for composite resins with certain flow characteristics has been addressed by the introduction of packable and flowable composite resins. Packable composite resins were first introduced as an alternative to amalgam.10 They are characterized by a high filler load and a filler distribution that gives them a different consistency when compared with traditional composite resins. Flowable composite resins contain lower filler concentrations and are characterized by a lower elastic modulus and viscosity.19 For the average clinician, the ideal composite resin material would be viscous enough to facilitate placement but flowable enough for adequate marginal adaptation.19

SonicFill (Kerr Corporation) is a new composite resin material that the manufacturer claims to address many of the problems listed above. SonicFill is a single-step, bulk-fill composite resin system that, according to the manufacturer, has...
“...ultraefficient curing characteristics that ensure an optimal, full 5 mm depth of cure in 20 seconds.”

Sonic activation purportedly lowers the viscosity of the material to allow for easy adaptation to cavity walls. The manufacturer also claims that, after placement, the composite resin returns to a “non-slumping state” that allows for easy contouring.

To fully understand SonicFill’s place in a clinician’s daily practice, one must first understand the different types of composite resins available on the market. Most dental composite resin materials are composed of a polymeric matrix (typically dimethacrylate), reinforcing fillers (typically radiopaque glass), a silane coupling agent to bind the filler to the matrix, and chemicals that promote or modulate the polymerization reaction. Because of the major influence of fillers on the physical properties of dental composite resins, their classification is based on the type and particle size of fillers. Currently, the most traditional methacrylate composite resins for restorative purposes are the hybrid and microfill types. Microfill composite resins are formulated with fillers having an average particle size ranging from 0.01 to 0.05 µm and pre-polymerized particles approximately 50 µm in size. These composite resins were designed to overcome the problems of poor esthetic properties. However, the mechanical properties of microfills are typically too low for applications in areas of high functional stress. Microhybrids offer intermediate esthetic properties but excellent mechanical properties by the incorporation of fillers with different average particle sizes, 15-20 µm and 0.01-0.05 µm. A recent development with methacrylate-based composites has been nanocomposites, which contain nanoscale particles and nanohybrids, which contain a mixture of nanoscale particles and larger particles. The manufacturers of these nanocomposites claim that they combine the mechanical strength of hybrids and the superior polishability of microfills, in addition to high wear resistance and reduced polymerization shrinkage. In general, it is difficult to discern dramatic differences between nanohybrids and the more traditional microhybrids because many manufacturers have simply modified their microhybrid composition to include more nanoparticles or even pre-polymerized resin fillers. The physical properties of the flexural strength and modulus of nanohybrids and microhybrids tend to be similar. Filtek Z250 (3M ESPE) is a traditional microhybrid composite resin that has demonstrated excellent mechanical properties in multiple laboratory studies and is often used as a standard to compare various new restorative materials.

In addition to the traditional composite resin restorative materials, a unique composite resin, Filtek LS (3M ESPE), has recently been marketed for posterior restorations. Instead of the conventional methacrylate-derived monomer, Filtek LS utilizes a ring-opening silorane monomer. It demonstrates mechanical properties similar to those of methacrylate composite resins but has the distinct advantage of reduced polymerization shrinkage. The expansion of the ring before polymerization has been shown to decrease the polymerization shrinkage to <1.5%. Historically, the maximum incremental thickness with composite resin placement has been 2 mm. However, restoring deeper preparations with 2 mm increments is time consuming and relatively technique sensitive. Manufacturers have introduced new “bulk-filled” restorative composites, which reportedly can be cured in increments of ≥4 mm. Examples include SonicFill, Tetric EvoCeram Bulk Fill (Ivoclar Vivadent, Inc.), and QuiXX (DENTSPLY Caulk). The compositions of the new bulk-fill composites appear to be similar to those of the nanohybrid and

---

**Table 1. Composite resin components.**

<table>
<thead>
<tr>
<th>Composite</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Resin</th>
<th>Filler</th>
<th>Weight %</th>
<th>Volume %</th>
<th>Filler size</th>
</tr>
</thead>
<tbody>
<tr>
<td>SonicFill</td>
<td>Nanohybrid</td>
<td>Kerr Corporation</td>
<td>3-trimethoxysilylpropyl methacrylate, ethoxylated bisphenol-A-</td>
<td>Silicon dioxide, barium glass</td>
<td>83</td>
<td>Unreported</td>
<td>Unreported</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dimethacrylate (Bis-EMA), bisphenol-A-bis-(2-hydroxy-3-methacryloxyp-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>propyl) ether, triethylene glycol dimethacrylate (TEGDMA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QuiXX</td>
<td>Hybrid</td>
<td>DENTSPLY Caulk</td>
<td>Urethane dimethacrylate (UDMA), TEGDMA</td>
<td>Silanated strontium aluminum sodium fluoride phosphate silicate glass</td>
<td>86</td>
<td>66</td>
<td>Unreported</td>
</tr>
<tr>
<td>Tetric EvoCeram Bulk Fill</td>
<td>Nanohybrid</td>
<td>Ivoclar Vivadent, Inc.</td>
<td>UDMA, bisphenol A glycidylmethacrylate (Bis-GMA)</td>
<td>Barium glass, ytterbium trifluoride, mixed oxide prepolymer</td>
<td>82-84</td>
<td>64</td>
<td>550 nm mean particle size; range: 40 nm to 3000 nm</td>
</tr>
<tr>
<td>Filtek Z250</td>
<td>Microhybrid</td>
<td>3M ESPE</td>
<td>TEGDMA, UDMA, Bis-EMA</td>
<td>Zirconia/silica particles</td>
<td>82</td>
<td>60</td>
<td>0.01-3.5 µm</td>
</tr>
<tr>
<td>Filtek LS</td>
<td>Silorane</td>
<td>3M ESPE</td>
<td>Silorane</td>
<td>Quartz, ytterbium trifluoride</td>
<td>76</td>
<td>55</td>
<td>0.04-1.7 µm</td>
</tr>
</tbody>
</table>

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*Dental Materials* Physical properties of a new sonically placed composite resin restorative material
microhybrid restorative composites currently available. However, a greater depth of cure may be obtained by improving the translucency or by the incorporation of additional photoinitiators. Very little information has been published on the physical properties of this new class of materials.

The purpose of this study was to compare the physical properties of the new sonically placed composite and other composite resin restorative materials marketed for posterior placement or bulk fill. The null hypothesis tested was that there would be no significant difference in physical properties among the various composite resin restorative materials.

Materials and methods
The resin composites used in this study were SonicFill (shade A2), QuixX (universal shade), Tetric EvoCeram Bulk Fill (shade IVA), FiltekZ250 (shade A2), and Filtek LS (shade A2) (Table 1). The following properties were evaluated: depth of cure, volumetric polymerization shrinkage, flexural strength, flexural modulus, fracture toughness, and internal porosity.

Depth of cure
To determine depth of cure, the composite resins were tested using the scraping technique (ISO 4049). Five specimens per group were created. A 4 mm diameter by 14 mm long stainless steel split mold (Sabri Dental Enterprises, Inc.) was placed on a plastic strip-covered glass slide on a standard white background. The composite resin was injected into the mold and the plastic strip was placed. The composite resin was condensed with a glass slide to displace excess resin. The glass slide was removed and the specimens were immediately polymerized with a curing light (Bluephase G2, Ivoclar Vivadent, Inc.) for 20 seconds. Each specimen was polymerized at a distance of 0 mm utilizing a clamp to hold the curing light. The light emission from the Bluephase G2 was analyzed with a spectrophotometer (Blue Light Analytics, Inc.) and a laser power meter (FieldMax II, Coherent, Inc.). The curing light was connected to a power cord to provide continuous, consistent operation. The emitted light was analyzed during a 20-second curing cycle and the following data were collected: mean irradiance, 1132 mW/cm²; total energy density, 22.8 J/cm²; energy density in the 360-420 nm spectrum, 4.2 J/cm²; and energy density in the 420-540 nm spectrum, 18.6 J/cm². The uncured resin was then scraped with a plastic instrument starting from the deepest point on the underside of the mold until polymerized resin was reached. The composite resin was removed from the mold and the length of the remaining polymerized material was measured with an electronic digital caliper (GA182, Grobet USA) and divided by 2, according to the ISO standard.24

Volumetric polymerization shrinkage
To determine polymerization shrinkage, the AcuVol method by Bisco, Inc. was used. Ten specimens per group were created. The composite resins were placed on a pedestal in a video imaging device (AcuVol, Bisco, Inc.). The specimens were imaged from the side at a distance of 10 cm. The video camera digitized and analyzed the images with the provided image processing software. The specimens were light-cured for 40 seconds using the curing light unit as before. Polymerization shrinkage was recorded continuously for 5 minutes after the light initiation.

Flexural strength and flexural modulus
To determine flexural strength and flexural modulus, a 3-point bending test was used. Ten specimens per group were created. A 2 x 2 x 25 mm stainless steel mold (Sabri Dental Enterprises, Inc.) was placed on a plastic strip-covered glass slide. The specimens were created by injecting the restorative material into the mold until completely filled. The top surface of the mold was covered with a second plastic strip and glass slide as before. One side of the specimen was then exposed to a light polymerization unit for 20 seconds each in 5 separate overlapping increments. Next, the mold was turned over, and the opposite side of the specimen was exposed to the light in a similar manner. The specimens were stored as before, and after 24 hours, the notched specimens were fractured in the universal testing machine similar to flexural strength testing, but at a crosshead speed of 1.0 mm/min, with the notch on the tensile side. The load-deflection (F = load vs u = deflection) curves were recorded; the height, h, and width, w, of the specimens were measured with the inside jaws of an electronic digital caliper as before and the notch depth, d, with a measuring stereomicroscope (Nikon SMZ-1B, Nikon USA) at 10X magnification. Fracture toughness (KIC) was calculated from measurements with
## Table 2. Physical properties of the restorative materials.

<table>
<thead>
<tr>
<th>Restorative material</th>
<th>Depth of cure (mm)</th>
<th>Volumetric polymerization shrinkage (%)</th>
<th>Flexural strength (MPa)</th>
<th>Flexural modulus (GPa)</th>
<th>Fracture toughness (MPa m$^{1/2}$)</th>
<th>Percent porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SonicFill (A2 shade)</td>
<td>3.67 (0.02)$^a$</td>
<td>1.88 (0.15)$^b$</td>
<td>136.81 (16.29)$^b$</td>
<td>10.32 (0.38)$^b$</td>
<td>0.56 (0.03)$^{a,b}$</td>
<td>0.02 (0.04)$^a$</td>
</tr>
<tr>
<td>QuiXX (universal shade)</td>
<td>6.31 (0.02)$^a$</td>
<td>2.00 (0.08)$^a$</td>
<td>111.86 (16.84)$^a$</td>
<td>13.34 (0.84)$^a$</td>
<td>0.61 (0.05)$^b$</td>
<td>1.42 (1.17)$^c$</td>
</tr>
<tr>
<td>Tetric EvoCeram Bulk Fill (IVA shade)</td>
<td>4.08 (0.03)$^a$</td>
<td>2.31 (0.11)$^b$</td>
<td>101.41 (5.86)$^a$</td>
<td>8.55 (0.55)$^a$</td>
<td>0.52 (0.05)$^a$</td>
<td>0.40 (0.76)$^b$</td>
</tr>
<tr>
<td>Filtek LS (A2 shade)</td>
<td>2.06 (0.02)$^a$</td>
<td>1.21 (0.08)$^b$</td>
<td>113.89 (18.57)$^a$</td>
<td>9.17 (0.39)$^a$</td>
<td>0.52 (0.05)$^a$</td>
<td>0.44 (0.57)$^b$</td>
</tr>
<tr>
<td>Filtek Z250 (A2 shade)</td>
<td>3.79 (0.02)$^c$</td>
<td>2.13 (0.08)$^b$</td>
<td>139.41 (16.35)$^b$</td>
<td>10.86 (0.46)$^b$</td>
<td>0.62 (0.08)$^b$</td>
<td>0.13 (0.09)$^b$</td>
</tr>
</tbody>
</table>

Groups with the same lowercase letter per column are not significantly different.

The single-edge notched-bend specimens using the equation:

$$K_{IC} = \frac{3(a/w)^{3/2}(1–9.3a/w + 2.7(a/w)^2)FS}{2(1 + a/w)(1 - a/w)^{3/2}hw^{3/2}}$$

Where $S$ is the span distance (20 mm) between supports.

### Internal porosity

A novel microtomographic technique was used to evaluate internal porosity. Ten specimens per group were created. To prepare each specimen, a 2 mm long and 8 mm diameter plastic mold (Sabri Dental Enterprises, Inc.) was placed on a plastic strip-covered glass slide. The restorative materials were injected into the mold until completely filled. Then, the top surface of the mold was covered with a second plastic strip and glass slide as before. Both ends of the specimen were exposed to a visible light polymerization unit as before for 20 seconds. After storage for 24 hours as before, they were placed in a microtomography unit (No. 1172, Bruker MicroCT) and scans of the samples were made. Recorded images were then reconstructed (NRecon, version 1.4.4, Bruker MicroCT) into 3-dimensional images, which were analyzed using proprietary software (CT Analyzer, version 1.6.0.0, Bruker MicroCT) for percent porosity.

A mean and standard deviation were determined per group. Data were analyzed with a 1-way ANOVA and Tukey's post hoc tests per test type ($\alpha = 0.05$). Due to the non-normal distribution of the data, percent porosity was evaluated with the nonparametric Kruskal-Wallis and Mann-Whitney tests. A Bonferroni correction was applied because multiple comparison tests were completed simultaneously ($\alpha = 0.005$).

### Results

Significant differences were found between groups per test type ($P < 0.05$) (Table 2). For the depth of cure measurements, all the groups were significantly different from each other. QuiXX had the greatest depth of cure ($6.31 \pm 0.02$ mm) and Filtek LS had the lowest ($2.06 \pm 0.02$ mm). Tetric EvoCeram Bulk Fill, Filtek Z250, and SonicFill performed more moderately.

Filtek LS had the lowest polymerization shrinkage ($1.21\% \pm 0.08\%$). SonicFill and QuiXX had low shrinkage and were not significantly different from each other. Filtek LS was not significantly different from Filtek Z250. Tetric EvoCeram Bulk Fill had the greatest shrinkage ($2.31\% \pm 0.11\%$).

Filtek Z250 had the greatest flexural strength ($139.41 \pm 16.35$ MPa), but it was not significantly different from SonicFill. Tetric EvoCeram Bulk Fill had the lowest flexural strength ($101.41 \pm 5.86$ MPa), but it was not significantly different from QuiXX and Filtek LS.

QuiXX had the greatest flexural modulus ($13.34 \pm 0.84$ GPa). Filtek Z250 and SonicFill had more moderate flexural moduli and were not significantly different from each other. Tetric EvoCeram Bulk Fill had the lowest flexural modulus ($8.55 \pm 0.55$ GPa), but it was not significantly different from Filtek LS.

Filtek Z250 had the greatest fracture toughness ($0.62 \pm 0.08$ MPa m$^{1/2}$), but it was not significantly different from QuiXX or SonicFill. Tetric EvoCeram Bulk Fill and Filtek LS had the lowest fracture toughness ($0.52 \pm 0.05$ MPa m$^{1/2}$), but they were not significantly different from SonicFill.

SonicFill had the lowest percent porosity (0.02\% \pm 0.04\%). QuiXX had the greatest porosity (1.42\% \pm 1.17\%). Filtek LS, Tetric EvoCeram Bulk Fill, and Filtek Z250 had more modest porosity formation and were not significantly different from each other.

### Discussion

The null hypothesis was rejected in this study. Statistically significant differences in physical properties were found between composite resins per test type. Very little published research is available evaluating the depth of cure of the new bulk-fill composite resin restorative materials. In this study, using the ISO 4049 standard, SonicFill’s average depth of cure was 3.67 mm. Recent studies by Garcia et al and Benetti et al found similar depths of cure of 3.46 mm and 3.43 mm, respectively, using the same ISO 4049 standard.$^{26,27}$ Other studies have concluded that the ISO 4049 method is very liberal, and may overestimate the depth of cure compared to other techniques, such as hardness or degree of conversion.$^{27,28}$ The depth of cure for SonicFill (3.67 mm) was slightly less than Filtek Z250’s average depth of cure of 3.79 mm, which is recommended by the manufacturer for placement in incremental layers of only 2.5 mm.$^{29}$ The composite resin which had the highest depth of cure was QuiXX at 6.31 mm, which exceeded the manufacturer’s claim of 4.2 mm.$^{30}$ The greater depth of cure may be due to the...
translucent appearance of QuiXX when completely polymerized. Tetric EvoCeram Bulk Fill also met the manufacturer's claim of a 4 mm bulk fill. The manufacturer states that in addition to the traditional camphorquinone/amine photoinitiator system, it contains Ivocerin, an "initiator booster" which reportedly contributes to the increased depth of cure. The manufacturer of SonicFill recommends that it be cured with 10 seconds of additional light curing on the buccal and lingual surfaces after the initial 20 second light cure from the occlusal. Additional light curing from the proximal would likely increase the polymerization of the other composite resins tested in this study. However, laboratory studies have shown that enamel and dentin significantly attenuate the light from a curing unit. Limited research has been completed on the effects of tri-sited light curing on the depth of cure of bulk-fill composites.

Studies evaluating the efficacy of incremental versus bulk filling have been somewhat equivocal, with higher shrinkage stress and cuspal deflection in some studies but reduced cuspal deflection in others. Incremental layering may allow flow during curing with additional free surface area. However, incremental curing allows more maximum polymerization and potentially more shrinkage stress. Little clinical evidence exists to support one particular composite resin application method over another.

Polymerization shrinkage has been steadily reduced through improvements in chemistry and composition. A new composite resin, Filtek LS, is promoted as a low-shrinking composite resin based on a ring-opening polymerization mechanism. As expected, Filtek LS had the lowest shrinkage of all the composite resins tested (1.21%). SonicFill had the second lowest polymerization shrinkage of (1.88%), although it was not significantly different from QuiXX (2.00%). However, all the composite resins tested exhibited relatively volumetric low shrinkage. An average volumetric shrinkage of 2%-3% occurs when restorative composite resins are polymerized, with the ring-opening silorane-based composite, Filtek LS, reportedly approaching 1%.

For restorations exposed to greater mechanical loads, the ideal minimum flexural strength is 90-100 MPa. In addition, a relatively high modulus is expected from posterior composite resin restorations to withstand the occlusal forces and preserve the adhesive interface. All composite resins tested showed adequate flexural strength and flexural moduli, although there were statistically significant differences among groups.

Another important mechanical property for dental composite resin materials is fracture toughness, which indicates the relative resistance to crack propagation from the surface or inherent flaws in the materials. Resin composites with higher fracture toughness will be better able to withstand high stress levels and thus have improved clinical outcomes. Filtek Z250 and QuiXX had the highest relative fracture toughness values, while SonicFill, Filtek LS, and Tetric EvoCeram Bulk Fill had slightly lower fracture toughness values. Despite the statistical differences, the results of this study show that all the restorative materials tested have adequate fracture toughness for use in posterior restorations.

Voids within a composite resin restoration may cause marginal leakage and discoloration, increased wear (due to stress concentration around the voids), decreased flexural strength, and incomplete adhesion between the resin composite and tooth structure. These voids may be incorporated into the composite material due to the manufacturing process or from handling techniques during clinical placement. With the new sonically placed composite resin, it was unknown if sonic energy would have an influence on the number and size of porosities. The results of this study showed less porosity with SonicFill, at least within the body of the specimen, as compared to the other composite resins tested (Figure). QuiXX had the largest number of porosities. Significant variability in porosity was found in the composite resins tested. The variability may be due to differences in handling characteristics of the different composite resin and the subsequent inclusion of larger voids during the fabrication of the specimens.

Overall, SonicFill has satisfactory mechanical properties for use as a direct posterior composite resin restorative material. The potential convenience of sonic placement and the advantage of the reduction in viscosity would likely be operator-dependent preferences. However, a disadvantage of SonicFill is that the depth of cure was determined to be significantly less than the other bulk-fill composites tested in this study. Furthermore, although the composite resin refill compules are similar in price to other comparable materials, the restorative dentist would incur an additional expense per each SonicFill handpiece and coupler. More research is necessary to evaluate the clinical performance of this new sonically placed composite resin material and the new class of bulk-fill restorative materials.

Conclusion

Compared to the other composite resin restorative materials, SonicFill showed low shrinkage and percent porosity, moderate fracture toughness and flexural modulus,
Dental Materials  Physical properties of a new sonically placed composite resin restorative material

and high flexural strength. However, it had a relatively reduced depth of cure compared to the other composites.

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Disclosure
The views expressed in this study are those of the authors and do not reflect the official policy of the United States Air Force, the United States Government, or the Department of Defense, or the United States Government. The authors do not have any financial interest in the materials whose characteristics are discussed in this article.

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Bruker MicroCT, Kontich, Belgium 32.3877.5705, www.skyscan.be
Coherent, Inc., Santa Clara, CA 800.227.8840, www.coherent.com
DENTSPLY Caulk, Milford, DE 800.532.2855, www.caulk.com
Grobet USA, Carlstadt, NJ 800.537.7123, www.kerrdental.com
Ivoclar Vivadent, Inc., Amherst, NY 800.533.6825, www.ivoclarvivadent.us
Kerr Corporation, Orange, CA 800.537.7123, www.kerrdental.com
Sabri Dental Enterprises, Inc., Downers Grove, IL 630.316.1471, www.sabridentalenterprises.com
3M ESPE, St. Paul, MN 888.364.3577, solutions.3m.com
The 15 questions for this exercise are based on the article, *Physical properties of a new sonically placed composite resin restorative material*, on pages 51-56. This exercise was developed by Jean J. Carlson, DDS, FAGD, in association with the General Dentistry Self-Instruction Committee.

Reading the article and successfully completing this exercise will enable you to:
- understand the physical properties of heavily filled resins compared with flowable resins;
- recognize the differences between bulk-fill and packable composite resins; and
- understand the advantages and disadvantages of a sonic-activated bulk-fill composite material.

1. The most common cause of failure of composite restorations is _________.
   A. improper material selection
   B. incomplete curing
   C. recurrent caries
   D. occlusal overload

2. Heavily filled resins have a maximum filler volume of about ____%.
   A. 40
   B. 50
   C. 60
   D. 70

3. Heavily filled composite resins exhibit all of the following improvements in handling except one. Which is the exception?
   A. marginal adaptability
   B. mechanical strength
   C. fracture properties
   D. wear resistance

4. Flowable composite resins exhibit all of the following traits except one. Which is the exception?
   A. decreased filler concentration
   B. lower viscosity
   C. decreased filler wettability
   D. lower elastic modulus

5. The ability of a composite material to flow may play a major role in the success of a restoration. In many Class II cavity preparations, it is easy to obtain proper contour and contacts.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

6. SonicFill reportedly can be used in cavity preparations up to ____ mm deep with only 20 seconds of light curing.
   A. 3
   B. 4
   C. 5
   D. 6

7. Microfill composite resins contain fillers with an average particle size in the range of ________ µm.
   A. 0.16-0.20
   B. 0.11-0.15
   C. 0.06-0.10
   D. 0.01-0.05

8. The silorane ring expansion of Filtek LS has been shown to decrease polymerization shrinkage to <______%.
   A. 0.5
   B. 1.5
   C. 2.5
   D. 3.5

9. All of the following properties were evaluated in the study except one. Which is the exception?
   A. depth of cure
   B. polymerization shrinkage
   C. flexural strength
   D. internal translucency

10. The greatest depth of cure was exhibited by the ________ composite resin.
    A. Filtek LS
    B. SonicFill
    C. QuiXX
    D. Filtek Z250

11. SonicFill demonstrated an average depth of cure of ____ mm.
    A. 3.17
    B. 3.67
    C. 4.17
    D. 4.67

12. Incremental layering may inhibit flow during curing. Incremental curing allows maximum polymerization.
    A. Both statements are true.
    B. The first statement is true; the second is false.
    C. The first statement is false; the second is true.
    D. Both statements are false.

13. For restorations exposed to greater mechanical loads, the ideal minimum flexural strength is ________ MPa.
    A. 90-100
    B. 80-89
    C. 70-79
    D. 60-69

14. Which of the following restorative materials was found to have the highest relative fracture toughness?
    A. QuiXX
    B. SonicFill
    C. Filtek LS
    D. TetricEvoCeram

15. All of the following are characteristics of SonicFill except one. Which is the exception?
    A. high shrinkage
    B. high flexural strength
    C. moderate fracture toughness
    D. low percent porosity
Fracture resistance of weakened roots restored with different intracanal retai

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Luiz Felipe Valandro, MSD, PhD • Osvaldo Bazzan Kaizer, MSD, PhD

The purposes of the study were to evaluate the effect of mechanical cycling (MC) on the fracture resistance of endodontically treated weakened roots restored with different intraradicular retainers and to analyze the failure mode. Eighty bovine roots were prepared and restored: 20 roots were reconstructed with cast post-and-cores (CPCs); 20 with fiber posts (FPs); 20 with fiber posts with larger coronal diameter (FPLs); and 20 with anatomic posts (APs). Metal crowns were cemented in all the roots. Half of specimens from each restoration strategy (n = 10) were submitted to MC: CPC-MC, FP-MC, FPL-MC, and AP-MC. The specimens were subjected to a fracture resistance test. The results showed that the type of retainer used was statistically significant (P < 0.0004). The CPC specimens demonstrated a fracture resistance similar to that of the APs, but greater than that of the FPs and FPLs. MC was statistically significant (P < 0.003) and affected AP-MC fracture resistance, which was lower than that of CPC-MC and similar to those of FP-MC and FPL-MC.

Key words: nonvital tooth, fracture resistance, weakened teeth

The restoration of endodontically treated teeth is a complex procedure. It becomes even more challenging when the radicular canals are excessively weakened due to substantial loss of tooth structure. If more than half of the coronal tooth structure is lost due to carious lesions, fractures, or extensive cavity preparation, it is necessary to use an intraradicular retainer. However, intracanal anchorage does not reinforce or protect the remaining dental structure. As such, the primary objective in cases of substantial loss of tooth structure is the retention of the material used to reconstruct the tooth crown. For selection of the intracanal retainer, the rigidity of the material should be considered since it may influence the mechanical behavior of the reconstructed tooth. Therefore, the use of posts with rigidity values (modulus of elasticity) higher than that of dentin—such as cast post-and-cores (CPCs), metallic prefabricated posts, and ceramic posts—may increase the risk of root fracture. Conversely, posts with properties similar to dentin, such as fiber-reinforced posts (glass, carbon, quartz, or polyethylene), support the material of coronal reconstruction and the weakened dentin structure. These types of posts also transmit less tension to the root, so that it is likely that the post will fail before the remaining root fractures.

Considering the intraradicular retainer systems available for use in enlarged canals, CPCs—despite providing adequate adaptation to the canal walls—may produce a wedge effect, which could lead to root fracture. Conversely, prefabricated fiber posts (FPs) have the advantage of allowing more homogeneous stress distribution to the tooth structure due to having mechanical properties similar to dentin, but they usually adapt imprecisely to the conduit, generating a thicker cement layer around the post. To overcome this problem, anatomic posts (APs) and double-tapered fiber posts with a larger coronal diameter (FPLs) can be used to obtain better adaptation and retention to the root canal. APs and FPLs can also reduce the thickness of the cement in the post-dentin interface in cases with increased internal radicular destruction.

The use of APs is especially recommended for flared root canals when removing extra dentin structure is not indicated. The layer of composite resin surrounding the AP—in order to individualize the retainer to the canal—eliminates the need to enlarge the conduit to enable the post to fit or to apply an extremely thick cement layer in the space between the post and dentin. The use of an AP also improves the retention of the post by providing close contact of the relining resin and the canal walls, as well as a thin cement layer. FPL systems, which have the same apical and middle diameters as an FP but a larger coronal diameter, have been recently developed as alternative options for flared roots with cervical dentin loss. Moreover, the proposed configuration of FPLs provides an adequate adaptation in the cervical portion without excessive removal of sound tissue in the apical region.

It is known that in the oral environment, dental reconstructions usually fail due to damage caused by cumulative effects such as fatigue, which differs from what occurs in monotonic tests that apply a unique static load until a specimen fails. For that reason, aging by means of mechanical cycling (MC) is a method of evaluating the behavior of different restorative systems by generating a thicker cement layer around the post.
approximately simulating actual clinical conditions, such as the angle of the applied load and the frequency of application.19

Within this context, the purposes of the study were to evaluate the effect of MC on fracture resistance of endodontically treated weakened teeth restored with different intraradicular retainers and to analyze the failure mode after compressive testing. The null hypotheses tested were that the different retainers would present similar values of fracture resistance and that MC would not affect the values.

Materials and methods

Selection and adequacy of the specimens

Eighty single root bovine teeth were sectioned to standardize the root lengths at 15 mm. The coronal diameters of the canals were measured with a digital caliper (Starrett 727, The L.S. Starrett Company); teeth with diameters larger than the drill used to prepare the conduits (1.8 mm) were excluded. The roots were endodontically treated with stainless steel K Flexofile reamers (DENTSPLY International) of increasing diameter (up to No. 4) until a diameter of 1.3 mm was reached. The canals were then prepared with a White Post DC No. 2 drill (FGM Produtos Odontologicos) to a 10 mm length. In order to simulate extensively enlarged canals, the most cervical 5 mm of all roots were weakened with a diamond-tapered bur (4138 HL, KG Sorensen) until the remaining dentin thickness was 1 mm (Fig. 1).

Embedment and periodontal ligament simulation

To simulate the periodontal ligament, the external surface of the roots was covered by a uniform 0.5 mm layer of wax, except for the last 3 mm of the cervical portion.20 Each root was then embedded in plastic cylinders with autocuring acrylic resin (Dencrilon, Dencril Produtos Odontologicos); the bur of the post system was inserted into the prepared canal and attached to a surveyor so that the long axes of the root, bur, and cylinder were perpendicular to the ground. Acrylic resin was poured inside the cylinders up to the last 3 mm of the coronal portion of the roots.21 After the acrylic resin had polymerized, the roots were taken off the cylinder and the wax was removed. Medium-bodied polyether (Impregum Soft, 3M ESPE) was manipulated and inserted in the space left by the wax removal. The root was repositioned on the cylinder and the excess was removed with a scalpel blade after the polymerization of the Impregum Soft.

All specimens were numbered from 1 to 80, and 8 random sequences of 10 numbers (n = 10) were generated by Random Allocation Software (M. Saghaei, Isfahan University of Medical Sciences), according to the retainer type and application of MC (Fig. 2).

Preparation of the specimens

CPCs

CPCs were made with a chemically curing acrylic resin (Duralay, Reliance Dental Mfg. Co.) and cast with Ni–Cr alloy (Fit Cast-SB Plus, Talmax). To standardize the dimensions and shape of the coronal portion of the cores, the acrylic resin was inserted in polypropylene matrices with the anatomic configuration of an upper canine prepared for a full crown (6 mm height).

The CPCs were abraded with aluminum oxide (particle size 50 µm). Coronal and radicular dentin was etched with 37% phosphoric acid (Condac, FGM Produtos Odontologicos) for 15 seconds and washed with water for 15 seconds. Excess water was removed with paper points. An adhesive (Ambar, FGM Produtos Odontologicos) was applied to the canal with a microbrush (Cavibrush, FGM Produtos Odontologicos) and photoactivated for 20 seconds with a high power LED (Radii Cal, SDI (North America), Inc.). Next, a dual resin cement (AllCem, FGM Produtos Odontologicos) was mixed and inserted into the canal with a Lentulo drill. The CPCs were positioned, excess cement was removed, and photoactivation was performed for 10 seconds on each surface (buccal, mesial, lingual, and distal).

FPs

Smooth, double-tapered FPs (White Post DC No. 2, FGM Produtos Odontologicos) with apical diameter of 1.05 mm and coronal diameter of 1.8 mm were cemented on the roots of the 20 specimens. Before cementation, the FPs were cleaned.
Fracture resistance of weakened roots restored with different intracanal retainers

Table 1. Fracture resistance means and standard deviations (N) for the experimental groups in the study.

<table>
<thead>
<tr>
<th>Retainer</th>
<th>Mechanical cycling Without</th>
<th>With</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPC</td>
<td>1396.8 (265.95)</td>
<td>1120.0 (242.26)</td>
</tr>
<tr>
<td>FP</td>
<td>976.7 (236.28)</td>
<td>1017.4 (230.70)</td>
</tr>
<tr>
<td>FPL</td>
<td>927.3 (177.29)</td>
<td>896.5 (150.97)</td>
</tr>
<tr>
<td>AP</td>
<td>1103.5 (192.15)</td>
<td>780.0 (200.83)</td>
</tr>
</tbody>
</table>

Different uppercase letters indicate a clinically significant difference (P < 0.05) for the same column. Different lowercase letters indicate a clinically significant difference (P < 0.05) for the same row. Abbreviations: AP, anatomic posts; CPC, cast post-and-cores; FP, fiber posts; FPL, fiber posts with larger coronal diameter.

with 70% ethyl alcohol and a silane-coupling agent (Prosil, FGM Produtos Odontologicos) was applied all over the FPs with a microbrush. The cementation technique used for those groups was identical to that used for the CPCs. After cementation, a layer of composite resin (Oppalis, FGM Produtos Odontologicos) was applied over the coronal portion of the FPs to avoid the incorporation of bubbles and to ensure that the entire post surface was covered by resin. Photoactivation was performed for 10 seconds on each surface, for a total of 40 seconds. Then, plastic matrices identical to those used for the CPCs were filled with the composite resin, positioned over the coronal portion of the FPs, and photoactivated for 10 seconds on each surface. After the resin polymerization, the matrices were removed and the cores presented the same anatomical shape and dimensions as the CPCs.

FPLs
FPLs (White Post DC No. 2E, FGM Produtos Odontologicos) were cemented on the roots of 20 specimens. These FPLs had the same apical diameter as the FPs but a larger coronal diameter (2.2 mm); they are recommended by the manufacturer for use in flared canals. Post cementation and coronal reconstruction were identical to the methods used for the FPs.

APs
To produce APs, White Post DC No. 2 FPs were relined inside the canals with a low-viscosity composite resin (Oppalis Flow, FGM Produtos Odontologicos) in order to provide adequate adaption to the enlarged root conduit. The FPs were cleaned with 70% ethyl alcohol and Prosil (FGM Produtos Odontologicos) was applied over the surface. Ambar adhesive was applied to the APs and photoactivated for 20 seconds. The root canals were lubricated with hydrosoluble insulation (K-Y Jelly, Johnson & Johnson) and composite resin was inserted in the canal with the Lentulo drill. The fiber post was positioned in the center of the conduit and photoactivation was performed for 20 seconds on the occlusal surface. The relined post was removed from the canal and additional photoactivation was performed for 10 seconds on each surface. Subsequently, the canals were washed with distilled water to remove the insulation. The adhesive procedures of post cementation and coronal reconstruction described for FPs and FPLs were conducted.

Cementation of full metal crowns
After cementation, all specimens were stored in distilled water at a temperature of 37°C for 24 hours. Identical full metal crowns simulating the anatomy of upper canines (8 mm in height and a slightly rounded concavity located 3 mm from the incisal edge on the palatal aspect) were cemented over the coronal portion of the casts in the roots of all the groups. The functions of the concavity were to prevent the sliding of the active end of the testing machine and to establish the same point of load application for all the specimens. The crowns were internally abraded with particles (50 µm) of aluminum oxide. AllCem was inserted inside the crowns, which were then settled in position over the casts, and a weight of 2 kg was applied on the crowns. Photoactivation was performed for 40 seconds (10 seconds on each face) and the load was removed after 5 minutes, allowing chemical polymerization of the cement. After cementation of the crowns, the specimens were stored in distilled water at 37°C for 24 hours.

Mechanical cycling
Half of the specimens of each restorative strategy were immersed in distilled water and subjected to 100,000 cycles in the mechanical fatigue simulator (ER 11000, ERIOS Equipamentos), corresponding to 1 year of clinical service, according to an MC protocol: load of 88 N, frequency of 2.2 Hz, temperature of 37°C, and angle of 45 degrees to the specimen long axis (135 degrees in relation to the ground). The specimens that were not mechanically cycled were stored in distilled water at a temperature of 37°C during the same period of the MC specimens. According to the type of retainer used and presence or absence of MC, the following 8 groups were designed: CPC, FP, FPL, and AP (no MC); and CPC-MC, FP-MC, FPL-MC, and AP-MC (with MC).

Compressive strength test
The fracture resistance test was executed in a universal testing machine (EMIC DL 2000, EMIC Equipamentos e Sistemas de Ensaio LTDA) for all groups (MC and no MC) 24 hours after the MC was finished. The specimens were positioned in a device at an angle of 45 degrees in relation to the horizontal plane, reproducing the clinical condition of a Class I occlusion. A constant load was applied at a crosshead speed of 1 mm/min until failure.

Failure mode analysis
Failures were classified as favorable or unfavorable. Vertical and oblique root fractures below the simulated bone level (the tooth area exposed outside the acrylic resin, corresponding to the biologic space) were considered unfavorable failures. Failures at or above the simulated bone level, fractures of the coronal portion of the cast, and dislodgment of the coronal portion of the cast and/or post were considered as favorable failures.
With MC was made to weaken the roots until 1 mm. In the present study, the choice of remaining dentin thickness was reached. This procedure has been done by other authors, as it is believed that the remaining quantity is consistent with actual clinical observations.6,13,23,24,26,27 The results of the present study demonstrate that the fracture resistance was influenced by the different intraradicular retainers (P < 0.05), so the first null hypothesis was rejected.

Differential rehabilitation procedures for restoring teeth with widely flared root canals have been investigated in many studies with the intention of predicting which method makes the restoring complex (root, intraradicular post, cement, cast, and crown) more resistant to masticatory loads, thus providing a less damaging failure pattern in unsuccessful cases.6,13,23,24,26,27 There were significant differences between the CPC and FP, CPC and FPL, FP-MC, and AP-MC groups, as well as the AP and AP-MC groups (Table 1). Table 2 shows the percentage of favorable and unfavorable failures in each group.

### Table 2. Percentage of failure modes for each group in the study.

<table>
<thead>
<tr>
<th>Failure modes</th>
<th>Without MC</th>
<th>With MC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPC</td>
<td>FP</td>
</tr>
<tr>
<td>Favorable</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Unfavorable</td>
<td>70</td>
<td>10</td>
</tr>
</tbody>
</table>

**Abbreviations:** AP, anatomic posts; CPC, cast post-and-cores; FP, fiber posts; FPL, fiber posts with larger coronal diameter; MC, mechanical cycling.

### Statistical analysis
Considering the 2 variables of the study (type of retainer and MC), the fracture resistance values were analyzed by 2-way analysis of variance (ANOVA) and Tukey’s test (α = 0.05). Comparisons were done among the different retainers under the same cycling options (present or absent) and for the same retainers (MC and no MC).

### Results
None of the specimens presented root fracture or restoration failure during the MC. Two-way ANOVA showed that the type of intraradicular retainer, MC, and the interaction between the 2 factors were statistically significant (P < 0.0004, P < 0.003, and P < 0.02, respectively). There were significant differences between the CPC and FP, CPC and FPL, FP-MC, and AP-MC groups, as well as the AP and AP-MC groups (Table 1). Table 2 shows the percentage of favorable and unfavorable failures in each group.

### Discussion
Teeth that have severe coronal destruction resulting from caries and/or dental fractures, as well as from the opening of the pulp chamber for endodontic treatment, make the retention of restorative materials used for dental reconstruction difficult. Evaluation of the mechanical behavior of such dental elements is important, since it is common to encounter widely enlarged teeth in a routine clinical examination.

Several studies have evaluated the behavior of weakened roots, resulting in diverse canal weakening levels and different preparation designs, as there is no standardized protocol for the amount of remaining radicular dentin for flared canal simulation.6,13,23,27 In the present study, the choice was made to weaken the roots until 1 mm of remaining dentin thickness was reached. In relation to the roots reconstructed with AP—which showed fracture resistance similar to that of the CPC—it is probable that the accurate adaption and retention to the flared canal walls provided by the relining of the fiber posts with composite resin (thus reducing the cement thickness around the post) was an important factor in obtaining acceptable mechanical performance in those teeth.14,15

Considering the utilization of double-tapered FPs, there was no statistical difference (regardless of MC) between the groups restored with FPs and the groups restored with FPLs. Although the FPLs generated a thinner layer of cement, which in terms of adhesion is favorable, the greater diameter did not affect the compressive resistance values of the restorative unit, which probably could be explained by the standard weakening of all the groups.6,36 As a result of the canal preparation simulating weakened radial walls, there was no contact of the post with the canal walls in the cervical portion of the conduit in the groups of FPs and FPLs, even though the posts were adapted in the apical third. It is suggested that more laboratory and long-term clinical studies should be conducted to test FPLs in root canals with different weakening levels in order to verify whether the larger diameter really provides significant resistance values, thereby enhancing its indication for flared teeth.

The second hypothesis of the study was rejected because MC had a significant effect on the fracture resistance of the retainers (P < 0.05). When the different intraradicular retainers were compared among themselves, it was observed that the CPC-MC group showed fracture resistance statistically similar to that of the FP-MC, FPL-MC, and AP-MC groups. Although the groups restored with FPs and FPLs showed fracture strengths inferior to those of other groups when MC was not applied, these post systems presented good mechanical behavior after aging, and were the groups that showed the lowest reduction in fracture resistance after MC. This finding is directly related to the mechanical and physical properties of the retainers, which are very similar to those of the dental structure and therefore...
homogeneously dissipate the stresses generated to the root.7 Moreover, this result is in agreement with other studies that also observed satisfactory behavior for teeth restored with these kinds of post systems.13,24,26,28,30

Comparing the MC and non-MC groups, it was verified that only the group reconstructed with APs showed statistically inferior fracture resistance after aging. These results highlight another finding of the present study: the AP behaved as well as the CPC group; however, when MC was imposed, the APs experienced a significant decrease in fracture resistance. Because both systems (APs and CPCs) had adequate adaptation to the canal walls (since they were individualized retainers and the adhesive systems were the same for all the groups), it is possible that the weak component of the APs was the low-viscosity composite resin used to reline the original FP. Therefore, the teeth reconstructed with APs presented good behavior for the static test, but after MC, the flowable resin apparently showed degradation, which was reflected in the lower fracture resistance.

Compared to microhybrid resins, flowable composite resins present a reduction in filler volume, which results in better flowing properties, reduced viscosity, lower modulus of elasticity, and easier handling.37,38 However, certain studies have suggested that flowable resins demonstrate decreased mechanical properties, such as compressive resistance, flexural resistance, and fracture toughness, which could explain the reduction of fracture resistance when the specimens were mechanically cycled in the present study.39,40 It is likely that if another composite resin with greater inorganic filler content—such as a hybrid or microhybrid resin—had been used, the cycled anatomic posts would have had higher compressive strength values.

Some studies did not find a significant decrease in fracture resistance after simulated aging with MC, which is in accordance with the results shown for the CPC and CPC-MC groups in the present study, as well as for the FP and FP-MC and the FPL and FPL-MC groups.26,41

With respect to the CPCs, in spite of not being statistically significant, the MC induced a reduction of fracture strength. If a greater number of cycles had been applied, it is reasonable to suppose that such a reduction could be significant.

The primary advantage of FPs used conventionally or individualized by the relining of the canal with resin (APs), was the more favorable failure mode (in comparison with CPCs), which clinically would allow for the recovery and maintenance of the dental element in almost all the cases (70%-90% of repairable failures), which is in agreement with previous studies.9,29,31,42 For that type of reconstruction, the materials have elasticity moduli near to that of dentin, which provides a more uniform stress distribution to the remaining root and to the periodontium, minimizing the risk of radicular fracture.3,5,6,7,10 In the groups in which CPCs were used, the failure pattern was mostly of irreparable failures (70%-100%), which is also in agreement with prior studies; the rigidity of this type of retainer generates nonuniform high stresses to the remaining dental structure.5,7,9,41,42 It may also have a wedge effect on the restored root, leading to radicular fractures.10,11

Despite the advances in dentistry, many professionals continue to choose to extract flared dental elements for fear of an adverse prognosis over the long term.13 Nevertheless, radicular destruction is usually restricted to the cervical part of the canal, whereas the middle and apical thirds have adequate radicular wall thickness; hence, these partially weakened roots could be maintained if adequately restored.12 A correct diagnosis is indispensable for improved planning and for selection of the most suitable treatment option to successfully restore endodontically treated teeth with weakened roots.

**Conclusion**

CPCs, FPs, and FPLs remained stable after MC, while MC significantly reduced the fracture resistance of APs. CPCs promoted a high percentage of irreparable failures, while the other retainers generated a high number of repairable failures.

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Dental management of a patient with Wilson’s disease

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Marina Gallottini, DDS, MsC, PhD

Wilson’s disease (WD) is an autosomal recessive genetic disease, characterized by the accumulation of copper in the body—primarily in the brain and liver—due to defective biliary copper excretion by hepatocytes. WD may manifest clinically as liver disease, neurologic symptoms, and Kayser-Fleischer corneal rings. This article presents a case involving a 43-year-old man who had WD prior to liver transplantation. Oral examination revealed petechiae in the oral mucosa, poor oral hygiene, periodontal disease, missing teeth, and several carious teeth. Patients with WD may present systemic changes that affect dental care. Dental treatment prior to liver transplantation is recommended to eliminate the oral foci of infection and control oral disease.

Wilson’s disease (WD) was first described by Dr. Samuel Wilson in 1912.1 He described it as a “progressive hepatolenticular degeneration.” WD is relatively rare and occurs equally among males and females; a 1999 study reported an estimated prevalence of 1:35,000 among Japanese patients.2

WD is an autosomal recessive genetic disease. It is characterized by the accumulation of copper in the body (primarily in the brain and liver) due to defective biliary copper excretion by hepatocytes.3 The disease is caused by mutations in the ATP7B gene located in chromosome 13, which functions as a biliary copper excretory pathway.3-5 Copper is essential for enzymatic reactions involving free radical scavenging, pigment production, neurotransmission, connective tissue formation, and iron homeostasis.6 However, copper accumulation in hepatocytes can cause severe mitochondrial dysfunction with subsequent decreased enzymatic activity in the liver, resulting in hepatic steatosis. When the accumulation of copper exceeds the liver’s capacity to metabolize it, the copper is released into the circulatory system and taken up by all organs. The resultant copper toxicity mainly affects the central nervous system, causing neuronal damage.7

WD may manifest in a variety of clinical conditions, such as liver disease, neurologic symptoms, and Kayser-Fleischer corneal rings; the latter are characterized by a golden-brown ring of pigmentation at the outer margin of the cornea. Manifestations in the nervous system include a decline in intellectual function, movement disorder, depression, loss of emotional control, dystonia, orthostatic hypotension, parkinsonism, and an altered gag reflex.3,7,8

Treatment options depend on a patient’s clinical manifestations. In asymptomatic cases, the goal of therapy is to remove copper from the tissues with a chelating agent, such as penicillamine and zinc acetate. Penicillamine is a reductive chelator that acts to mobilize copper from the liver and other organs, causing its excretion in the urine; however, there are numerous (and often serious) side effects to this agent, including bone marrow suppression, hypersensitivity, proteinuria, and autoimmune diseases. Zinc acetate induces intestinal cell metallothionein,
which inhibits the absorption of copper; the only side effect of this agent is gastric irritation. A patient with severe liver failure requires hepatic transplantation. There are few studies in the literature that profile the oral health and dental management of these patients. This article presents a case report involving a patient who had WD prior to a hepatic transplant and discusses the oral aspects and dental management of individuals with WD.

Case report
A 43-year-old man who had been diagnosed with WD 2 years earlier was referred for dental treatment prior to receiving a liver transplant. The patient had no specific dental complaints. His medical history included end-stage liver disease requiring liver transplantation and various neurological impairments, including dystonia and parkinsonism. The patient was taking medications (zinc acetate and penicillamine) daily and had reported no side effects. Laboratory tests showed significant changes in coagulation and liver function, including a low platelet count, prolonged prothrombin time, an increased international normalized ratio, increased gamma glutamyl transferase, and increased aspartate amino transferase (Table).

A clinical examination revealed movement disorders, dystonia, tremors, and a Kayser-Fleischer ring (Fig. 1). An intraoral examination identified petechiae in the oral mucosa, poor oral hygiene, periodontal disease, missing teeth, and several carious teeth (Fig. 2). Radiographic examinations (including periapical and panoramic radiographs) were also performed (Fig. 3). The treatment plan focused on preventing caries and periodontal disease, restorative and periodontal treatment, and tooth extraction. The restorations were replaced with composite resin, avoiding alloys that might release copper. Successive sessions of scaling and root planning (SRP) were performed around all teeth to prevent gingival bleeding. To prevent caries and periodontal disease, oral hygiene instructions concerning the control of plaque were emphasized at each appointment. A third molar surgery was conducted in an outpatient clinic using local hemostatic measures, tranexamic acid paste, and absorbable gelatin sterile sponges.

Discussion
As stated previously, patients with WD may exhibit clinical manifestations, such as liver disease and neurological impairment. Laboratory tests measuring hemostatic disorders should be considered during dental care. In the present case report, the patient had signs and symptoms of neurologic impairment and end-stage liver disease with important coagulation abnormalities.

Neurological impairment—including orthostatic hypotension and an altered gag reflex—needs to be considered during the dental treatment of a WD patient. Dental professionals must always be aware of these potential complications and keep the dental chair in a vertical position during the dental treatment to reduce the likelihood of a fall when the patient rises. This precaution also prevents aspiration of water or materials used during dental procedures. All dental procedures in the present case were performed with the dental chair in a vertical position.

Patients with WD have difficulty maintaining oral hygiene due to their physical disability. Some drugs (such as antimuscarinic or antiparkinsonian agents) can reduce salivation, potentially increasing the incidence of caries. The patient in the present case had some carious lesions but had not reported symptoms of xerostomia. He had not been prescribed drugs to control his nervous system; however, he had severe motor impairment that affected his oral hygiene, potentially causing caries.

Lohe et al conducted a literature review of clinical aspects related to Wilson’s disease and the impact of WD on dental management. The authors stressed that when patients have a tendency to bleed, dentists should confirm WD with various tests—such as complete blood counts, coagulations studies, and liver and kidney functions tests—before

Fig. 2. Intraoral photograph of the patient’s mouth showing petechiae in the oral mucosa.

Fig. 3. A pretreatment panoramic radiograph of the patient showing periodontal disease, missing teeth, several carious teeth, and an impacted left mandibular third molar.
Perforing any surgical or periodontal procedures. Furthermore, the authors emphasized the need to avoid drugs metabolized by the liver and noted that a WD patient must be treated in the upright position to avoid alteration of the gag reflex and the aspiration of water or materials used during dental procedures.8

Although patients with WD may develop oral complications due to the disease, there may be other complications associated with prolonged therapy. Tovaru et al described 2 patients with multiple small red papules of the lips, gingival enlargement, early-onset periodontitis, and repeated oral candidiasis associated with D-penicillamine, a drug used to treat WD.9 The patient in the present case did not show these oral manifestations, which may be due to shorter periods of D-penicillamine treatment as compared to the cases described by Tovaru et al.

In terms of dental management, bleeding disorders are the greatest concern for patients with end-stage liver disease. Routine dental procedures (such as SRP and tooth extractions) can result in serious complications in these patients if the dentist is unaware of the risks of impaired hemostasis and increased bleeding. For patients with hemostatic impairment, surgical techniques and successive sessions of SRP should be used, including local hemostatic measures and primary wound closure.10,11

Although the patient in the present case showed abnormal coagulation values, he did not exhibit critical values that would contraindicate invasive dental treatment. For this reason, the dental treatments were conducted in an outpatient clinic. Dental extraction and periodontal treatment were conducted using local hemostatic measures, particularly a tranexamic acid paste and absorbable gelatin sponge.10,11

Providing oral health care before and after liver transplantation is essential for establishing a good prognosis and quality of life in transplant recipients. Before transplantation, the main concern is to eliminate the oral foci of infection, including those of periapical and periodontal origins.12 The treatment plan in the present case focused on restorative and periodontal treatment with an emphasis on prevention, orientation, and education to maintain the patient’s oral health while respecting the limits of his clinical condition and the laboratory parameters of coagulation.

Conclusion
Patients with WD and end-stage liver failure require judicious, special dental care to eliminate the oral foci of infection and to control oral disease prior to transplantation with minimal risk of complications to the patient.

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References
Endodontic treatment of mandibular molars with atypical root canal anatomy: reports of 4 cases

Raju Chauhan, BDS, MDS • Shweta Singh, BDS, MDS

The variations in root canal anatomy of multirooted teeth represent a continuous challenge to endodontic diagnosis and treatment. Although the most common configuration of mandibular molars is one containing 2 roots and 3 root canals, there are many different combinations. Very rarely, an additional third (supernumerary) root is seen. When it is located distolingually to the main distal root, this third root is called radix entomolaris (RE), and when it is located mesiobuccally to the mesial root, it is called radix paramolaris (RP). Variations of root canal systems need not always be in the form of extra roots or extra canals. Single roots with single canals can also occur. A general dentist should be aware of these unusual root canal morphologies in mandibular molars for the success of endodontic treatment. These case reports describe the root canal treatment of a case of RE in the mandibular first molar, 2 rare cases of RP (1 each in the mandibular first and second molars), and a mandibular second molar with a single root and root canal.

Key words: mandibular first molar, mandibular second molar, radix entomolaris, radix paramolaris, single root

The main objectives of root canal therapy are the thorough debridement of the entire pulp space, 3-dimensional obturation with an inert material, and placement of a coronal filling that prevents the ingress of microorganisms. Two of the main factors associated with endodontic failure are the persistence of microbial infection in the root canal system and the complexity of root canal anatomy. The clinician must have an in-depth knowledge of root canal anatomy and be aware of its anatomic variations—including extra roots and/or extra canals—which may complicate an endodontic procedure. The mandibular molars typically present with 2 well-defined roots: a mesial root characterized by a flattened mesiodistal surface and widened buccolingual surface, and a distal root that is mostly straight with a wide oval canal or 2 round canals. An important variation found in mandibular molars is the existence of a third root. If this extra root is present on the distolingual side, it is termed radix entomolaris (RE). If this extra root is present on the mesiobuccal side, it is termed radix paramolaris (RP).

The presence of an RE in the mandibular first molar is associated with certain ethnic groups. According to various studies, the prevalences of an RE in the mandibular first molar are 22.3% in Koreans, 3.9% in Jordanians, 3.1% in Africans, 0.7% in Germans, and 2.2% in Caucasians. The presence of an RP is very rare in both European and Mongolian populations. In a study conducted by Visser, the incidence of RP was 0%, 0.5%, and 2.0% for the mandibular first, second, and third molars, respectively. However, other studies have reported RP in mandibular first molars.

The most important root canal variation in the mandibular second molar is a C-shaped anatomy. Both the mesial and distal roots can be fused to form a single conical root with varying internal anatomy, often resulting in a C-shaped canal configuration. In a study of 75 human extracted second molars, Weine et al found 1 tooth with 1 root canal (1.3%). A study conducted by Rahimi et al on 139 extracted mandibular second molars in an Iranian population found 8 (5.7%) teeth had single roots and/or canals.

The following case reports describe the endodontic management of RE in a mandibular first molar, RP in mandibular first and second molars, and a single-rooted mandibular second molar.

Fig. 1. Case No. 1. A. Preoperative radiograph showing radix entomolaris (RE) in tooth No. 19. B. Working length radiograph that revealed the presence of RE. C. Master cone radiograph. D. Postoperative radiograph with obturated canals.
Case No. 1
A 29-year-old man presented with an extensive distal carious lesion in the mandibular left first molar. The patient also complained of dull pain from the tooth. No periodontal pockets were present. Clinical examination of the surrounding teeth did not reveal any clinical signs or symptoms. A radiograph of the involved tooth revealed deep distal canals in tooth No. 19 with no periapical changes. The tooth was not sensitive to percussion but responded negatively to sensitivity testing (cold testing and electrical pulp vitality testing). Based on the findings, the tooth was diagnosed with chronic irreversible pulpitis.

Examination of the preoperative radiograph revealed the presence of 3 roots in tooth No. 19 (Fig. 1A). The extra root was an RE. Nonsurgical endodontic treatment was planned in tooth No. 19. The tooth was anesthetized and accessed under rubber dam isolation. Initially, 2 mesial canal orifices and 1 distal canal orifice were located. In addition, a dark line led to the RE. The root canals were explored with a precurved K-file No. 15 (DENTSPLY Maillefer), and the radiographic length measurement was established (Fig. 1B). The canals were cleaned and shaped in a crown-down manner with nickel-titanium rotary files (ProTapers, DENTSPLY Maillefer), while they were copiously irrigated with 5% sodium hypochlorite and 17% ethylene-diaminetetraacetic acid (EDTA). A master cone radiograph was also taken with corresponding ProTaper gutta percha cones (Fig. 1C). Obturation of the root canals was performed using gutta percha and AH Plus sealer (DENTSPLY Maillefer) with a cold lateral condensation technique. The access cavity was restored with restorative composite resin, and a radiograph was taken to confirm the quality of the obturation (Fig. 1D).

Case No. 2
A 24-year-old woman with a noncontributory medical history reported with a chief complaint of pain and sensitivity in her lower left posterior teeth. Intraoral examination revealed the presence of a deep carious lesion in the left mandibular first molar. A radiograph was taken, revealing deep occlusal caries and condensing periosteitis in tooth No. 19 (Fig. 2A). Vitality tests (cold and electrical pulp tests) on the involved tooth showed abnormal responses, indicating that irreversible pulpitis had occurred. A periapical radiograph revealed 2 periodontal ligament outlines in the mesial root, indicating the presence of RP. The tooth was anesthetized and accessed under rubber dam isolation. Initially, 2 distal canals and 1 mesial canal were located. A fourth canal was located when further cutting was done on the mesiobuccal side; thus it was identified as an RP. All the canals were instrumented with precurved K-file No. 15, and a working length radiograph was taken (Fig. 2B). The working length radiograph confirmed the presence of an RP. Cleaning and shaping in all the canals was accomplished with a crown-down technique using ProTapers. During cleaning and shaping, the canals were irrigated with 5% sodium hypochlorite and 17% EDTA. A radiograph was taken with the master cone (Fig. 2C). The canals were obturated with a cold lateral condensation technique using AH Plus sealer and gutta percha cones. The access was restored with composite restorative resin. A postoperative radiograph was taken to confirm the quality of the obturation (Fig. 2D).

Case No. 3
A 38-year-old man was referred for endodontic treatment. The patient complained of pain in relation to the right mandibular posterior region, especially

Fig. 2. Case No. 2. A. Preoperative radiograph showing the presence of 2 separate roots mesially diagnosed as radix paramolaris (RP) in tooth No. 19 (arrows). B. Working length radiograph confirming RP. C. Master cone radiograph. D. Postoperative radiograph.
after consuming hot drinks. Intraoral examination revealed deep caries in tooth No. 31. An intraoral periapical radiograph revealed deep caries approximating the pulp without any associated periapical changes (Fig. 4A). The tooth responded abnormally to pulp testing. Based on the findings, the tooth was diagnosed as having irreversible pulpitis. A detailed examination of the radiograph revealed the presence of a single root with a wide canal. Therefore, a C-shaped canal configuration was anticipated.

After anesthesia, the access cavity was opened under a rubber dam, and the pulp was extirpated. Examination of the pulpal floor revealed a single round-shaped orifice, a classical C-shaped canal orifice configuration. No other canal orifices could be located. The working length was determined radiographically with a K-file No. 30 (DENTSPLY Maillefer) (Fig. 4B). Cleaning and shaping was completed by the step-back method along with a combination of irrigants. A snug-fitting master cone was selected. Obturation of the canal was done by a combination of warm vertical condensation and a thermoplastized injectable gutta percha technique (E & Q Plus, META-BIOMED Co., Ltd.). The access cavity was sealed with an amalgam restoration, and a radiograph was taken (Fig. 4C).

**Discussion**
Clinicians must have thorough knowledge of root canal anatomy and the morphology of the pulp chamber before initiating endodontic treatment on a patient. All root canals should be identified, cleaned, and shaped to receive a hermetic filling of the entire root canal space. Incomplete cleaning, shaping, and obturation of any root canal will lead to almost certain endodontic failure.

Over the years, there have been numerous studies that described the morphologies of various teeth, including mandibular molars. The major variant in this group is the mandibular first molar with 3 roots. The additional root is usually located on the lingual aspect. This type of root canal anatomy occurs less frequently in mandibular second molars, but these teeth have a high incidence of C-shaped root canals. A general dentist needs to be aware of the high frequency of variation found in the morphologies of mandibular molars.

An RE is located on the distolingual side of the tooth, with its coronal third completely or partially fixed to the distal root in the form of a short conical extension to a mature root with a normal length and root canal. In general, the RE is smaller than the distobuccal and mesial roots and can be separate from—or partially fused with—the other roots. An RP is located on the mesiobuccal side of the tooth. As with an RE, the dimensions of an RP can vary from a mature root with a root canal to a short conical extension. This additional root can also be separate or nonseparate.

An accurate diagnosis of these supernumerary roots can avoid complications or a missed canal during root canal treatment. A thorough inspection of the preoperative radiograph and interpretation of particular marks or characteristics, such as an unclear view or outline of the distal/mesial root contour or the root canal, can indicate the presence of a hidden RE and/or RP. With
RE and RP, the conventional triangular access cavity must be modified to a more trapezoidal or rectangular form to better locate and access the additional orifice of the extra root. Calberson et al recommended using flexible nickel-titanium rotary files to allow a more centered preparation and restricted enlargement of the coronal third of the root canal. In a 2009 study of permanent 3-rooted mandibular first molars conducted by Tu et al, the mean interorifice distances from the distolingual canal to the distobuccal, mesiobuccal, and mesiolingual canals of the molars were 2.7, 4.4, and 3.5 mm, respectively. These values can help dentists to locate orifices and to achieve successful endodontic treatment of RE.

In Cases No. 1-3, RE and RP were diagnosed in the preoperative radiographs along with the working length and master cone radiographs. The access cavities were then modified to more trapezoidal forms to locate the orifices of the extra roots and canals. Cleaning and shaping was accomplished with nickel-titanium rotary instruments in combination with irrigants in order to limit procedural errors. Subsequently, the canals were obturated with a cold lateral condensation technique. Another important variation which frequently occurs in the mandibular second molar is a C-shaped root and/or canal. This variation may also occur in mandibular first molars, maxillary molars, mandibular first premolars, and even in maxillary lateral incisors. Typically, this canal configuration is found in teeth with fusions of the roots either on the buccal or lingual aspects. The main anatomic feature of C-shaped canals is the presence of a fin or web connecting the individual root canals.

The morphologic C-shaped canal variation is unusual and can lead to difficulties during treatment, so proper diagnosis of this situation is mandatory before treatment. A preoperative radiograph and an additional radiograph from a 20 degree mesial or distal projection may provide clues about the canal morphology. The root configuration of molars having this canal shape may be represented as a single fused root or as 2 distinct roots with a communication. Clinically, this anatomy can be diagnosed by gaining access and observing the pulp chamber. The clinician may find a large occlusogingival pulp chamber, a single large canal orifice, or multiple orifices that are interconnected. The prevalence of single-rooted and single-canal mandibular second molars ranged from 1.3% to 8.0% in previous studies.

In Case 4, after access cavity preparation, only 1 canal with a round orifice was located, suggesting the presence of a single canal. Further exploration of the pulpal floor did not reveal the presence of any additional orifice opening. Biomechanical preparation and copious irrigation were done to ensure complete removal of debris. The canal was obturated using thermoplasticized gutta percha with a master cone to prevent extrusion beyond the apex. The advantage of using a thermoplasticized injectable obturating technique is that it ensures compact obturation of wide canals without voids and obturation of any aberration present in these canal systems.

**Conclusion**

A general dentist should be aware of the morphological variations in mandibular molars, such as additional roots, additional canals, and C-shaped canals. The morphological variations of RE and RP in terms of root inclination and root canal curvature demand careful, adapted, clinical approaches to avoid procedural errors during endodontic therapy. The initial diagnosis of RE, RP, or C-shaped canals prior to endodontic treatment is important to facilitate procedures during treatment and avoid the mislocation of any canal. Periapical radiographs executed in the preoperative stage with different horizontal angulation help to identify these anatomic variations. Management of such cases requires the judicial application of diagnostic tools and endodontic skills.

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**Manufacturers**

DENTSPLY Maillefer, Tulsa, OK
800.924.7393, www.maillefer.com

META-BIOMED Co., Ltd., Chalfont, PA
Hearing loss associated with long-term exposure to high-speed dental handpieces

Sarah M. Theodoroff, PhD • Robert L. Folmer, PhD

The purpose of this study was to record and compare audiometric pure tone thresholds of dental clinicians (DCs), dental professionals (DPs), and dental students (DSs); determine the percentage of these groups who use hearing protection devices while at work in the clinic; and measure the sound intensities generated by a few representative high-speed handpieces while they are being used on patients. Participants included DCs who regularly used these handpieces (n = 16), DPs who did not use these handpieces (n = 13), and DSs (n = 8). A questionnaire was used to collect demographic information, assess occupational and recreational noise exposure, and note the level of hearing protection used. A sound level meter was used to measure the sound intensity generated by dental instruments near a clinician’s ear. Results showed that DCs who regularly used high-speed handpieces had worse hearing than did members of the other study groups. These results indicate that the implementation of protective strategies should help to reduce the prevalence of occupational hearing loss among DCs.

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Key words: noise-induced hearing loss, high-speed handpieces, hearing protection

The cause-and-effect association between loud noise exposure and hearing loss is well established.1 The National Institute on Deafness and Other Communication Disorders website reports that approximately 15% of Americans between the ages of 20 and 69—26 million Americans—have high-frequency hearing loss that may have been caused by exposure to loud noises at work or in leisure activities.2 In an attempt to reduce workers’ risk of developing noise-induced hearing loss (NIHL), the United States Occupational Safety and Health Administration (OSHA) established safety standards related to noise exposure.3 Originally published in 1983, the standard states that the maximum permissible exposure limit (PEL) in an 8-hour day should not exceed 90 dBA SPL (decibel sound pressure level using an A-weighted scale).3 OSHA’s standard uses a 5 dB exchange rate, meaning that the PEL for 95 dB noise is reduced to 4 hours, the PEL for 100 dB sound is 2 hours, and so on. However, these standards are applied to large populations of people. Within these populations, some individuals are more susceptible to noise-induced auditory dysfunction than others.

Sound intensity generated by high-speed dental handpieces

It has been suspected for decades that high-speed handpieces might contribute to the hearing loss exhibited by some dental clinicians (DCs). Consequently, several investigators have measured the sound intensities generated by these devices.4-8 Barek et al analyzed the sound intensities generated by high-speed handpieces in both the audible (<20,000 Hz) and ultrasonic (>20,000 Hz) frequency ranges.4 The authors reported that the MICRO-MEGA brand handpiece (MICRO-MEGA SA) generated a maximum of 95 dB SPL in the audible range, but 112 dB SPL at 50,000 Hz. The Siemens (Siemens Corporation) and KaVo (KaVo Dental) brand handpieces generated high intensity sounds (101 and 115 dB SPL, respectively) in the ultrasonic frequency range. Barek et al concluded that all these instruments “reach levels that may provoke short- or long-term negative physiological disturbances and hearing damage risk.”9

Kilpatrick listed the sound intensities generated by high-speed handpieces (70-92 dB SPL), ultrasonic scalers (86 dB SPL), stone mixers (84 dB SPL), and low-speed handpieces (74 dB SPL).3 Sorainen & Ryrkonen reported that the A-weighted sound pressure level generated by a variety of handpieces ranged from 76 to 89 dB SPL.6 In Portugal, Sampaio Fernandes et al measured sound levels in different areas of a dental school and reported intensities ranging from 60 to 99 dB SPL.7 Kadankanuppe et al recorded a strikingly similar range of sound levels (64-97 dB SPL) at a dental school in India.8

A key question is whether or not these reported sound intensities can cause hearing loss. The physiological effects of sound on hearing depend on both the intensity of sound and the duration of exposure.2,3 Because dental professionals (DPs) do not use high-speed handpieces or other instruments continuously during the workday, they do not usually exceed OSHA’s PEL or the more conservative PEL (85 dB) recommended by the National Institute for Occupational Safety and Health.5,9 While considering these recommendations, it is important to remember that Park cautioned, “There is a danger, however, of finding comfort in the results of group studies and group standards. Every group is made of individuals, and individuals react to different things in different ways at different times.”10 Merrell & Claggett expressed similar sentiments: “Ears differ in their susceptibility to damage through exposure to noise, thus exposure in a common work environment may cause hearing loss in one person and not in another.”11 Since most people do not know their personal susceptibility to loud noise exposure, Park—along with Merrell & Claggett and others—recommended that DPs implement strategies in the workplace to reduce their risk of occupational hearing loss.10,11

Evidence of noise-induced hearing loss among dental professionals

More than 12 published studies have assessed the hearing of DCs to determine
Protective strategies in the workplace. Regarding the implementation of hearing protection devices (HPDs) when using noisy equipment or instruments in the clinic or laboratory.²² Before and after publication of this report, many researchers and clinicians recommended that DCs utilize hearing protection devices (HPDs) when using noisy equipment or instruments in the clinic or laboratory.⁶,¹⁰,¹¹,¹⁴,¹⁵,²³–³⁰ Although the recommendation that DCs utilize HPDs while using noisy instruments has been made repeatedly during the last 4 decades, few studies of HPD implementation among them have been conducted. Serafini et al reported that only 1 of the 23 dentists in their study used HPDs at work.²⁹

**Current investigation**

This pilot study was undertaken to record and compare audiometric pure tone thresholds of DCs, DPs, and dental students (DSs); determine the percentage of DCs, DPs, and DSs who use hearing protection devices while at work in the clinic; collect data from DCs, DPs, and DSs regarding nonoccupational noise exposure; and measure the sound intensities generated by a few representative high-speed handpieces while they are being used on patients.

**Materials and methods**

Study participants were recruited and data were collected at the Oregon Health & Science University (OHSU) Dental School. Participants included DCs who regularly used high-speed handpieces (n = 16), DPs who did not use high-speed handpieces (n = 13), and DSs (n = 8). Pure tone audiometric data were collected at 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz using a portable audiometer (Beltone model 119, Beltone) in a quiet room. A portable audiometer was used in order to make testing more convenient for the dental school faculty, staff, and students. Audiometric thresholds were later verified by retesting a subset of research subjects in a clinical sound booth. A questionnaire was used to assess occupational and recreational noise exposure, note any use of hearing protection, and collect demographic information. A Brüel & Kjaer Type 2250 sound level meter (Brüel & Kjaer Sound & Vibration Measurement A/S) was used to measure the sound intensity generated by dental instruments near each clinician’s ear. Informed consent was obtained before any measurements or tests were performed. All research procedures were approved by the OHSU Institutional Review Board. Written informed consent was obtained from all study participants.

**Results**

**Participants**

Table 1 shows descriptive statistics for each of the study groups. The noise-exposed DC group included 15 dentists and 1 prosthodontist. The minimal noise exposure DP group included radiologists, radiology technicians, and clinic administrators. The third group comprised DSs. A 2-tailed t test revealed no statistically significant differences between the mean ages of the noise-exposed DCs compared to the DPs with minimal noise exposure (P > 0.05). The DSs were significantly younger than the members of the other groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean age in years (SD)</th>
<th>Gender (n)</th>
<th>Average number of years (SD) in profession</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental clinicians</td>
<td>16</td>
<td>53.5 (12.0)</td>
<td>M (16), F (0)</td>
<td>22.3 (12.3)</td>
</tr>
<tr>
<td>Dental professionals</td>
<td>13</td>
<td>47.3 (11.5)</td>
<td>M (4), F (9)</td>
<td>21.8 (11.1)</td>
</tr>
<tr>
<td>Dental students</td>
<td>8</td>
<td>28.9 (3.4)</td>
<td>M (5), F (3)</td>
<td>2.8 (0.4)</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; M, male; n, number; SD, standard deviation.
Audiometric results
The averaged audiograms for each study group are shown in the Chart. Audiometric thresholds collected via portable audiometer were verified by retesting a subset of 12 research subjects in a clinical sound booth. This verification process revealed that thresholds collected using the 2 methods agreed within 5 dB for all test frequencies, which is within the clinical standard of error for pure tone hearing sensitivity tests. The mean audiometric results for the group of noise-exposed DCs revealed a sloping high-frequency hearing loss. The group of DPs with minimal noise exposure had hearing thresholds within the normal range of hearing, but their thresholds were poorer compared to the DSs. A 1-way ANOVA and a Bonferroni correction for multiple comparisons showed a significant difference (P < 0.05) among the mean thresholds of the 3 groups (for both ears) from 3000 to 8000 Hz (Table 2). Post hoc testing revealed that the mean thresholds of the DC group were significantly worse compared to the DP and the DS groups for 4000 to 8000 Hz in the right ear and approached statistical significance at 3000 Hz (P = 0.055 compared to the DP group; P = 0.058 compared to the DS group). Left ear data revealed significant differences from 3000 to 6000 Hz between the DCs and DSs, and significant differences between the DC group and the other 2 groups at 8000 Hz (Table 3). Audiometric mean thresholds for the DP group were not significantly different from the DS group in either ear.

Hearing protection device use
The use of HPDs in the OHSU dental clinics was rare, with only 1 of 16 DCs, 0 of 13 DPs, and 1 of 8 students reporting that they used earplugs in the workplace.

Nonoccupational noise exposure
In addition to work-related noise exposure (such as high-speed handpieces, suction devices, or ultrasonic scalers), many study participants also reported histories of significant exposure to loud sounds outside of the dental clinic. For example, several noise-exposed clinicians and other DP's served in the US military and were exposed to extremely loud sounds—gunfire, artillery fire, and explosions—during training or combat. Some study participants also reported being exposed to recreational gunfire, fireworks, loud sounds from power tools, music, factory machinery, or farm equipment. Participants reported that they “sometimes” or “never” wore HPDs during these activities. None of the participants “always” wore HPDs in these situations. The primary source of noise exposure for the students was loud music—at concerts, nightclubs, or via personal stereo equipment. It is impossible to quantify the amounts of these exposures for individuals or study groups, but it is important to remember that nonoccupational noise was a factor in the hearing loss exhibited by some participants.

Sound intensities generated by high-speed handpieces
The Bruel & Kjaer sound level meter was used to measure the peak sound intensities (A-weighted) generated by instruments while they were being used during dental procedures. The sound meter’s microphone was positioned near
the clinician’s ear that was closest to the handpiece during the procedure. The following peak sound intensities were recorded: Midwest Tradition High-Speed Handpiece (DENTSPLY International) with friction grip No. 2 round bur, 88-94 dB SPL; Micro-Mega High-Speed Handpiece with No. 4 round carbide bur, 98-102 dB SPL; and Cavitron Select Ultrasonic Scaler (DENTSPLY International), 92-98 dB SPL.

These sound intensities are high enough to contribute to cochlear damage and noise-induced hearing loss over time.2,3 Although the DCs’ duration of exposure to these sounds might be relatively brief (as little as 30-45 minutes per day), the cumulative effects of such exposures over years or decades of practice might very well contribute to occupational hearing loss and/or tinnitus for some individuals. Additional sources of loud sounds in a clinic (such as suction devices or other instruments being used in nearby operatories) can also increase clinicians’ total noise exposure and risk for developing NIHL.

Discussion
Because this was a pilot study with a relatively small number of participants, the results are considered preliminary. Potential confounding factors—including age and gender of participants, duration and type of handpiece usage throughout each person’s career, and precise measurements of occupational and recreational noise exposure—were not controlled in this investigation. In spite of these limitations, the sloping high-frequency hearing loss exhibited by DCs in this study is consistent with long-term exposure to loud sounds. Measurements of sound levels generated by instruments in the current study revealed intensities that can contribute to the pattern of hearing loss observed in the DC group. However, age, genetics, and other sources of loud sounds also contributed to the hearing loss exhibited by subjects in this study. While hearing loss due to aging or genetic factors is not preventable, NIHL can be prevented by using HPDs in noisy environments.

The lack of HPD use by DCs and DSs in this study is not surprising considering their use (or lack thereof) in the workplace overall. Workers in noisy conditions—including industrial and military environments—often have low rates of HPD utilization, even after they have been ordered to use the devices.31-34 Reasons for not using HPDs during noisy dental procedures include discomfort, fear that HPDs will interfere with communication, inconvenience, negative feedback from coworkers or patients, and the belief that noise levels from dental instruments will not damage hearing. In fact, earplugs equipped with filters (known as musician’s earplugs) will not interfere with a clinician’s ability to understand coworkers or patients. Custom-made musician’s earplugs can be obtained from any practitioner who fits patients with hearing aids, such as an audiologist or hearing aid dispenser. Noncustom (and therefore disposable) musician’s earplugs are also available. While these disposable earplugs may only provide minimal noise reduction (15 dB

Table 3. Multiple comparisions of audiometric thresholds at tested frequencies.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Group</th>
<th>Groups</th>
<th>Mean difference</th>
<th>P value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE 500 Hz</td>
<td>DC</td>
<td>DP</td>
<td>3.08</td>
<td>0.659</td>
<td>Lower: 3.12, Upper: 9.27</td>
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<tr>
<td>RE 1000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>5.58</td>
<td>0.130</td>
<td>Lower: -1.12, Upper: 12.27</td>
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<tr>
<td>RE 2000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>7.16</td>
<td>0.332</td>
<td>Lower: -3.85, Upper: 18.18</td>
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<tr>
<td>RE 3000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>19.30</td>
<td>0.055</td>
<td>Lower: -0.31, Upper: 38.92</td>
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<tr>
<td>RE 4000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>21.73*</td>
<td>0.036</td>
<td>Lower: 1.12, Upper: 42.34</td>
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<tr>
<td>RE 6000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>22.33*</td>
<td>0.012</td>
<td>Lower: 4.19, Upper: 40.47</td>
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<tr>
<td>RE 8000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>23.49*</td>
<td>0.008</td>
<td>Lower: 5.22, Upper: 51.97</td>
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<tr>
<td>LE 500 Hz</td>
<td>DC</td>
<td>DP</td>
<td>5.07</td>
<td>0.238</td>
<td>Lower: -1.99, Upper: 12.14</td>
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<tr>
<td>LE 1000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>6.64</td>
<td>0.091</td>
<td>Lower: -0.75, Upper: 14.02</td>
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<td>LE 2000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>6.23</td>
<td>0.612</td>
<td>Lower: -5.88, Upper: 18.34</td>
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<tr>
<td>LE 3000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>15.12</td>
<td>0.134</td>
<td>Lower: -3.14, Upper: 33.38</td>
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<tr>
<td>LE 4000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>16.64</td>
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<td>Lower: -4.16, Upper: 37.43</td>
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<td>LE 6000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>17.48</td>
<td>0.010</td>
<td>Lower: -2.61, Upper: 37.56</td>
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<tr>
<td>LE 8000 Hz</td>
<td>DC</td>
<td>DP</td>
<td>22.09*</td>
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<td>Lower: 0.41, Upper: 43.77</td>
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<td>0.266</td>
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<td>10.63</td>
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<td>LE 2000 Hz</td>
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<td></td>
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<td>0.058</td>
<td>Lower: -0.56, Upper: 44.94</td>
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<td>LE 3000 Hz</td>
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<td></td>
<td>19.30</td>
<td>0.055</td>
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<td>21.73*</td>
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<td>LE 6000 Hz</td>
<td>DS</td>
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<td>22.33*</td>
<td>0.012</td>
<td>Lower: 4.19, Upper: 40.47</td>
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<td>LE 8000 Hz</td>
<td>DS</td>
<td></td>
<td>23.49*</td>
<td>0.008</td>
<td>Lower: 5.22, Upper: 51.97</td>
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*Designates clinical significance (P < 0.05). Abbreviations: DCs, dental clinicians; DPs, dental professionals; DSs, dental students; LE, left ear; RE, right ear.
of attenuation), it is enough to greatly reduce a clinician’s risk of developing NIHL from the noise generated by handheld instruments. Patients can also be given the opportunity to wear disposable foam ear plugs during dental procedures. However, patients who are exposed to noise from dental instruments only occasionally have minimal risk of developing NIHL or tinnitus from this sound source.

Results from this study are consistent with the findings of previous studies that showed clinicians who operate dental handpieces or other loud instruments are at risk of developing NIHL. Multiple factors contribute to this risk, including variations in the frequency composition of the noise, the number of hours per week that handheld devices are used, and variations in sound intensity over time related to turbine speed and maintenance of the devices. Setcios & Mahyuddin described these and additional factors in a 1998 article. It is unlikely that a DC’s daily exposure to high-speed handpieces will surpass OSHA’s PEL for an 8-hour workday. However, it is the authors’ opinion that OSHA standards are probably not stringent enough and also do not take individual susceptibilities to NIHL or tinnitus into account.

Conclusion

To decrease their risk of developing NIHL, dental practitioners are encouraged to follow the recommendations by the ADA Council on Dental Materials and Devices, which states:

...preventive measures for noise attenuation should be directed in three areas: optimum maintenance of rotary equipment, reduction of the ambient noise level in the operatory (soundproofing, acoustical ceilings, baffle drapes, resilient floors, rational location of the compressor and other noise-making equipment), and personal protection through the use of ear plugs.

Additionally, the ADA Council recommended that...

...practitioners concerned about the potential impairment should have an otologic examination and have an audiometric evaluation in a silent room to assess the present condition. Noise levels in the individual offices should be studied with monitoring periods of more than a week. An audiometric evaluation should be made after a typical workday and again at the beginning of the next day to observe temporary threshold shift and apparent recovery. Annual tests of hearing should be taken.

To these recommendations, the authors of the present study suggest adding the caveat that hearing protection strategies should always be implemented during noisy recreational as well as occupational activities.

Regarding future research in this area, the authors concur with Hyson in recommending that additional studies should be conducted to investigate the hearing loss potential among students, faculty members, practicing dentists, and other dental staff members who work with air-turbine handpieces; to determine whether there is a correlation between the use of the air turbine and hearing loss; and to determine whether dentists and staff members should wear ear protection.

The following investigations could yield valuable information:

• Longitudinal studies of students, faculty members, practicing dentists, and hygienists to assess their hearing annually and to determine if they exhibit NIHL or tinnitus. Regarding tinnitus, Devlin & Leandro wrote about a clinician’s personal experience:

I have been practicing dentistry for 15 years now. About 7 years ago, I developed tinnitus in my left ear. It is an annoying, high-pitched whine, sounding almost like a high-speed handpiece that runs 24 hours a day, 7 days a week. Although it was uncertain as to why I developed this condition, I wish that I had started wearing earplugs in dental school, and had continued the practice throughout my dental career.

• A large-scale study of the current hearing protection practices of DCs. This study should include questions regarding their attitudes and behaviors related to utilization of HPDs.

• A study to determine if specific educational interventions related to hearing and noise exposure would affect the attitudes and behaviors of DCs regarding hearing loss prevention practices.

• A study to determine which HPDs are preferred by DCs.

Author information

Drs. Theodoroff and Folmer are research investigators for the US Department of Veterans Affairs (VA) Rehabilitation Research and Development Service (RR&D), National Center for Rehabilitative Auditory Research, Portland VA Medical Center, Oregon, and assistant and associate professors, respectively, Department of Otolaryngology, Head and Neck Surgery, Oregon Health & Science University, Portland.

Acknowledgments

Support for this study was provided by the Tinnitus Clinic and Department of Otolaryngology at OHSU. Additional support was provided by the VA National Center for Rehabilitative Auditory Research (funded by the VA RR&D Center of Excellence grant No. C9230C) at the Portland VA Medical Center, Oregon. The authors wish to thank April Kaelin, faculty members, staff, and students at the OHSU School of Dentistry for their assistance with data collection.

References


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Reading the article and successfully completing this exercise will enable you to:
• learn about noise-induced hearing loss (NIHL);
• understand the risk of NIHL among dental professionals; and
• follow recommended methods to prevent NIHL.

1. The National Institute on Deafness and Other Communication Disorders claims that approximately ___% of Americans between the ages of 20 and 69 have high frequency hearing loss that may have been caused by exposure to loud sounds or noise at work or in leisure activities.
   A. 5
   B. 10
   C. 15
   D. 20

2. According to OSHA, the maximum permissible exposure limit (PEL) in an 8-hour day should not exceed _____ decibels sound pressure level using an A-weighted scale (dBA SPL).
   A. 90
   B. 95
   C. 100
   D. 105

3. OSHA recommends a maximum of _____dBA SPL for a 4-hour PEL.
   A. 90
   B. 95
   C. 100
   D. 105

4. High frequencies become audible below ______Hz.
   A. 21,000
   B. 20,000
   C. 19,000
   D. 18,000

5. _____ exposure, _____ intensity will likely contribute most to auditory dysfunction.
   A. Long; high
   B. Short; high
   C. Long; low
   D. Short; low

6. According to the OSHA standard, the PEL for 105 dB is _____ hour(s).
   A. 4
   B. 3
   C. 2
   D. 1

7. Because dental professionals do not use high-speed handpieces continuously during the workday, they do not usually exceed OSHA’s PEL. Additional sources of loud sounds in a clinic, such as suction devices being used in nearby operatories, will not increase risk for developing NIHL.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

8. The noise-induced hearing loss exhibited by dental clinicians was characterized by elevated auditory thresholds at ________Hz.
   A. 4000-6000
   B. 7000-9000
   C. 10,000-12,000
   D. 13,000-15,000

9. The ADA Council on Dental Materials and Devices recommends that preventive measures for noise attenuation should include “personal protection through the use of ear plugs.” Additionally, the Council recommended that “practitioners concerned about the potential impairment should have an audiometric evaluation in a silent room to assess the present condition.”
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

10. All of the following pure tone audiometric frequencies were collected except one. Which is the exception?
    A. 500 Hz
    B. 1500 Hz
    C. 3000 Hz
    D. 6000 Hz

11. ______ dental clinicians who regularly used high-speed handpieces were included in the study.
    A. Twenty
    B. Sixteen
    C. Thirteen
    D. Eight

12. All of the following are reasons given for failing to use hearing protection devices except one. Which is the exception?
    A. Fear they will interfere with communication
    B. Negative feedback from coworkers or patients
    C. Belief that noise levels from dental instruments will not damage hearing
    D. High cost is prohibitive

13. All of the following factors associated with dental handpieces increase the risk of NIHL except one. Which is the exception?
    A. Variations in frequency composition of the noise
    B. Number of hours per week the device is used
    C. Proper maintenance of the devices
    D. Sound intensity over time

14. Attenuating _______ db of noise generated by handheld instruments is enough to reduce a clinician’s risk of developing NIHL.
    A. 5
    B. 10
    C. 15
    D. 20

15. Ambient noise levels can be reduced by all of the following except one. Which is the exception?
    A. Acoustical ceilings
    B. Baffle drapes
    C. Marble floors
    D. Soundproofing

Answer form is on the inside back cover. Answers for this exercise must be received by April 30, 2016.
Apical lesion of mandibular bicuspid (Case courtesy of Dr. Michael A. Herman, Dayton, OH.)

A periapical radiograph was obtained from a 35-year-old male patient and revealed a radiopacity fused to the root of the mandibular first bicuspid on the right side (Fig. 1). The lesion was asymptomatic and not associated with any significant cortical expansion. The tooth responded within normal limits upon vitality testing.

Which of the following is the most appropriate diagnosis?
A. Cementoblastoma
B. Cemento-osseous dysplasia
C. Condensing osteitis
D. Hypercementosis

Diagnosis is on page 79.

Apical lesion of maxillary molar (Case courtesy of Dr. Michael Bobo, Murray, KY.)

A 16-year-old male patient presented with discomfort and expansion of the posterior maxilla on the left side. The teeth within the quadrant responded within normal limits to vitality testing. A periapical radiograph revealed a radiopacity surrounding and continuous with the distal root of the maxillary first molar (Fig. 1). An incisional biopsy was performed (Fig. 2).

Which of the following is the most appropriate diagnosis?
A. Cementoblastoma
B. Cemento-osseous dysplasia
C. Condensing osteitis
D. Hypercementosis

Diagnosis is on page 79.

Author information
Dr. Damm is a professor, Department of Oral Health Sciences, Division of Oral Pathology, College of Dentistry, University of Kentucky, Lexington.
Oral Diagnosis

Apical lesion of mandibular bicuspid

Diagnosis:
B. Cemento-osseous dysplasia

Cementoblastomas present as radiopaque tumor-like masses fused to the root of a tooth and surrounded by thin radiolucent periodontal ligament. The current case closely mimics this radiographic pattern. Despite the close radiographic similarities, the clinical presentation is not typical for the diagnosis of cementoblastoma. Approximately 75% of cementoblastomas arise prior to the age of 30, and close to 70% of affected patients complain of pain with significant associated expansion.

Cemento-osseous dysplasia (osseous dysplasia) may be localized to the anterior mandible (periapical variant), multifocal beyond the anterior mandible (florid variant), or isolated (focal variant). The lesions initially appear radiolucent but develop intermixed opacities over time. Upon full maturation, cemento-osseous dysplasia becomes predominantly opaque with a thin radiolucent rim. During this stage, the altered bone is hypovascular with an increased prevalence of osteonecrosis when secondarily inflamed. In addition, ankylosis with adjacent teeth can occur and create a pattern that mimics cementoblastoma. Patients should be encouraged to practice excellent oral hygiene to prevent significant inflammation of the altered bone.

Reference

Apical lesion of maxillary molar

Diagnosis:
A. Cementoblastoma

Incisional biopsy revealed radiating trabeculae of cellular woven bone-like material intermixed with numerous basophilic globules and sheets of plasmacytoid osteoblast-like cells (Fig. 2). Microscopically, cementoblastoma is identical to the osseous neoplasm, osteoblastoma, with attachment to a tooth utilized to separate these closely related pathoses.

As mentioned in the previous case (cemento-osseous dysplasia), the vast majority of cementoblastomas arise before the age of 30 years and usually present with pain and swelling. Approximately 90% originate in the posterior region with close to 50% associated with a permanent first molar. Involvement of the deciduous dentition is rare. The tumor is truly neoplastic and mandates assured surgical removal.

Reference
Self-Instruction

Exercise No. 349  
May/June 2014, p. 45

Exercise No. 350  
May/June 2014, p. 53

Exercise No. 351  
May/June 2014, p. 62

Erratum

With regard to the article, *Maxillary first molar with 8 root canals detected by CBCT scanning: a case report*, by Almeida et al, which appeared in the March/April 2015 issue of *General Dentistry*, the correct author information reads: Dr. Almeida is a professor, Endodontics, Brazilian Dental Association, ABO, Ilheus, Bahia, Brazil. Dr. Machado is a doctoral student, Endodontics, Ribeirao Preto Dental School, University of Sao Paulo, Brazil; a professor, Endodontics, School of Dentistry, Paranaense University, Francisco Beltrao, Parana, Brazil; and in private endodontic practice in Navegantes, Santa Catarina, Brazil. Dr. Cunha is a professor, Endodontics, School of Dentistry, University of Manitoba, Winnipeg, Canada. Dr. Vansan is a professor, Department of Endodontics, Ribeirao Preto Dental School, University of Sao Paulo, Brazil. Dr. Neelakantan is a professor, Endodontics, Saveetha Dental College and Hospitals, Saveetha University, Chennai, India.

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EVALUATION  Please respond to the statements below, using the following scale: 1 Poor; 2 Below average; 3 Average; 4 Above average; 5 Excellent

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Evaluation of the bond strengths of 3 endodontic cements via push-out test

Nadia de Souza Ferreira, PhD • Raffaela Di Iorio Jeronimo Ferreira, PhD • Patricia Campos Ferreira da Rosa, MS
Ana Paula Martins Gomes, PhD • Carlos Henrique Ribeiro Camargo, PhD • Claudio Antonio Talge Carvalho, PhD
Marcia Carneiro Valera, PhD

In this study, the push-out method was used to evaluate the bond strengths of 3 types of endodontic cements according to their composite base: methacrylate, epoxy resin, and an experimental copaiba oil resin. The study hypothesis was that the methacrylate-based and experimental cements would have bond strengths equal to or greater than that of the epoxy resin-based cement. Thirty bovine tooth roots, 18 mm long, were divided into 3 groups (n = 10) based on the chosen cement treatment. After treatment, the specimens were sectioned and submitted to a push-out test. Results showed that there was no statistically significant difference (P < 0.05) between the cements used or between the middle and apical thirds of the roots. It could be concluded that the tested cements had satisfactory and similar bond strengths to dentin.

Key words: root canal, endodontics, dentinal bonding

One of the objectives of root canal filling is to obtain adequate sealing between the filling material and root canal walls in order to prevent the reinfection of the root canal system and improve the success of endodontic treatments. Moreover, it is frequently necessary in endodontic treatment to use intraradicular retainers to reconstruct the teeth prosthetically. However, a rupture of the filling seal may occur due to mechanical stress caused by the flexure of the tooth or the preparation for the post. Therefore, the mechanical forces at the dentin-cement interface are important factors to consider when selecting a filling material.1

Endodontic cement bonding is defined as the ability of a cement to adhere to the root canal walls and promote the bond of the gutta percha cones to each other and to dentin.2 It has been suggested that a cement’s capacity to adhere to gutta percha and dentin may result in a greater sealing ability, thus reducing coronal and apical leakage.3,4

EndoREZ (Ultradent Products, Inc.) is a methacrylate-based endodontic cement that uses hydrophilic monomers to improve its penetration into the dentinal tubules after removal of the smear layer from the canal and is designed for use with a single gutta percha cone.5,6 AH Plus (DENTSPLY Maillefer) is an epoxy resin-based cement that has shown good physicochemical properties, low solubility, good bonding, antimicrobial action, and good biological properties and is widely considered the endodontic cement of choice for the majority of cases.8,9

Recently, natural extracts have been extensively studied in endodontics. A copaiba oil-based resin (derived from *Copaifera multijuga*) has been shown to have healing, analgesic, and anti-inflammatory properties as well as good biocompatibility and a rigid structure.10,11 This oil-based resin has been used in the reconstruction, replacement, and filling of bone defects.12 Thus, an experimental copaiba oil resin-based sealer (Biosealer) created by Garrido et al may be suitable for clinical use; however, little is known about the bonding ability of this endodontic cement.13

The purpose of this study was to evaluate—by means of the push-out method—the bonding capabilities of AH Plus, EndoREZ, and Biosealer to the root dentin of bovine teeth.

The study hypothesis was that the EndoREZ cement and the Biosealer would have bond strengths equal to or greater than those of AH Plus cement.

Materials and methods

Thirty bovine teeth were cleaned with periodontal curettes and stored in physiological solution until they were used in this study. The crowns of the teeth were removed with a diamond disc (90 µm, Microdont) at low speed under constant cooling, and the root remainder was standardized to a length of 18 mm.

All the canals were manually prepared up to 17 mm with K files (DENTSPLY Maillefer) up to a K-50 file and scaled with progressively programmed withdrawal (every 1 mm) with up to a K-80 file. During biomechanical preparation, the canals were irrigated with 5 ml of 2.5% sodium hypochlorite with every change of a K file. After this, the canals were irrigated with 1 ml of 17% EDTA for 3 min, and final irrigation was performed with 5 ml of saline solution.

The roots were divided into groups (n = 10) according to the filling cement used: Group 1, AH Plus; Group 2, EndoREZ; Group 3, Biosealer. The most apical portions of the specimens were embedded in 3 mm of colorless acrylic resin (Jet, Artigos Odontologicos Classico, Ltda). During this procedure, the specimens were maintained perpendicular to the ground, according to the following protocol: 1 Largo bur No. 3 (DENTSPLY Maillefer) was inserted into the prepared canal; the set was fixed in an adapted delineator so that the long axes of the cutter, specimen, and vertical mobile rod of the delineator remained parallel to one another and to the y-axis; the acrylic resin was manipulated and poured into a silicone mold; then the bur/specimen set was lowered to the 3 mm mark and fixed in the acrylic resin.

After this procedure, the specimens of Groups 1 and 3 were completely dried with absorbent paper cones and filled with their respective endodontic cements.
with the aid of a Lentulo spiral connected to a counter-angle at low speed. The AH Plus cement was proportioned and spatulated in accordance with the manufacturer’s instructions. The Biosealer was spatulated using 0.43 g of powder and 0.2 ml of liquid.\(^{15}\)

The specimens of Group 2 were left humid for filling with the aid of a Lentulo spiral connected to a counter-angle at low speed; after filling, they were light polymerized for 40 seconds (in accordance with the manufacturer’s recommendations) with the tip of a light-polymerizing unit (Curing Light XL3000, 3M ESPE) placed in the cervical opening of the canal.

All the specimens were stored in an oven at 37°C and 100% humidity for 7 days to allow the endodontic cements to set completely. After the cements had hardened, the specimens were fixed onto a metal base in a cutting machine (LabCut 1010, Extec Corp.) and sectioned perpendicular to the long axis of the root, using a diamond disc (WFR BLDE 4 x 0.12 × 0.5 inch, Extec Corp.) under constant water cooling. The first cervical slice (approximately 1 mm thick) was discarded.

For each specimen, 4 slices, each approximately 2 mm thick, were obtained. For the push-out test, the first slice, representative of the middle third of the root, and the fourth slice, representative of the apical third, were used.

During the mechanical test, each specimen was placed with the most coronal face of the specimen facing down, and a load was applied (in the direction of the apical to the coronal) until the cement was debonded. The test was performed in a universal testing machine (EMIC Model DI-1000, EMIC Equipamentos e Sistemas de Ensaios LTDA) at a speed of 1 mm/min with a load cell of 50 kgf.

The original data obtained in the push-out test were submitted to descriptive and inferential statistical analysis using a 2-way ANOVA test with a level of significance of 5%.

**Results**

The data (in MPa) that demonstrated normal distributions of the samples—thereby enabling the performance of parametric tests—were submitted to preliminary tests. The data used for this study were the values corresponding to the maximum stresses borne by each filling cement before it was debonded from the root canal walls. In each of the 3 groups, 10 specimens were used with 2 values each for their middle and apical thirds so that a total of 60 values were obtained.

The Table shows the mean values and standard deviations of the maximum force of resistance to displacement for each cement used.

The values were submitted to a 2-way ANOVA test. The ANOVA demonstrated that there was no statistically significant difference (\(P < 0.05\)) between the endodontic cements used or between the middle and apical thirds.

**Discussion**

Periapical tissue repair after endodontic treatment partly depends on the chemical composition and physicochemical properties of the filling materials.\(^{16}\)

Copaiba oil-resin is a polyester formed by an amine radical that gives it a bactericidal effect, causing damage to the bacterial cell walls and thus increasing their biocompatibility with living tissues.\(^{17,18}\) The possibility of a chemical reaction between the acid components of the copaiba oil-resin and the alkaline constituents of calcium hydroxide and zinc oxide have resulted in the development of phytotherapeutic cements. Zinc oxide may act as a base, reacting with the acids of the copaiba oil-resin and causing the cement to assume a rigid structure.\(^{15}\)

Resin epoxy-based cements penetrate deeply into microirregularities due to their fluidity throughout their polymerization process, thus contributing to the mechanical interlocking between the cements and the dentin.\(^{19}\) In addition to this interlocking, the adhesiveness of the AH Plus cement is due to the formation of covalent bonds between the epoxide rings and the exposed amino acids in the dentin collagen network.\(^{20}\) These factors are associated with the cohesion between the molecules of the cement that increase the resistance to removal or to displacement of the material from the dentinal surface, a property that translates into excellent bonding.\(^{21,22}\) Moreover, resin epoxy-based cements penetrate into the dentinal tubules exposed after removal of the smear layer, forming tags similar to those that occur with the adhesive systems.\(^{23}\)

In 2012 Chadha et al found greater penetration of the EndoREZ cement into dentinal tubules in comparison with AH Plus cement; however, Fisher et al in 2007 and Eldeniz et al in 2005 found lower bond strength values for EndoREZ when compared with AH Plus.\(^{9,20,24}\)

The hydrophilic property of EndoREZ cement necessitates its use in humid root canals, thereby increasing its penetration into the dentinal tubules; however, its bond may be prejudiced by polymerization shrinkage due to the thick layer of cement that is frequently associated with the filling of a single gutta percha cone.\(^{5,25,26}\)

To minimize the effect of this polymerization shrinkage, a filling technique may be used in which, after injection of the EndoREZ cement into the canal, a main cone is placed and accessory cones are passively inserted, thereby reducing the volume of the cement.\(^{5,27}\)

Moreover, with methacrylate-based cements, the lack of light activation throughout the entire extension of the root canal—due to the reduction in exposure to light in the deeper regions of the canal—contributes to incomplete polymerization, leaving residual monomers that may contribute to a reduction in bonding to the dentin; the oxygen present on the root canal walls and in the dentinal tubules may also affect the polymerization process.\(^{22,28}\) In the present study, the numerical values of bond strength to dentin were lower for the EndoREZ cement; however, there was no statistically significant difference between the studied cements. In this study, the canals were filled only with cement, differing from

<table>
<thead>
<tr>
<th>Groups (n = 10)</th>
<th>Apical (N)</th>
<th>Middle (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.430 (1.860)</td>
<td>2.655 (1.304)</td>
</tr>
<tr>
<td>2</td>
<td>2.356 (1.806)</td>
<td>2.476 (1.458)</td>
</tr>
<tr>
<td>3</td>
<td>2.601 (2.275)</td>
<td>2.726 (1.748)</td>
</tr>
</tbody>
</table>
clinical practice in which cones are used, especially the gutta percha type. However, the use of gutta percha cones makes the push-out test unfeasible since, once the bond between the cement and the cones is ruptured, it becomes difficult to evaluate the bond of the cement to the dentin. Moreover, it was verified that the bond strengths of the cements were similar, irrespective of their locations (apical or middle third), since the variations in tubular density and sclerotic dentin along the root canal do not alter their mechanical retentions. Thus, the results of this study showed that the bond strengths of the studied cements were similar, demonstrating that in these conditions, EndoREZ has adequate bond strength and that Biosealer has promising potential for use in endodontic practice.

**Conclusion**

It could be concluded that the bond strengths of EndoREZ and Biosealer were similar to that of AH Plus and that the root third did not interfere in the bond strengths of the studied cements.

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**Disclaimer**

The authors have no financial, economic, commercial, and/or professional interests related to topics presented in this article.

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**Manufacturers**

Artigos Odontologicos Classico, Ltda, Sao Paulo, Brazil 55.11.3022.2588, www.classico.com.br
DENTSPRAY Maillefer, Tulsa, OK 800.924.7393, www.maillefer.com
EMIC Equipamentos e Sistemas de Ensaio LTDA, Sao Jose dos Pinhais, Brazil 55.42.3035.9400, www.emic.com.br
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Management of uncommon complications in seemingly routine oral surgeries

Shayan Salim, BS • Andrew Newman, BS • James J. Closmann, DDS • Thomas J. Borris, DDS

Major complications in outpatient oral surgeries are relatively rare. This article presents 4 cases of molar extraction with unusual complications and describes how the clinician in each case altered the treatment, resulting in a successful conclusion. The first case describes a fracture during the removal of a maxillary first molar. The second case describes a fracture after a mandibular third molar extraction. The third case describes a maxillary third molar displaced into the infratemporal space. The final case describes necrosis of the maxillary soft tissue after fracture of the tuberosity during a third molar extraction.

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Most outpatient oral surgical procedures are performed with few, if any, complications. When a major complication occurs, management of the situation is critical. The practitioner is required to address the problem promptly and seek help if indicated. This article presents unusual complications found in 4 cases and how these situations were managed, in the hope that it will guide a general dentist should he/she encounter these scenarios while performing routine outpatient procedures.

Case No. 1. Maxillary fracture during first molar removal

A 23-year-old female patient presented to her general dentist for extraction of nonrestorable tooth No. 14. Her past medical and surgical histories were noncontributory, and she had no allergies to medications. After obtaining consent, local anesthesia was administered. While elevating the tooth, a cracking noise was heard, and the tooth rotated downward. Examination revealed the tooth was attached to a segment containing the alveolar bone, maxillary lateral wall, and palatal bone (including the second and third molars in that quadrant). A gross malocclusion was noted. At that point, the surgery was discontinued and a panoramic radiograph was taken that revealed a fractured maxilla (Fig. 1).

The patient was referred to an oral and maxillofacial surgeon for evaluation. After a review of the fracture and medical history, the patient was sedated and the segment of maxilla was repositioned and secured with a segmental stainless steel arch bar and 24-gauge wire (Fig. 2). The occlusion was adjusted slightly and the patient was placed on amoxicillin 500 mg every 8 hours for 7 days, pseudoephedrine 30 mg every 6 hours for 7 days, and oxymetazoline nasal spray (2 puffs per nostril) every 8 hours for 3 days. The patient was further instructed to avoid nose-blowing for 3 weeks and scheduled for follow-up in 1 week. The patient recovered uneventfully, and the arch bar was removed after 6 weeks. The patient then returned to the clinic 6 weeks later to have tooth No. 14 removed without incident.

Case No. 2. Mandibular fracture after third molar surgery

A 24-year-old male patient presented to his dentist for removal of his impacted third molars (Fig. 3). The patient was healthy and had a noncontributory medical history, with no drug allergies or contraindications to surgery. Written consent was obtained. The third molars were removed without incident under...
local anesthesia and intravenous sedation. On postoperative day 3, the patient called the office and stated he heard a “pop” in his jaw while eating. He was instructed to return to the office immediately, and a panoramic radiograph was obtained, revealing a nondisplaced mandibular fracture in the left angle region (Fig. 4). After the patient was presented with treatment options, he elected to have a closed reduction performed using stainless steel arch bars with maxillomandibular fixation for 6 weeks. The surgery was performed without incident, and the patient was placed on penicillin V 500 mg every 6 hours for 1 week; also prescribed was acetaminophen with codeine 300/30 mg every 4-6 hours as needed to relieve pain. The patient was referred for a computed tomography (CT) scan of the area to analyze the tooth 3-dimensionally (Fig. 7 and 8).

The tooth was located in the infratemporal soft tissues and not in the maxillary sinus as suspected. The patient was allowed to heal for 3 weeks then taken back to surgery under general anesthesia to remove the tooth through the same incision without incident.

Case No. 3. Maxillary third molar displaced into the infratemporal space
A 21-year-old male presented to his dentist for removal of his 3 remaining impacted third molars (Fig. 6). The medical history was reviewed and noted to be noncontributory. The patient had no contraindications to surgery, and written consent was obtained. Local anesthetic was administered, and tooth No. 16 was exposed in the usual fashion with a flap elevated in the subperiosteal plane. A No. 301 elevator was placed on the mesial aspect of the tooth and rotated posteriorly. The tooth moved posteriorly and superiorly and was visually lost with a moderate amount of bleeding into the site. At that point, the surgery was stopped, the wound was closed, and the arch bars were removed after 6 weeks without malocclusion.

Case No. 4. Necrosis of maxillary soft tissue after tuberosity fracture during third molar extraction
A 35-year-old male patient presented to his dentist for extraction of tooth No. 16. The tooth was noted to have been in full occlusal function with some minor occlusal decay. The patient had a noncontributory past medical history and smoked 1 pack of cigarettes per day. The patient was scheduled for extraction of the tooth under local anesthetic. A consent form was signed, listing the usual complications of maxillary third molar surgery including the risk of sinus injury. The patient was anesthetized, and an attempt to elevate the tooth with a No. 34 elevator resulted in a cracking noise. Immediately the tooth became mobile, and the soft tissue was noted to move with the tooth when further elevation was attempted. A
tuberosity fracture was suspected, and the decision was made to remove the tooth and the segment of tuberosity (Fig. 9).

The resulting surgical site was noted to contain a >6 mm sinus exposure. The wound was closed in a watertight fashion using the redundant soft tissue and slowly resorbing sutures. The patient was placed on amoxicillin 500 mg every 8 hours for 10 days, oxymetazoline nasal spray (2 puffs per nostril) every 8 hours for 3 days, pseudoephedrine 30 mg every 6 hours for 1 week, and, for pain relief, acetaminophen with codeine 300/30 mg every 4-6 hours. Additionally, the patient was instructed not to blow his nose for 3 weeks and to avoid water sports and flying in unpressurized aircraft. The patient returned to the clinic approximately 1 week postsurgery and presented with halitosis and a surgical site that appeared to have a necrotic flap covering the wound (Fig. 10).

The patient was instructed to continue his antibiotic therapy, avoid smoking, and to rinse with lukewarm saline 3-4 times daily and was scheduled for a 1 week follow-up. At that visit, the patient stated that he had expectorated a large piece of dead tissue. Upon examination, the wound was slightly open but appeared to be healing without infection. A small (<2 mm) sinus perforation was noted. Three weeks later, the wound had closed. The patient recovered uneventfully without any complaints of sinus symptoms.

Discussion

Case No. 1

The rate of maxillary tuberosity fractures during molar extractions is relatively low (0.15%). In adults, these fractures are often associated with an enlarged maxillary sinus, which can lead to oroantral fistula formation or serious infection. These complications may result in maxillary necrosis or, rarely, deafness. Studies utilizing CT have shown that the posterior limit of the maxillary sinus is located in the tuberosity 94% of the time; otherwise it is located in the maxillary second molar area. In those rare (6%) cases, the location may greatly weaken the maxillary tuberosity and surrounding bone. Due to the necessity of the maxillary tuberosity for stability of

![Fig. 6. Case No. 3. Preoperative radiograph of impacted third molars.](image)

![Fig. 7. Case No. 3. Computed tomography (CT) coronal view of tooth No. 16 (arrow) displaced into the infratemporal space.](image)

![Fig. 8. Case No. 3. CT transverse view of tooth No. 16 (arrow) displaced into the infratemporal space.](image)

![Fig. 9. Case No. 4. Segment of tuberosity and tooth No. 16 removed after fracture of the tuberosity.](image)

![Fig. 10. Case No. 4. Necrotic flap covering the wound of the surgical site 1 week postsurgery.](image)
maxillary fractures, a fractured tuberosity should be preserved whenever possible, and a referral to an oral and maxillofacial surgeon is advised should a fracture occur.3

Most case reports in the literature report that excessive, uncontrolled forces—and not using a pinch grasp technique—can result in a fracture of the maxilla.4,5 Dental anomalies—such as tooth fusion, tooth isolation, hypereruption, ankylosis, hypercementosis, chronic periapical infection, sclerotic bone, divergent roots, abnormal number of roots, multiple extractions and early loss of teeth—may lead to infiltration of the sinus into the alveolus, thus further complicating extractions. If preoperative radiographs indicate that the antrum compromises the bone surrounding the root tips, a surgical technique that removes a single root at a time is advised.5,6

If a large fracture of the maxillary alveolus takes place, immediate cessation of the extraction is advised to avoid further damage to the mucosal membrane, vasculature, musculature, or sinus and osseous structures. Preservation and stabilization by fixation of the fractured alveolus for 4-6 weeks is ideal.4,5 If the extraction must be completed, surgical techniques—avoiding twisting and excessive movement of the alveolus—are advised to preserve as much of the bone as possible.4,5 To aid the healing of the bone, occlusal adjustment may be needed to prevent injurious occlusal forces of the teeth being fixated.4,5

If the tooth is infected or symptomatic at the time of fracture, removal of the infection source should still be accomplished. Doing so by conservative surgical means to maintain the alveolus and its attachment to the periosteum will aid healing.6,7 If this is not possible, removal of the tooth and bone should be followed by a watertight closure of the tissues. After 4-6 weeks of healing, the area may be grafted if deemed necessary.6,7

Postoperative instruction should include avoiding forcible rinsing or any nose-blowing for 2 weeks to prevent oroantral fistula development. This should be accompanied with an antibiotic regimen, nasal decongestants, and anti-inflammatory analgesics. In the authors’ experience, it is common for light bleeding to occur from the ipsilateral nostril for 1-2 days. Radiographs should be ordered 2 months postsurgery to determine the adequacy of healing. It is common to have radiopacity in the affected maxillary sinus for a short period of time.6,7 No further treatment is needed unless symptoms of an infection arise. In rare cases, if the pterygoid hamulus and tensor veli palatini are disrupted, the collapse of the Eustachian tube can cause decreased hearing acuity on the ipsilateral side.4,5

The authors’ procedural recommendations for maxillary fracture during first molar removal are listed in Table 1.

Case No. 2

In order to prevent mandibular fracture during extraction of a third molar, a thorough understanding of the population at risk, common sites, risk factors, and signs is necessary. Factors that may play a role in mandibular fractures include the magnitude of tooth impaction, angulation of the tooth, size and shape of the roots, age and gender of the patient, dentist’s level of experience, presence of pathoses and infection around the tooth, systemic diseases, and medications that can affect bone strength.8 When the amount of force on the bone exceeds the strength of that bone, a fracture will occur. Due to less bony support, mandible fractures occur 2-3 times more often than those of other facial bones during routine dental extractions.8 Long or bulbous roots, hypercementosis, and multi-rooted teeth can also be risk factors.9 The experience level of the surgeon—as it relates specifically to management of the elevator—can significantly impact the potential for fracture. It is recommended that elevators be used in a rotational fashion rather than a lever fashion.9 Pathoses such as cysts, osteoporosis, ankylosis, and alveolar atrophy can also contribute to fracture.9 Women >25 years of age are more at risk for fracture, because their masticatory force is inherently greater than that of women.9,10 Additionally, it has been found that fractures tend to occur more often on the left side, as seen in this case. This is possibly due to the decreased visualization on that side by a right-handed operator.10 The extent to which the tooth is impacted and the portion of the mandibular volume occupied by the tooth are also important factors. The risk of fracture is higher when the relative portion of the mandible taken up by the third molar exceeds 50%.8 As seen in Figure 3, the third molar in this case occupied >50% of the volume of the mandibular bone.

If a fracture is suspected, a thorough assessment to determine the severity of the fracture must be performed. Radiographs must be obtained to locate the fracture, the occlusion must be assessed, and the degree of mobility across the suspected fracture must be established.9 After the local anesthesia has worn off, the patient should be checked for any altered sensations in the lip and/or chin.

Table 1. Authors’ procedural recommendations for maxillary fracture during first molar removal (Case No. 1).

| Stabilization of the maxillary segment | Stainless steel arch bars and wire or Resin-bonded appliances for 4-6 weeks |
| Standard regimen for oroantral communication | Amoxicillin 500 mg every 8 hours for 7 days (if patient is allergic to penicillin, prescribe clindamycin 300 mg every 6 hours for 7 days) Pseudoephedrine 30 mg every 6 hours for 7 days Oxyometazoline nasal spray (2 puffs per nostril) every 8 hours for 3 days Analgesics as needed |
| Sinus precautions and instructions | Instruct patient not to blow nose or cause excessive sinus pressure for at least 3 weeks. Consider referral to oral surgeon as needed. Weekly follow-up visits are recommended to ensure proper healing. |
A suggested measure to prevent post-operative fracture would be placing the patient on a no-chew diet for the first 4 weeks.9,10 Lastly, the literature has shown that the most common complication in the treatment of mandibular fractures is postoperative infection.10 Therefore, a patient should be placed on antibiotic therapy.

A survey done by Perry & Goldberg in 2000 questioned 106 oral and maxillofacial surgeons in Connecticut about their experience with late mandibular fractures over a 10-year period. The survey results indicated that there is a low incidence of postoperative fracture, occurring in only an estimated 0.005% of impacted third molar surgeries in the 10-year period covered.11 The extent of impaction plays a key role in determining postoperative fracture. The more deeply impacted the third molar, the higher the risk for postoperative fracture. Another risk factor for postoperative fracture is a history of preoperative infection. Chronic or deep infections will calcify and destroy bone, potentially leading to fractures. These fractures tend to occur at a higher rate during postoperative days 8-21. As stated previously, it is important to stress to the patient the importance of a no-chew diet for a period of at least 4 weeks postsurgery.12

Patients should also be made aware of the possibility of malocclusion, depending on how well the segments heal and what type of surgery was conducted.9 There can be loss of vitality in the teeth adjacent to the fracture, parasthesia in the area of the fracture, and possible infection (such as osteomyelitis).9

The authors’ procedural recommendations for mandibular fracture after third molar surgery are listed in Table 2.

Table 2. Authors’ procedural recommendations for mandibular fracture after third molar surgery (Case No. 2).

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilization of maxillary and mandibular arches</td>
<td>Stabilize with arch bars and wire (for 6 weeks)</td>
</tr>
<tr>
<td>Drug therapy</td>
<td>Amoxicillin 500 mg every 8 hours for 7 days</td>
</tr>
<tr>
<td>Instructions</td>
<td>Consider referral to oral surgeon as needed</td>
</tr>
</tbody>
</table>

Case No. 3

Although complications are rare in the removal of impacted third molars by oral and maxillofacial surgeons, tooth displacement is a potential problem.13 Displacement into anatomical spaces—such as the infratemporal fossa, pterygomandibular space, maxillary sinus, buccal space, or the lateral pharyngeal space—have all been reported in the literature. Most often these are due to insufficient clinical and radiographic examinations, deficient anatomical and surgical knowledge, inadequate flap placement, limited site visibility, and excessive or uncontrolled forces applied during extraction.14 Multiple reports have been published on the displacement of third molars during surgery.13,15 Due to the crucial anatomical structures in the head and neck, retrieval of the foreign object by a trained surgeon is advised. In the case of a tooth displaced into the infratemporal space, immediate retrieval of the tooth may not be possible due to lack of visibility from the bleeding into the area, poor flap design, and/or instability of the tooth, even if the tooth is palpable extraorally.15 Restricted opening, localized pain, swelling, and infection in the antrum may occur if an antibiotic regimen is not given to the patient following surgical manipulation and displacement. Regimen options include amoxicillin (500 mg every 8 hours for 1 week) or clindamycin (300 mg every 6 hours for 7 days). Waiting 3-4 weeks postsurgery for fibrous tissue to form around the displaced tooth helps stabilize and immobilize it, reducing the risk of deeper displacement and damage to other structures. Some clinicians believe that the use of the masticatory muscles will help a displaced tooth in the infratemporal space to descend, making the removal potentially less complicated. The decision to wait to retrieve the displaced tooth must be made by the patient after a thorough treatment plan is presented.13

Prior to retrieval, the tooth should be radiographically located, even if it is palpable. CT or cone beam computed tomography (CBCT) can give the most accurate location of the object. Clinicians are undecided about the most appropriate approach for retrieval.11 Depending on the surgeon, molar retrieval and removal of granulation tissue may be performed in various ways: via an incision in the buccal sulcus, a classic subperiosteal flap (for third molar extractions), the Gillies approach, the Caldwell-Luc approach (after removal of the posterior sinus wall), or via resection of the coronoid process. The decision to perform the retrieval under general or
local anesthesia is dependent upon the patient and the location of the tooth. Postoperative nonsteroidal anti-inflammatory drugs, analgesics, and antibiotics are prescribed to aid recovery.

The authors’ procedural recommendations for a maxillary third molar displaced into the infratemporal space—once the tooth is no longer identifiable—are listed in Table 3.

**Case No. 4**

Maxillary tuberosity fracture is more common than one would expect with molar extractions, especially third molars. Etiological factors contributing to this complication are large maxillary sinuses with thin walls, sinus extension into the maxillary tuberosity, and the projection of root apices into the sinus cavity. It has been recommended that such teeth should be sectioned and removed root at a time. Other etiological factors include teeth with large or abnormal number of roots, as well as dental anomalies such as tooth fusion, tooth isolation, overeruption, ankylosis, and hypercementosis. Chronic apical infections of the molar can render the bone of the tuberosity more liable to fracture as well. Radiographic examination can aid in preoperative planning, as well as identifying some of the etiological factors listed above. The floor of the maxillary sinus can extend between adjacent teeth and/or between roots; this creates an elevation in the antral surface, referred to as *billocks.* This elevation causes a reduction in the thickness of the sinus floor, making an oroantral communication more likely.

A major concern in a maxillary fracture is the vasculature of the area, which increases the possibility of a hemorrhage. This life-threatening event can happen in medically compromised patients with a coagulopathy as well as in healthy patients. The incidence of maxillary tuberosity fracture is 0.6%. Management of severe hemorrhage can require hospitalization and subspecialty care by an interventional radiologist.

The potential for hemorrhage can be understood by studying the anatomy of the maxillary tuberosity region. The main blood supply to the area is the maxillary artery. It traverses anteriorly and obliquely past the lateral pterygoid muscle before entering the pterygopalatine fossa. Prior to entering the fossa, the posterior superior alveolar artery branches off from the maxillary artery and wraps around the tuberosity, descending anteriorly and inferiorly. There is also a buccogingival branch from the posterior superior alveolar artery that approaches the infraorbital region of the maxilla, which may anastomose with the infraorbital artery. If the fracture were to extend posteriorly and superiorly toward the pterygopalatine fossa, damage could occur to branches of the maxillary artery (descending palatine artery; descending pharyngeal artery; sphenopalatine, infraorbital, and vidian arteries). Venous supply is provided by the pterygoid venous plexus, located between the medial and lateral pterygoid muscles as well as the temporalis and lateral pterygoid muscles. The plexus wraps around the maxillary artery in order to protect it from occlusion during mastication. There is an intimate relationship between the vasculature and the overlying periosteum. In the event of severe bleeding during extraction of a maxillary third molar, the key vessels involved are the posterior superior alveolar artery along with the tuberosity itself.

When fracture of the tuberosity is suspected, it is important to stop any further attempts at extracting the tooth, then splint where necessary, and follow with a prompt referral to an oral and maxillofacial surgeon. The goal of management is to secure the fractured bone in place to provide an ideal environment for healing; if the segment cannot be stabilized, it must be removed.

It is recommended that the clinician discuss the potential of a tuberosity fracture while obtaining patient consent. Routine treatment for such a situation is stabilization with rigid fixation techniques for 4-6 weeks. Then, surgical extraction should again be attempted. There are situations in which the tooth is severely infected, and leaving it in can be more problematic. Removal is attempted via reflection of the gingiva cuff while avoiding the separation of the periosteum from the fractured tuberosity. If removing the tooth without the tuberosity is unavoidable, the tissue should be closed in a watertight fashion. Grafting of the area can then be accomplished after 4-6 weeks’ healing and an antibiotic therapy regimen. In addition to the usual postextraction instructions, the patient must be advised to avoid blowing his/her nose for 3 weeks to prevent oroantral communication (if one has not already occurred). Antibiotics, nasal decongestants, and anti-inflammatory analgesics should be prescribed to prevent development of a maxillary sinusitis. The patient should avoid rinsing his/her mouth with saline or mouthwash.

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**Table 4. Authors’ procedural recommendations for necrosis of maxillary soft tissue after tuberosity fracture during third molar extraction (Case No. 4).**

<table>
<thead>
<tr>
<th>Stabilization of the maxillary segment</th>
<th>Stainless steel arch bars and wire or Resin-bonded appliances for 4-6 weeks for immobilization during healing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>If the tooth is significantly infected, removal of the tooth and bone is indicated with the least soft tissue reflection possible; suture in a watertight fashion.</td>
</tr>
<tr>
<td>Standard regimen for oroantral communication</td>
<td>Amoxicillin 500 mg every 8 hours for 7 days (if patient is allergic to penicillin, prescribe clindamycin 300 mg every 6 hours for 7 days)</td>
</tr>
<tr>
<td></td>
<td>Pseudoephedrine 30 mg every 6 hours for 7 days</td>
</tr>
<tr>
<td></td>
<td>Oxymetazoline nasal spray (2 puffs per nostril) every 8 hours for 3 days</td>
</tr>
<tr>
<td></td>
<td>Analgesics as needed</td>
</tr>
<tr>
<td>Sinus precautions and instructions</td>
<td>Instruct patient not to blow nose or cause excessive sinus pressure for at least 3 weeks. Consider referral to oral surgeon as needed. Weekly follow-up visits are recommended to ensure proper healing.</td>
</tr>
</tbody>
</table>
forcefully and be assured that bleeding from the nostril on the affected side for 1-2 days is common. Sutures placed to close the defect should be removed after 2 weeks, and a radiograph should be taken 2 months postoperatively to determine healing.

Oral and maxillary soft tissue, causing collapse of the Eustachian tube. Proper preoperative radiographic interpretation and knowledge of the structures involved are essential to understand such complications.

The authors’ procedural recommendations for necrosis of maxillary soft tissue after tuberosity fracture during third molar extraction are listed in Table 4.

**Conclusion**

Although severe complications in the dental office are rare, they do occur, and a general dentist needs to know how to handle the situation. Even if all precautions are taken, complications may still arise, and proper care of the patient is essential. Referral to an oral surgeon should be considered if the dentist is unfamiliar with or unable to perform the tasks required to remedy the situation. It is important to remember that with proper care, most severe complications will heal and allow the patient to return to function.

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**References**

Unusual cases of transmigrated mandibular canines

Lata Goyal, MDS

Transmigration, an extremely rare anomaly that happens almost exclusively with mandibular canines, is defined as a pre-eruptive migration across the midline. It can lead to various restorative, surgical, orthodontic, and interceptive problems. This condition usually is not related to any painful symptoms and cannot be detected on clinical examination. This article presents 3 cases of transmigration. In 1 case, the right canine was involved, which is considered to be especially rare. This case series also highlights the importance of early diagnosis for the interceptive treatment of transmigration.

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Key words: transmigration, impaction, migration, mandibular canine

Transmigration refers to pre-eruptive migration of a tooth across the midline. This rare phenomenon occurs almost exclusively in mandibular canines. Although the term was first coined in 1964, it was a 1971 study by Tarsitano et al that defined it as the phenomenon of an unerupted mandibular canine crossing the midline. A 1985 article by Javid stated that in a true transmigration, the midline had to be crossed by half of the tooth. But rather than the distance of migration, a canine’s tendency to cross the barrier of the mandibular midline suture is a more important factor to be considered.

A 2002 article by Mupparapu used 5 criteria to classify transmigrated canines based on their position within the jaw when first diagnosed and their migratory pattern. In cases of Type 1 transmigration, the canine is positioned mesioangularly across the midline within the jaw bone, labial or lingual to anterior teeth, with the crown portion of the tooth crossing the midline. In cases of Type 2 transmigration, the canine is impacted horizontally, near the inferior border of the mandible and below the apices of the incisors. In Type 3, the canine erupts either mesial or distal to the opposite canine. With Type 4, the canine is impacted horizontally near the inferior border of the mandible below the apices of either the premolars or molars on the opposite side. In Type 5, the canine is positioned vertically in the midline (the long axis of the tooth crossing the midline), regardless of eruption status. (Fig. 1)

Types 1-5 define the most common locations for transmigrated canine teeth, although some unusual positions have been reported, including reverse oblique migration of the mandibular canine, which crossed the midline and pierced the lower border of the mandible. Transmigration is much more common in mandibular canines; some instances have been reported in the maxilla. While various theories concerning the etiology of transmigration have been suggested, the most accepted is an abnormal displacement of the dental lamina in embryonic life. This condition usually is not related to any painful symptoms and cannot be detected on clinical examination; rather, it is best diagnosed by a panoramic radiograph.

This article describes 3 clinical cases of transmigration (including the rarer Types 4 and 5) involving impacted mandibular canines and highlights the importance of using an orthopantogram (OPG) in cases involving “missing” canine teeth, so that interceptive treatment can position the transmigrated canine correctly.

Case No. 1
A 25-year-old man presented with the chief complaint of “dirty teeth.” Clinical examination revealed the missing right mandibular canine. A panoramic radiograph showed...
an impacted canine crossing the midsagittal plane in a mesioangular direction; thus it was classified as a Type 1 transmigration (Fig. 2). This condition was left untreated as the patient was asymptomatic; however, he agreed to return for periodic follow-up appointments.

Case No. 2
A 35-year-old man presented for orthodontic treatment to close spacing between the mandibular anterior teeth. Clinical examination showed the spacing between the mandibular anterior teeth as well as the absence of the permanent mandibular left canine. A panoramic radiograph was taken, which revealed the impacted tooth. The impaction was categorized as a Type 4 transmigration, as it crossed the midline and impacted near the inferior border of the mandible, below the apices of the premolar (Fig. 3). There was no abnormal pathological change detected in the radiograph. The patient was informed of this condition and scheduled for routine checkup procedures. No treatment was recommended because the patient was asymptomatic.

Case No. 3
A 27-year-old man was referred to have his retained primary teeth extracted. Intraoral radiographs and clinical examination showed the retained primary teeth and the coronal portion of an impacted tooth. The patient was asked to return for a panoramic radiograph, which showed an unerupted impacted mandibular left canine tooth, classified as a Type 5 transmigration (Fig. 4). Regular follow-up appointments were planned; unfortunately, the patient did not return (Table).

Discussion
Although the etiology of transmigration is still not clear, many hypotheses have been proposed. One commonly accepted theory involves the abnormal deviation or displacement of a tooth bud during its developmental period. Other contributing factors may include genetics, premature loss or late retention of primary canine teeth, an interrupted path of eruption, osteodental discrepancies, odontomas, cysts, and tumors.

Transmigration can be predicted by examining canine tooth germ inclination. If the angle formed by the midsagittal plane and the dental axis exceeds 50 degrees, transmigration is indicated. An angle of 30-50 degrees indicates possible transmigration. When the angle is less than 30 degrees, transmigration is unlikely. A 2003 article by D’Amico et al suggested that canines that lie between 30 and 40 degrees tend to cross the midsagittal plane, and when the angle exceeds 50 degrees, an impacted canine becomes displaced.

According to Vichi & Franchi, proclination of the mandibular incisors increases the axial inclination of unerupted canines, and the symphyseal cross-sectional area of the chin could play a role in the transmigration mechanism.
Yavuz et al classified mandibular canines according to their angulations and depth of involved teeth. The present report was based on the behavior patterns of impacted canines as described by Mupparapu based on migratory paths. The first case reported in this article was a Type 1 transmigration with a mesioangular position below the anterior teeth and a coronal portion crossing the midline. Type 1 is the form most commonly reported in the literature; however, case No. 1 was a rare example of right canine transmigration.

In the second case report, the mandibular canine was transmigrated and appeared in a very rare horizontal position, making it a Type 4; only 0.13% of transmigration cases are reported as this type. This finding confirms Thoma’s 1952 statement that a horizontally positioned transmigrated mandibular canine is very unusual.

In the third case report, the canine was positioned vertically in the midline; thus it was classified as a very rare Type 5 transmigration. Transmigration is more common in mandibular canines than in maxillary canines because of the strong eruptive forces that direct the crown through the dense mandibular symphysis to the other side. It is difficult to determine the prevalence of the phenomenon as the literature consists largely of isolated case reports. A 2004 study by Aydin et al reviewed 4500 panoramic radiographs and identified 14 transmigrant canines (0.3%). More recently, a 2010 study by Vuchkova & Farah reviewed 60,000 OPGs over a period of 6 years and found only 4 cases. That same year, Aktań et al studied 5000 OPGs in a Turkish population and found 20 transmigrated mandibular canines in 17 patients (0.34%).

Treatment for transmigration depends on tooth position, eruption, angulation of tooth at the time of diagnosis, stage of development, and distance of migration. Interceptive treatment is most successful when transmigration is found in patients 8–9 years of age. The early age of these patients provides a greater number of treatment options, the most suitable involving surgical repositioning and autotransplantation. Surgical repositioning should ideally be performed when the root length of the tooth is 50%-75% complete. The length of time between removal and reinsertion should be minimal to prevent necrosis of the periodontal ligament, which can cause resorption and ankylosis. Verma et al reported a successful instance in which a transmigrated mandibular right canine was transplanted into the prepared socket of a retained primary canine; however, external root resorption has also been observed.

A transmigrated canine that is detected early can be exposed surgically and corrected by means of orthodontic traction. A 2012 article reported that orthodontic traction was used successfully to treat a case in which a transmigrated mandibular left canine had its crown below the apices of the right central incisor. Trakyali et al reported how a transmigrated mandibular right canine was aligned orthodontically, followed by recontouring to simulate a lateral incisor. In general, once transmigration is established, the most favored treatment is the extraction of the impacted tooth. However, if patients are asymptomatic, regular observation and periodic radiographic assessment is the recommended treatment option. In the present cases, all 3 patients were asymptomatic with no associated pathological condition or abnormality detected during clinical or radiographic examination. In each case, the condition was left untreated and regular follow-up visits were scheduled.

Conclusion

It is rare for an impacted maxillary or mandibular canine to migrate through the midline. A thorough clinical checkup and proper investigation (including panoramic radiographs) is necessary to detect the position of migrated and impacted teeth. Additional research should be conducted to determine the etiology and treatment modality of such an unusual condition. Early diagnosis is important for preventing more complicated situations.

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Clinical outcomes of indirect composite restorations for grossly mutilated primary molars: a clinical observation

Neeti Mittal, BDS, MDS • Binita Srivastava, BDS, MDS

This study was conducted to report the clinical outcomes and the parental and child satisfaction of onlays for restoring mutilated primary molars. Twenty subjects, ages 3-8 years, with the presence of at least 1 mutilated primary molar (≥3 carious surfaces and a carious surface area ≥3/4 of the occlusal surface) were recruited. This study assessed the clinical success, gingival health, and parent/child satisfaction of 28 indirect composite onlays. The onlays showed a 100% retention rate at 12 months follow-up and a marginal integrity of 96.43%. High rates of satisfactory Alpha ratings for color stability (92.86%), surface texture (92.86%), and anatomic form (100%), coupled with significant improvements in gingival health of the restored teeth (P < 0.05), were reported. Indirect composite onlays successfully restored anatomic form and function of the grossly decayed primary molars—with shorter chairside times—while satisfying the esthetic demands of the young pediatric patients.

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Key words: grossly decayed molars, esthetics, indirect composite onlays, mutilated molars, primary teeth

Although preventive dentistry is remarkably successful, a sizeable section of the pediatric population presents at high risk for caries with grossly decayed dentition.1 In such cases, pediatric dentists are responsible not only for restoring the function and esthetics of the teeth but also the self-esteem of these young children to prevent an unpleasant appearance as well as avoid future negative psychological sequelae due to the patient’s self-image. Gone are the days when the desire to look good was the privilege of adults only; today, even young children are demanding better looking white restorations.2

Esthetic alternatives to stainless steel crowns (SSCs), the gold standard restorative modality for mutilated posterior primary teeth, include celluloid strip crowns, indirect composite restorations, open-faced stainless steel crowns, and preveneered stainless steel crowns.3-6 These alternatives, although esthetically more acceptable, are still not ideal, owing to their requirements for long chairside times. Furthermore, commercially available preveneered crowns are sometimes difficult to fit, and the esthetic material has a tendency to fracture and/or chip off during contouring and crimping.

Rehabilitation with various types of direct restorations, although providing satisfactory esthetics, can sometimes be problematic in a young child with behavioral issues. On the other hand, indirect restorations can still be performed due to their shortened chairside times. Additional clinical benefits include precise marginal integrity, wear resistance, ideal proximal contacts, and excellent anatomic morphologies.7-9 To date, only a few isolated case reports have been published describing indirect composite restorations in primary teeth. Keeping this dearth of information in mind, we conducted this trial to report...
on the clinical outcomes and acceptability of indirect composite onlays in primary molars in children.4,10,11

Materials and methods

Study design and setting

The present clinical trial was conducted in the Pediatric and Preventive Dentistry Department of the Santosh Dental College and Hospital, Santosh University, India. The study was approved by the review board of the university’s ethics committee.

Source of data

A total of 20 children (3-8 years of age) who presented to the outpatient unit of the Pediatric and Preventive Dentistry Department were included in this evaluation.

Criteria for selection of participants

Inclusion criteria consisted of the presence of ≥1 grossly decayed primary molar that was not likely to exfoliate within 2 years of the cementation of the restoration and had >2/3 of the root length present when observed on a periapical radiograph. Only those teeth with ≥3 carious surfaces and a carious surface area ≥3/4 of the occlusal surface were included (Fig. 1). Exclusion criteria included children with intellectual and/or learning disabilities, abnormal parafunctional habits (such as bruxism), or primary molars with missing antagonists/adjacent contact teeth, or any child that reported issues with mobility, sinuses, abscesses, or tenderness. Failure to obtain informed consent from the parents for any reason also resulted in exclusion from this trial.

Operative procedure

All clinical and laboratory steps were performed by a single operator.

Phase I

Complete caries removal was completed, and areas in proximity to the pulp were protected by applying calcium hydroxide (Dycal, DENTSPLY International), followed by a glass ionomer cement (GIC) (GC Fuji II Glass Ionomer Restorative, GC America, Inc.). In the cases of nonvital teeth, pulpectomies were performed, followed by obturation with calcium hydroxide (ApexCal, Ivoclar Vivadent, Inc.). A 1 mm thick lining of the GIC was applied to seal the obturating material on the floor of the pulp chamber. Nonretentive withdrawal forms were established by smoothing all internal walls and rounding off all internal line angles. Shoulder finish lines with rounded internal angles were established, resulting in butt joints, such as a 90 degree cavosurface line angle, using a round-end cylindrical diamond. All internal walls were diverged from 5 to 15 degrees with no undercuts, using the round-end tapered diamond held parallel to the long axis of the tooth (Fig. 2). Following preparation, impressions were made with a 2-step putty wash technique using a polyvinyl siloxane (PVS) impression material (Fig. 3). First, an impression was made with putty using a preselected stock tray with tray adhesive applied over it. Then the impression was trimmed via the removal of interdental septa to create space for a light body impression material. Teeth were thoroughly isolated using high volume suction. The PVS impression material was spread over the prepared tooth surfaces, and the previous impressions were seated over them.

Temporization was done using GIC. GIC was chosen as the temporary restorative material as it is capable of maintaining its integrity between scheduled appointments while allowing for easy removal when needed.

Shade selection was conducted in natural light on wet tooth surfaces (as the shade of desiccated teeth is lighter than that of wet ones). Shade selections for dentin were done by examining the center of each tooth, while shade selections for enamel shades were done by examining the proximal/cusp-tip region of each tooth. These were approximated with the central portion of the VITASPAN Classical (Sirona Dental Systems, Inc.) tooth tab.

Phase II

In the laboratory, impressions were poured in die stones, and working models were made. Dies were separated with a saw to facilitate the fabrication of the onlays (Fig. 4). Cavity margins were marked in lead pencil, and cyanoacrylate separating media was applied.

Onlays were fabricated with Filtek Z350 XT Supreme Universal Restorative composite material (3M ESPE) using an...
incremental technique to carefully match anatomic form, proximal contact, and occlusion with opposing teeth (Fig. 5). The dentin shade was used for core build-up, and the enamel shade was used in a thickness of ≥1-2 mm. A thinner enamel shade layer was used in the cervical regions; a thicker layer was used in the incisal areas. Curing was done per manufacturer’s instructions, using an EzeeCure LED light (Unicorn DenMart) at 1200 mW/cm². Occlusions were checked using thin articulating paper by occluding with an opposing cast, followed by adjustments if required.

The finishing and polishing of margins was done using composite finishing and polishing tips (CompoSite Finishing Kit and CompoSite Polishing Kit, Shofu Dental Corporation).

**Phase III**

After removing the temporary restorations, onlays were checked for proper seating, marginal seal, and occlusion. Occlusion was checked in centric as well as eccentric positions. The internal surfaces of the onlays and the prepared teeth were acid etched with 35% phosphoric acid (3M ESPE) for 30 and 15 seconds, respectively. Prior to etching, circumferential mushroom undercuts were placed in the dentin just above the GIC layer using a round-end diamond.

Cementation was done with dual cure resin cement (RelyX U100 Self-Adhesive Resin Cement, 3M ESPE), per manufacturer’s instructions (Fig. 6). Excess cement was removed using an explorer (floss for proximal surfaces). The final finishing and polishing of margins were done using the same composite finishing and polishing tips used in Phase II.

**Evaluation criteria**

All the recordings were done by a blind observer who was unaware of the elapsed time period after the cementation of the restoration (such as at baseline or during follow-up).

The clinical success of indirect composite onlays was assessed in accordance with the modified United States Public Health Services (USPHS) criteria at baseline and at 1, 6, and 12 months follow-up. Restorations were rated for the following clinical parameters: color stability, retention, marginal integrity, recurrent caries, anatomic form, surface texture, and postoperative sensitivity. Each of these clinical parameters was

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alpha</th>
<th>Bravo</th>
<th>Charlie</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color stability</td>
<td>Restoration matches adjacent tooth color</td>
<td>Slight mismatch between restoration and tooth color</td>
<td>Strong mismatch between restoration and tooth color</td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>No loss of restoration</td>
<td>Partial loss or mobile restoration</td>
<td>Complete loss of restoration</td>
<td></td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>Explorer does not catch, and/or no crevice is visible</td>
<td>Explorer catches, and crevice is visible; however, no exposure of dentin, and restoration is not mobile</td>
<td>Explorer penetrates crevice defect and extends to dentin</td>
<td>Restoration is fractured, mobile, or missing</td>
</tr>
<tr>
<td>Recurrent caries</td>
<td>No caries present</td>
<td>Caries present and associated with restoration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatomic form</td>
<td>Restoration is continuous with existing anatomic form</td>
<td>Restoration is discontinuous, but missing material is not sufficient to expose dentin</td>
<td>Sufficient material lost to expose dentin</td>
<td></td>
</tr>
<tr>
<td>Surface texture</td>
<td>Texture similar to polished enamel</td>
<td>Surface texture gritty</td>
<td>Coarse surface pitting</td>
<td></td>
</tr>
<tr>
<td>Postoperative sensitivity</td>
<td>No complaint at all</td>
<td>Minor occasional complaint</td>
<td>Persistent pain, removal required</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5. Onlays seated on the cast of the mandibular molars.

Fig. 6. Final postoperative view of the mandibular molars.

Table 1. United States Public Health Services (USPHS) modified criteria.12
graded using the code designations (in decreasing order): Alpha, Bravo, Charlie, and Delta.12 The descriptions of the ratings are summarized in Table 1.

**Gingival health**
Gingival bleeding was scored as 0 = no bleeding, 1 = bleeding on probing, and 2 = spontaneous bleeding. The mean gingival bleeding scores for each tooth to be restored were recorded at the baseline and 12 months postoperatively.

<table>
<thead>
<tr>
<th>Type of molar</th>
<th>Number of restorations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary first</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Maxillary second</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mandibular first</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Mandibular second</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Evaluation of onlays (n = 28) according to USPHS criteria at baseline and 1, 6, and 12 months follow-up.**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Baseline</th>
<th>1 month</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color stability</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>27 1 0 NA</td>
<td>26 2 0 NA</td>
</tr>
<tr>
<td>Retention</td>
<td>28 0 0 NA</td>
<td>26 0 2 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>28 0 0 0 26 0 0 2 28 0 0 0 27 1 0 0 28 NA 0 28 NA 0 28 NA 0 28 NA 0 28 0 0 NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recurrent caries</td>
<td>28 NA 0 NA</td>
<td>28 NA 0 NA</td>
<td>28 NA 0 NA</td>
<td>28 NA 0 NA</td>
</tr>
<tr>
<td>Anatomic form</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
</tr>
<tr>
<td>Surface texture</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
</tr>
<tr>
<td>Postoperative sensitivity</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
<td>28 0 0 NA</td>
</tr>
</tbody>
</table>

Abbreviations: A, Alpha; B, Bravo; C, Charlie; D, Delta; NA, not applicable.

**Table 4. Satisfaction with onlays at 12-month follow-up.**

<table>
<thead>
<tr>
<th>Parental satisfaction</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown appearance</td>
<td>5.00 (0.000)</td>
<td>4.85 (0.366)</td>
<td>4.85 (0.366)</td>
</tr>
<tr>
<td>Shape</td>
<td>5.00 (0.000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>5.00 (0.000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>4.70 (0.923)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>4.80 (0.616)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>3.80 (1.196)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Child satisfaction**
A visual analogue scale was used to evaluate each child’s satisfaction with scores ranging from 1 to 5 where 1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent.14

**Statistical analysis**
Data were entered into an Excel spreadsheet (Microsoft) and imported into SPSS 16.0 software (SPSS, Inc.). A Kolmogorov-Smirnov test was used to determine the normality prior to analysis. Data were expressed as mean and standard deviation (SD). A paired t test was used for a comparative analysis of the gingival health at the baseline and during follow-up. A P value of <0.05 was considered to be significant.

**Results**
Eleven boys and 9 girls with a mean age of 6.35 ± 1.357 years were enrolled in this trial. A total of 28 (range: 1-4/subject) indirect composite onlays were placed. The majority of the onlays (18/28, 64.29%) were placed in the primary mandibular second molar (Table 2).

At baseline, 100% of the onlays had Alpha ratings for all evaluated parameters per the USPHS criteria (Table 3). At 1-month postoperative follow-up, 2 onlays had fallen out but had been recovered by the patients and were returned to the clinic. These were recemented and were not excluded from further evaluation. At 12 months follow-up, 7.69% of the onlays exhibited Bravo ratings for color stability and surface texture. A slight catch with an
explorer was noticed in 1 (3.57%) of the onlays. For all other parameters, 100% of the onlays exhibited Alpha ratings.

Regarding parental satisfaction, higher scores (5.00 ± 0.000) were observed for crown appearance, shape, and size among all the parameters scored (Table 4). The lowest parental satisfaction scores were reported for the cost (3.80 ± 1.196).

A statistically significant improvement was seen in the gingival health of the restored teeth \( (P = 0.000) \) (Table 5).

**Discussion**

The indirect composite onlays showed a 100% retention rate at 12 months follow-up and a marginal integrity of 96.43%. As such, the results from this preliminary observation are encouraging. High rates of satisfactory Alpha ratings for color stability (92.86%), surface texture (92.86%), and anatomic form (100%), coupled with significant improvement in the gingival health of the restored teeth, lend support for the use of indirect composite onlays as a successful mode of esthetic rehabilitation for grossly mutilated primary posterior teeth.

For mutilated posterior teeth postpulpectomy, various restorative modalities include multisurface restorations (such as amalgam, GIC, or composite) and stainless steel crowns.15,16 Significantly greater success rates have been reported for stainless steel crowns as compared to the abovementioned multisurface restorations.15,16 However, 1 obvious disadvantage is their poor esthetic appearance, owing to the metallic appearance that many patients and parents find unacceptable.2,17 Also, the poor adaptation of stainless steel crowns can result in a compromised periodontium. Esthetic alternatives to preformed stainless steel crowns include open-faced stainless steel crowns and preveneered stainless steel crowns. Although these options provide durability, marginal adaptation, and restoration of the morphological form and anatomy comparable to stainless steel crowns, an obvious disadvantage is the high rate of chipping of their veneers, resulting in poor esthetic appearance.18

Direct composite restorations also provide satisfactory esthetics, but their use is limited to smaller cavities. Moreover, it is very challenging to restore proper anatomic form and contour along with marginal adaptation in severely decayed primary molars by direct techniques for children demonstrating questionable compliance. Furthermore, direct composite restorations have been associated with postoperative pain due to the contraction of the resin that is bonded to thin cavity walls, marginal microleakage following polymerization shrinkage—especially at the cervical cavosurface margins—improper contact points, and relatively low wear resistance.7-9,19 The extraoral improved curing of the composite resin as used in the present study can minimize the abovementioned disadvantages of direct composite restorations.9

Despite the availability of a variety of specific systems for laboratory-processed indirect composites, we used the composite material that is currently routinely used for direct restorative procedures in the clinic used in this study, and curing was done with the same light-curing unit generally used for direct composite restorations. Commercially available indirect systems have greater filler loading for improved mechanical strength and better handling properties than direct composites, but these systems pose a greater economic burden due to their higher costs. Furthermore, these indirect systems were developed for permanent teeth that have to serve in the oral cavity for a much longer period of time than primary teeth. Moreover, the prime objective of this study was to test the indirect composite technique and not the specific material. For these reasons, the authors prefer to use direct composite material.

The successful execution of high-quality restorative care in young patients is often impeded by anxious and uncooperative behavior. Decreases in chairside time for restorative procedures would result in more satisfied pediatric patients and their caregivers. However, longer chairside times might be required to restore multiple mutilated primary molars. To restore grossly broken posterior teeth with little remaining tooth structure, the first step is to carry out a core build-up, followed by a restoration of the crown superstructure. Instead of this 2-step technique, we used a 1-step technique in which the core and crown superstructure were built as a single unit, thus reducing the chairside time. Furthermore, multiple teeth can be restored simultaneously with this technique. However, 1 disadvantage of this technique is the requirement of 2 visits versus 1 visit, resulting in more effort on the parts of both patients and parents.

For posterior teeth, it is not always feasible to fabricate single-unit indirect composite onlays. For adequate retention, at least 3-4 mm depth of the pulp chamber or a minimum of 1 mm cervico-occlusal dimension above the gingival margin is required, and such complex fabrication may not always be feasible. In the case of inadequate tooth structure to ensure sufficient retention, it is advisable to do a core build-up via direct techniques first and then prepare the tooth to receive complete coverage via indirect composite restoration.

Among all the parameters recorded while evaluating parental satisfaction, the lowest parental satisfaction scores were reported for the cost of the restorations. The cost of an indirect composite onlay is approximately US $8.30 in the clinic used in this study, while the approximate cost for an SSC is approximately US $5.80. Furthermore, patients visiting the clinic used in this study are from mixed socioeconomic backgrounds. The authors did not analyze the relationship of the parents’ socioeconomic background (such as ability to pay) with the satisfaction with the cost of indirect restorations. The lower satisfaction regarding cost might be due to the slightly higher cost of indirect composite restorations and/or poor socioeconomic status. These findings suggest that indirect composite restorations should be the treatment of choice only when the patient and/or his/her parents’ priority is excellent esthetics over cost. Even though an extra visit is required for placing indirect composite onlays, the overall chairside time is not much different since the dentist can place multiple onlays in a single visit.

This study is the first report on the clinical outcomes of indirect composite onlays in a pediatric population. The limitations of this study include a small convenience sample and the absence of any comparison group. Further randomized, controlled trials with comparative evaluations and established modalities—such as preformed SSCs, veneered SSCs, and direct composite restorations—are needed.
Conclusion
Indirect composite onlays not only satisfactorily restored function but also resulted in excellent esthetics for the patients in this study. However, the limitations of a slightly longer chairside time and a slightly higher cost must be kept in mind. More randomized, controlled trials to generate evidence to compare this technique to traditional treatment modalities are needed.

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Microsoft, Redwood, WA
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800.659.5977, www.sironausa.com
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852.2811.9662, www.spss.com
Unicorn DenMart, New Delhi, India
011.45551200, www.unicorndenmart.com
3M ESPE, St. Paul, MN
888.364.3577, solutions.3m.com
Clinicopathological aspects of 25 cases of sialolithiasis of minor salivary glands

Marco Tullio Brazao-Silva, DDS, PhD • Fabio Cesar Prosdocimi, DDS, PhD • Celso Augusto Lemos-Junior, DDS, PhD
Suzana Cantanhede Orsini Machado de Sousa, DDS, PhD

Sialolithiasis of minor salivary glands (SMSG) is rarely reported and presumably represents an underestimated disease. This study examined the clinicopathological aspects of 25 selected SMSG cases over an 11-year period at the Oral Pathology Department of the University of Sao Paulo, Brazil. SMSG was not a clinical diagnosis in 92% of the cases. Histologically, the sialoliths tended to be superficial and formed by concentric layers with variable degrees of mineralization. Chronic periductal and parenchymal inflammation were frequent, as well as squamous metaplasia of the affected duct. Ectasia, squamous and mucous metaplasia, mucous plug formation, and cellular debris were seen in adjacent ducts. Clinicians should be aware of SMSG, especially with regard to its higher incidence in the upper lip and buccal mucosa.

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Key words: sialolithiasis, salivary glands, minor, diagnosis, histopathology

Sialolithiasis is the most common form of obstructive sialadenitis. It is caused by the formation of a sialolith, a rigid structure generally consisting of a mixture of different calcium phosphates and an organic matrix. Sialolithiasis is one of the most common salivary gland diseases and is often attributed to the submandibular gland. The involvement of minor glands is rarely reported (<1%), and only a few studies have described the clinicopathological characteristics of sialolithiasis of minor salivary glands (SMSG) in the differential diagnosis of mucosal lesions. This omission has likely led to an underestimation of SMSG cases due to cases that are missed either clinically, as some lesions may resolve spontaneously, or histologically, as a sialolith may not appear in histopathological sections. Therefore, a retrospective study on these lesions can be helpful for clinicians and pathologists to improve their recognition of SMSG. The present study aimed to describe the clinical and histopathological aspects of SMSG cases diagnosed during a period of 11 years.

Materials and methods
Histopathology records from 2000-2011 were obtained from the Department of Oral Pathology of the University of Sao Paulo, Brazil, and all diagnoses containing the term sialolithiasis were reviewed. In addition, cases of salivary gland pathology with a descriptive diagnosis of ductal ectasia and/or sialadenitis were reviewed, since these conditions often result from the presence of a calculus, and an existing sialolith may have been missed due to an insufficient number of histological sections included in the original analysis.

In this study, a diagnosis of sialolithiasis was only confirmed if a sialolith was present. A sialolith was interpreted as a mineralized tissue lined by ductal epithelial cells...
or within the salivary gland parenchyma. In addition, an SMSG diagnosis was only considered when the sialolith was found within a minor salivary gland. Data such as age, gender, site of lesion, and clinical diagnosis, as well as histopathological characteristics—such as gland parenchyma alterations (atrophy, edema, and inflammation), duct alterations (metaplasia, ectasia, and adjacent inflammatory infiltrate), and aspects of the sialolith (structural arrangement, staining pattern, localization in the tissue, and number of calculi)—were analyzed. Descriptive statistics were used when appropriate.

### Results

Within the 11 year period, 25 cases of SMSG were reviewed, constituting 0.06% of all oral pathologies diagnosed in this period. Of the SMSG patients, 14 were males (56%), and the male to female ratio was 1.3:1. Patients’ ages ranged from 26 to 77 years, with a mean age of 58.7 (±14.9) years. Peak age of onset was in the seventh (8 cases) and eighth (6 cases) decades of life, occurring in 56% of cases. Almost all lesions were clinically misdiagnosed (92%). The suspicion of a salivary gland tumor was most common (24%), followed by fibroma (20%) and nonspecific sialadenitis (20%). When misdiagnosed, the incorrect choice of clinical diagnosis seemed to be site-specific (Chart 1). Clinicians tended to call the lesions sialadenitis, mucocele, or lipoma when they involved the buccal mucosa and fibroma or tumor of the salivary gland when they involved the upper lip. SMSG was suggested as a secondary clinical diagnosis in 2 cases (8%), one in the upper lip and the other in the buccal mucosa (Chart 2). Two clinicians did not provide any hypothesis of clinical diagnosis.

Histopathological analyses showed that 24% of the sialoliths occurred in multiples, while the rest were single. Sixty-four

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age (yr)</th>
<th>Anatomical location (depth)</th>
<th>Sialoliths</th>
<th>Number</th>
<th>Morphology</th>
<th>Color</th>
<th>Duct</th>
<th>Gland parenchyma</th>
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<td></td>
</tr>
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<td>Single</td>
<td>Laminated</td>
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<td>Atrophic/abscedation</td>
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</tr>
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<td>Homogeneous</td>
<td>Squamous metaplasia</td>
<td>Inflamed (L)</td>
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<tr>
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<td>Atrophic/abscedation</td>
<td>Inflamed (L)/atrophic</td>
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<td>Homogeneous</td>
<td>Squamous metaplasia</td>
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<td>Heterogeneous</td>
<td>Squamous metaplasia</td>
<td>Inflamed (S)/atrophic</td>
<td></td>
</tr>
</tbody>
</table>

1Depth of sialolith: D, deep; S, superficial. 2Level of inflammation: L, low; M, moderate; S, severe. Abbreviation: NA, not available.
percent were located superficially on the mucosa; the rest were located at deeper locations. The sialoliths were mostly composed of laminated concentric layers (68%), but some were formed by a continuous calcified mass showing a globular calcification pattern (20%). The staining characteristics varied from homogeneous (56%) to heterogeneous (44%); these were of a predominantly basophilic pattern. Direct contact between the sialolith and adjacent ductal epithelium revealed squamous metaplasia in 60% of the cases. Twenty-eight percent of the ducts were atrophic; mucous metaplasia was rare (8%). Periductal inflammation was present in 72% of the cases, and 48% of these cases were chronic. Abscess formation and granulation tissue surrounding the sialolith were observed in 16% of the cases. Parenchymal alterations included atrophy (48%) and chronic sialadenitis (68%), with 28% of the cases exhibiting moderate chronic sialadenitis. Ductal ectasia and mucous/squamous metaplasia were each found in 12% of the cases; exfoliated ductal epithelial cells were seen in the parenchyma or adjacent ducts in 8% of the cases (Table). Figures 1–3 depict illustrative cases of SMSG.

Discussion
The present study explored the clinical and histological aspects of SMSG diagnosed during a period of 11 years, and the small number of cases reported indicates that it is a rarely diagnosed disease. Previous studies have shown that SMSG is rarely considered among clinical diagnoses. In the present study, fibroma, mucocele, tumor of the salivary gland, and nonspecific sialadenitis were the most frequent presumptive diagnoses. It is interesting to note that even though mucoceles are uncommon in the upper lip and buccal mucosa, they were among the most common clinical diagnoses. Epidemiologically, more appropriate diagnoses would be fibroma, salivary gland tumors, and lipoma, considering their higher frequencies, similar clinical aspects, and common sites of involvement. The clinical diagnosis of SMSG was regarded in 2 cases as a secondary diagnosis.

SMSG has been characterized in the literature as a disease with no relation to age, gender, or site of involvement. However, we observed 2 peaks of incidence, both involving the elderly. Mean age of onset was 58.7 years. This finding has been corroborated in other studies that showed a higher prevalence of SMSG in patients over 45 years of age. This characteristic could indicate that the metaplastic changes of ductal cells and saliva due to aging may contribute to sialolith formation. However, the specific etiology of this disease is still unclear and may be multifactorial. A male predisposition was found in other studies, but the differences between the genders was not significant. With respect to the site of involvement, the data from this study support the conclusion that the upper lip is most susceptible to SMSG, as more than 40% of the cases occurred there. This finding is in accordance with a review that showed that upper lip lesions account for 49.2% of SMSG cases.

In view of the clinical aspects observed for SMSG, it can be defined as a submucosal and well-delimited palpable mass, mostly involving adults and elderly patients and the upper lip/buccal mucosa. An awareness of the features of this entity may aid in the differential diagnoses of submucosal masses. Additionally, periapical radiographs may have some value in the diagnosis of those cases with well-mineralized sialoliths.

In this study, the majority of the sialoliths were homogeneously stained, presenting concentric onion-like calcifications. However, there were some cases of sialoliths with heterogeneous staining characteristics presenting multifocal
internal globular calcifications. In addition, a majority of the cases presented multiple sialoliths, clearly indicating the existence of a distinct pathogenesis among cases, as well as the possibility of multiple areas of sialolithogenesis. Sialoliths consist of mixtures of different calcium phosphates in an organic matrix that appear to be required to trigger embedding within a duct. A variable spectrum of sialoliths was observed in this study, and they may represent distinct sources of organic material, including exfoliated ductal epithelial cells, bacterial colonies, foreign bodies, and mucous plugs. However, alterations of salivary composition—such as in viscosity or salt concentration—have also been presented as possible factors. Furthermore, isolated cases of sialolithiasis have been described in patients presenting primary hyperparathyroidism, gout, and kidney transplantation.

Currently, the findings of this and other studies indicate that SMSG is a multifactorial, nonspecific disease, and at present there is no study with a relatively large number of patients that indicates specific systemic predisposing factors.

Two of the retrieved cases in this study were previously diagnosed as ductal ectasia; these diagnoses were changed to SMSG during the reviewing process when sialoliths were found after additional histopathological sections were obtained and analyzed. Thus, to avoid laboratory misdiagnoses, it is important to emphasize the histopathological findings recorded in this study, such as squamous metaplasia of involved ducts (>50%, sometimes including adjacent ducts), mucous metaplasia (<50%), and inflammation of the gland parenchyma (68%). This suggests that SMSG should be suspected by clinicians facing a histological picture of a sialadenitis without apparent cause.

Acinar atrophy, ductal ectasia (sometimes with deep cystic dilatation), and peri-ductal inflammation were also found in this study; these are frequent components of SMSG histopathology. All of these findings must also be considered in distinguishing cases with mucous metaplasia from low-grade mucoepidermoid carcinomas or cases with cystic dilatation from cystadenomas. Furthermore, even in the presence of a calcification, other alterations such as phleboliths and dystrophic calcification (such as that caused by trauma) must be considered. Hence, alterations in the adjacent minor salivary glands and the presence of a surrounding duct epithelium in the histopathological sections are very important factors to be considered in a diagnosis. When the ductal epithelium is disrupted by a sialolith, microabscess formation and the development of granulation tissue can be observed. These cases may mimic mucocceles, as observed in a 2011 case report.

Finally, this study is in agreement with others that showed SMSG is an underestimated disease, occurring more frequently than previously assumed, and should be included in the clinical and histopathological differential diagnoses of intramucosal nodules (mainly in adults over 45 years of age) and nonspecific localized sialadenitis.

SMSG has been adequately treated by surgical excision of the mass containing the sialolith and the involved gland under local anesthesia. Spontaneous resolution in some cases is possible. Recurrence is not common and may indicate the presence of multiple, previously undiagnosed sialoliths.

**Conclusion**

Clinicians should be aware of the incidence of SMSG, especially with regard to its higher incidence in the upper lip and buccal mucosa, involving adults and the elderly. This study reported important elements to consider when identifying SMSG. The present data expand the knowledge about the spectrum of the disease.

**Author information**

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**References**

Oral manifestations in gastroesophageal reflux disease

Preetha A., MDS • Sujatha D., MDS • Bharathi A. Patil, MDS • Sushmini Hegde, MDS

Many systemic diseases exert their influence on oral health. Among these, gastroesophageal reflux disease (GERD) is the most common. In this study, 100 patients who were previously diagnosed with GERD were examined following a 12-hour fast and evaluated in terms of the severity (grade) of the disease as well as any oral, dental, and/or salivary pH changes. Results found 11 patients with tooth erosion. These patients were older, and their average mean duration of GERD was longer in comparison to those without erosion. There was an inverse relationship between salivary pH and the GERD duration and grade of severity. As the GERD grade increased, the severity of tooth erosion increased. Patients with erosion also exhibited oral mucosal changes. Thus severe, long-term GERD was found to be potentially detrimental to oral soft tissues, dental structures, and salivary pH, whereas milder forms of the disease did not necessarily cause dental side effects.

Key words: GERD, acid reflux, salivary pH, oral manifestations, xerostomia, taste change, burning mouth sensation, tooth erosion

Gastroesophageal reflux disease (GERD) is a common medical condition that affects 35%-40% of the adult population.1 GERD is characterized by the regurgitation of gastric and duodenal contents into the esophagus and oral cavity.2 The regurgitated acidic liquid usually contains pepsin, a digestive enzyme produced by stomach bile that has backed up into the stomach from the duodenum.3 Pepsin is most active in acidic environments and is believed to be the most injurious component of refluxed liquid, responsible for the oral and dental manifestations associated with GERD.1

Normally when acid enters the mouth from intrinsic or extrinsic sources, saliva washes the acid away. This results in an increase in the salivary flow rate and buffering capacity. The buffering capacity regulates the salivary pH. In an ideal oral environment, when an acid is introduced into the oral cavity, the acid is neutralized within minutes and the salivary pH returns to normal.4

The aim of this study was to evaluate the oral and dental manifestations of GERD, and to correlate these manifestations with salivary pH changes in patients with this disease.

Materials and methods
The study consisted of patients (n = 100) who were endoscopically diagnosed as having GERD by a gastroenterologist in the Department of Gastroenterology, Bangalore and Bhagwan Mahaveer Jain Hospitals, India.

Patients included in this study had at least 20 teeth in the mouth (including the maxillary anteriors from tooth No. 5 to tooth No. 12) and were diagnosed as having GERD by the gastroenterologist. All patients were required to sign an informed consent. Patients excluded from this study were those that were pregnant, edentulous, and/or on the following medications: anticholinergics, antidepressants, antipsychotics, antihypertensives, or antacids.

The 100 patients fasted for 12 hours, at which point each was examined under bright illumination using a mouth mirror and probe.

Salivary pH assessment
Unstimulated whole salivary pH was recorded. Salivary pH was recorded using

<table>
<thead>
<tr>
<th>Duration of GERD (years)</th>
<th>Patients (n)</th>
<th>Dry mouth</th>
<th>Taste change</th>
<th>Burning mouth sensation</th>
<th>Mouth sores</th>
<th>Tooth erosion</th>
<th>Tooth sensitivity</th>
<th>Myofascial pain</th>
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<td>&gt;5</td>
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<td>1 (50.0)</td>
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<tr>
<td>Total</td>
<td>100</td>
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<td>7 (7.0)</td>
<td>5 (5.0)</td>
<td>11 (11.0)</td>
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</table>

P value: <0.001 <0.001 <0.001 <0.001 <0.001 <0.001

Note: All P values in the table are considered to be strongly significant (P ≤ 0.01).
pH measuring strips (Universal strips, GlaxoSmithKline). Each patient was asked to pool saliva on the tongue and a pH strip was placed to wet it. The color change was immediately matched directly with the scale provided with the strip, and the pH was recorded.

**Oral manifestations**

Specific oral manifestations were classified into subjective and objective findings.

Subjective findings included dry mouth, changes in taste, burning mouth and pharynx sensations, and nonspecific itching. To assess the subjective findings, each patient was asked questions regarding the symptoms; their responses were recorded as present or absent. Dry mouth was self- recorded using a questionnaire.

Objective findings included oral ulcerations, dental erosion, dental hypersensitivity, temporomandibular disorder (TMD), and myofascial pain. Dental erosion was recorded as follows: Grade I, erosion lesion restricted to enamel; Grade II, erosion lesion involves dentin, but for <1/3 of the tooth surface; Grade III, erosion involves dentin for >1/3 of the tooth surface.

**Statistical analysis**

Descriptive statistical analyses were conducted in this study. Significance was assessed at 5%. Chi-square and Fisher exact tests were used to find the significance of study parameters on a categorical scale between 2 or more groups. A 95% confidence interval was computed to find the significant features. Results were deemed suggestive, moderately, or strongly significant based on P values of 0.05 < P < 0.10, 0.01 < P ≤ 0.05, and P ≤ 0.01, respectively. Statistical software (SPSS 15.0, SPSS, Inc.; Stata 8.0, StataCorp LP; MedCalc 9.0.1, MedCalc Software bvba; and Systat 11.0, Systat Software, Inc.) was used for the analysis of the data.5-7

**Results**

This study found that severe GERD of long duration was detrimental to teeth, whereas milder forms of the disease did not cause dental side effects (Table 1).8 GERD Grade A exhibits 1 (or more) mucosal breaks ≤5 mm and does not extend between the tops of 2 mucosal folds. GERD Grade B exhibits 1 (or more) mucosal breaks >5 mm long and does not extend between the tops of 2 mucosal folds; GERD Grade C, exhibits 1 (or more) mucosal breaks which are continuous between the tops of 2 or more mucosal folds but involves less than 75% of the circumference.

Nine percent of the patients in this study had dry mouth. The results indicated that as the GERD grade increased, the prevalence of dry mouth also increased. The percentage of patients exhibiting tooth sensitivity when subjected to thermal stimuli was also 9%. Both of these findings were statistically significant (P < 0.001). Seven percent of the patients had burning mouth sensations, and 11% had tooth erosion (Table 2); both values were deemed statistically significant (P < 0.001).

The results of this study showed that tooth erosion was prevalent at 6.5 salivary pH (Table 3). It was found that as the GERD grade increased, the severity of tooth erosion increased; however, the salivary pH decreased (Table 4).

Mouth sores in the present study were recorded based on each patient’s clinical history, and the prevalence was deemed...
to be statistically significant ($P < 0.001$). None of the patients in this study presented symptoms of TMD or myofascial pain.

**Discussion**

The mean age of patients in this study was 46.28 years for men and 44.75 years for women. The majority of patients were between 31 and 50 years of age. The majority of patients were male (64%). This was in accordance with previous studies by Kasper et al and Meurman et al, which showed male prevalences of 64.5% and 75.4%, respectively.  

**Acid regurgitation and dysphagia**

Typical symptoms of GERD are heartburn (72%), acid regurgitation (44%), and dysphagia (36%). However, a high percentage of patients with extraesophageal manifestations of GERD—such as laryngitis; chronic cough; chest pain; and ear, nose, and throat problems—do not display the typical symptoms. This could retard both the diagnosis and treatment of GERD. In the present study, 10% of the study population had dysphagia and 56% had gastric regurgitation as their presenting symptoms. However, a study by Moshkowitz et al reported 100% of the study subjects presenting with gastric regurgitation.  

**Oral manifestations**

The effects of chronic exposure of the oral cavity to gastric acid can be profound, and may include mucosal ulceration/erosion, loss of taste, soft/hard palate erythema, oral ulcers, xerostomia, dental erosion, dentinal hypersensitivity, severe tooth destruction (leading to loss of occlusion), TMD, and myofascial pain.  

Most previous GERD studies have focused solely on the effects of the disease on the teeth. While soft tissue symptoms have been mentioned in the literature, pathognomic soft tissue lesions have not been extensively documented.  

**Dry mouth**

The incidence of dry mouth in GERD patients has been previously studied, and the prevalence in these studies was statistically significant, in accordance with the present study. One study of a GERD patient population ($n = 200$) reported a 54.5% incidence of dry mouth, which was statistically significant ($P = 0.0001$). Campisi et al found in their study of 120 GERD patients that a statistically significant percentage of their patients (57.5) experienced dry mouth ($P < 0.0001$).  

The subjective feeling of mouth dryness is directly related to saliva. Saliva acts by directly neutralizing the acids in the oral cavity. A sensation of dry mouth might be indicative of a deficit in salivary secretion, with a resultant reduced salivation and subsequent insufficient clearance, dilution, and buffering of gastric acids.  

Upper gastrointestinal mucosal irritation has long been thought to stimulate salivation. Salivary hypofunction in patients with GERD is due to the inability to reach adequate stimulated performances, which suggests that there is a defect in the esophageal salivary reflux. An insufficient salivary flow has been associated with low clearance and a reduced capacity for esophageal acid neutralization; hence GERD could be considered as a primary etiopathogenic factor in salivary dysfunction. However, no definitive conclusions have been established with regard to the potential reactive or modulating relationship between the physiological mechanism of salivary hypofunction and GERD.  

According to the literature, drugs such as anticholinergics, antidepressants, antipsychotics, antihypertensives, antidiabetics, antihistamines, and antacids are all associated with decreased salivary secretion, thereby causing dry mouth. In the present study, any patients who were on these types of medications were excluded from the study. Hence, the dry mouth incidence in the present study was not related to these drugs or their side effects.  

**Taste change**

Very few studies have recorded the sensation of taste change in GERD patients. Correa et al found that GERD patients had a higher incidence of sour taste in the oral cavity. Taste change in GERD patients has been determined to be due to the regurgitation of the gastric contents into the mouth, which tends to present a sour, salty, bitter, or acidic taste.  

**Burning mouth sensation**

Regurgitated acid and the insufficient production of saliva may cause defective clearance and neutralization of acid that may result in burning mouth sensation. As stated earlier, the incidence of burning mouth sensation in this study was found to be statistically significant. However, this was not in accordance with previous studies. Venkatasywamy Reddy and Di Fede et al reported 48.3% and 43.2% of incidences of burning mouth sensation, respectively; neither value was deemed statistically significant.  

**Tooth sensitivity**

The primary cause for tooth sensitivity in GERD patients is tooth erosion. This can be indicated by a variety of symptoms, which include sensitivity to thermal or sweet stimuli. Tooth sensitivity often results in pain during mastication.  

**Tooth erosion**

The regurgitation of gastric acid into the mouth has been connected with tooth erosion in a number of studies. Tooth erosion has been defined as the superficial loss of the hard tissues of the teeth by a chemical process that does not involve the action of bacteria. It is the predominant oral manifestation of GERD. The early stages of erosion are difficult to identify; the only sign may be a barely noticeable loss of surface luster on clean, dry enamel.  

Erosion of the posterior teeth involving lingual and occlusal surfaces may suggest GERD, whereas erosion on the lingual surfaces of anterior teeth has been noted in bulimic patients, and patients exposed to acids from external sources mostly present with damage on the labial surfaces of the anterior teeth, with severity decreasing posteriorly.  

The reported prevalence of dental erosion in GERD patients varies widely. However, the findings of this study are in accordance with previous studies. In a study by Fennerty, patients who either exhibited symptoms of GERD or were clinically diagnosed with the disease had a statistically higher frequency of tooth erosion when compared with controls ($P = 0.0001$). A cross-sectional study by Pace et al evaluated 20 adult dentate subjects to find whether the loss of tooth structure was a result of dental erosion and GERD. The results showed that the subjects diagnosed with GERD had significantly higher tooth wear index scores compared to controls, indicating that a relationship exists between loss of tooth structure and GERD.
Tooth erosion and salivary changes
The prevalence of dental erosion in patients with GERD varies widely, and could be influenced by individual factors, such as differences in the defensive mechanism to acid reflux, including salivary flow rate, buffering capacity, and pH.27

Salivary flow rate increases when acid from intrinsic or extrinsic sources enters the mouth.4 It has also been found that esophageal acid infusion increases salivary flow. Hence, salivary flow is directly related to acid concentration. While it has been shown that decreased stimulated salivary flow rate and salivary hypofunction are present in GERD, no definitive conclusions have been established regarding the causation.10

A number of investigators have hypothesized that a low salivary flow rate is an important modifying factor affecting dental erosion. The risk of erosion in patients with low unstimulated salivary flow rate is 5 times the risk in patients with normal flow rates.11,15

The cross-sectional study by Campisi et al was conducted on 120 GERD patients and 98 healthy subjects in order to evaluate their salivary parameters (basal flow rate, stimulated flow rate, pH, and sodium and potassium concentrations).16 Both the GERD and control groups were found to have similar basal flow rates, with mean values of 0.39401 and 0.3185, respectively. However, there was a difference in stimulated salivary flow, with mean values of 0.48718 and 0.6108, respectively. The authors concluded that salivary secretion is altered in GERD patients and emphasized the need for further investigation in order to define the role of saliva in the etiopathogenesis of GERD.16

Buffering capacity
The buffering capacity of saliva refers to its ability to resist change in pH when acid is added to it. This property is largely due to the bicarbonate content of the saliva, which in turn is dependent on the salivary flow rate. If the buffering capacity is impaired (as is the case in GERD patients), the acid exposure is prolonged, which results in oral tissue damage.4 Silva et al evaluated the salivary parameters (buffering capacity, pH, and slow rate) of 62 patients with erosion compared to 50 randomly selected control subjects with no evidence of tooth erosion.22 The erosion patients had low salivary buffering capacity in comparison to the controls; this difference was highly significant (P < 0.001). There was no statistically significant difference in salivary flow rate and pH between the erosion patients and controls.26 Meurman et al evaluated 117 patients for oral, dental, and salivary findings.8 The authors found that 28 patients had erosion, and there was no statistical difference in resting and stimulated salivary flow rate in patients with erosion and those without erosion (controls). However, the patients with erosion had a low buffering capacity compared with the controls. The difference was not statistically significant (P = 0.008).8 In the present study, the salivary buffering capacity and flow rate were not examined. However, the unstimulated salivary pH was analyzed after the 12-hour fast.

Salivary pH
The patients in this study exhibited a decrease in the mean salivary pH as the duration and GERD grade increased. In addition, the severity of tooth erosion increased as the GERD grade increased. The inorganic material of teeth starts to dissolve when saliva ceases to be saturated with calcium and phosphate. This takes place below the critical pH level, which has been defined as 5.5.11,22,26 Hence, the exposure to the acid found in GERD is a necessary condition to provoke dental erosion, whereas other factors could influence the evolution of the lesion.27

The data in the present study data were not in accordance with the study by Campisi et al, which showed that there was an increase in mean salivary pH (8.9) in the test group compared with the healthy controls, who had a mean salivary pH of 7.8.16

Mouth sores
As previously mentioned, the presence of mouth sores in this study was found to be statistically significant. In a cross-sectional study of 50 patients with GERD compared with 50 controls, Correa et al found that 21 of the GERD patients complained of frequent episodes of canker sores. The authors concluded that patients with GERD present with a higher incidence of canker sores.21

Myofascial pain
Tooth erosion predisposes the teeth to attrition and abrasion, leading to a tendency to fracture. This in turn causes a progressive loss in the vertical dimension of occlusion, impairing both chewing and phonetics.1,4,27 This cumulative damage to the masticatory system is indicated by a variety of symptoms, such as pain on mastication, loss of masticatory efficacy, and TMD, eventually predisposing the patient to myofascial pain.1 However, in the present study, none of the patients exhibited TMD or myofascial pain.

Summary
The overall observation of the present study reveals that tooth erosion is a significant clinical sign in GERD patients, which can be related to the reduction of salivary pH. Dry mouth, taste change, burning mouth sensation, mouth sores, tooth erosion, and tooth sensitivity are significant symptomatic manifestations of GERD, and the results of this study presented clinically significant incidences of these. The severity of tooth erosion increased as the GERD grade and the duration of GERD increased. This can be explained by the fact that as the GERD grade increases, salivary pH decreases, which in turn predisposes the teeth to erosion.

This study also explored the association between general and oral health, and provided valuable information regarding the effects of GERD on the oral cavity. It is critical that general dentists collaborate with the GERD patient’s gastroenterologist to identify the oral involvement of this disease. Dentists should also report any patient with unexplained tooth erosion to a gastroenterologist to investigate whether GERD is a factor. This interdependent rapport between dental and medical professionals will help to provide optimal oral and general health to the patient, thereby improving the patient’s quality of life.

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Prosthodontics/Removable

Use of a bite registration vinyl polysiloxane material to identify denture flange overextension and/or excessive border thickness in removable prosthodontics

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Vinyl polysiloxane (VPS) has multiple applications in prosthodontics. This article describes how a bite registration fast-set VPS material was used to identify length overextension and/or excessive border thickness of denture flanges. In addition, the advantages of VPS over conventional materials are presented.

Proper fitting is critical for the successful treatment of patients requiring removable prosthodontics. The clinician must evaluate the prosthesis critically to ensure that insertion and removal are comfortable and atraumatic. The postdelivery evaluation of a patient’s complete or partial denture might seem a fairly straightforward procedure since there are techniques used commonly to identify pressure areas. However, it actually is more complex, as it relies on many variables, including the dentist’s ability to discern normal tissue from mucosa that has been irritated by the prosthesis.1,2 When diagnosing the cause of a denture sore or irritation, a dentist must be aware of the anatomical variations among patients, each patient’s ability to tolerate the wearing of a denture, the patient’s comfort level with the daily use of a prosthesis, and the patient’s psychological profile. Common complaints associated with a newly fabricated prosthesis include pain with function, rubbing or chafing of sensitive areas, and cheek or lip biting.1,2

In the authors’ experience, the first step during an insertion appointment should involve evaluating and adjusting the tissue side of the new prosthesis. In areas with mucosal or bony undercuts, relieving the intaglio surface of the denture will prevent lacerating or even stripping the soft tissue that covers the underlying bone. Pressure areas left untreated beneath a removable prosthesis can result in extreme patient discomfort, diminished blood supply, and loss of bony support.

Once the prosthesis has a positive and stable seat, the next step is to evaluate the borders and determine if their extension is adequate and the contours accommodate to the available space in the vestibule. A properly formed denture border should be smooth, rounded, and well-adapted to the vestibule. A variety of disclosing media, such as commercially available pastes and waxes, aid the dentist in the delivery process. Overextended flanges can be evaluated by instructing the patient to make certain movements of the facial musculature with the disclosing media in place. Thin borders or overextended flanges can cause lesions in the mucosa.1,2 Common areas of irritation include hamular notches, posterior palatal tissue, and areas associated with the mylohyoid muscle. Denture borders that fall short of filling the vestibule are another source of concern. These shortened borders can interfere with the peripheral seal and affect retention, resulting in denture movement and instability, and eventually leading to mucosal soreness.1,2

An ill-fitting denture can affect retention, stability, and occlusion. Digital palpation of ridges and careful examination can help with proper diagnosis of this dilemma. Jankelson classified pressure areas into 3 parts: the peripheral border, the basal seat, and the intaglio surface.2 Any problem that affects any one of these zones will compromise the success of a new prosthesis. It is imperative that a clinician take the time to evaluate and make any necessary adjustments to a new prosthesis to maximize the fit and thus minimize tissue irritation.1,2

New dentures require scrutiny at the time of delivery since the fabrication process can contribute to minor changes on the intaglio surface. These changes can be caused by undetermined pressure during the final impression procedure, overextension of border molding, irregular or rough finishing on the denture intaglio surface, tooth shifting, and other distortions associated with the fabrication process of the denture acrylic.1,2

The final step in the insertion procedure is occlusal correction, which ideally involves doing a clinical remount.1,2 This procedure helps to identify occlusal discrepancies and allows the clinician to achieve occlusal harmony, resulting in a more comfortable prosthesis with improved function while preserving supporting structures.

Vinyl polysiloxane (VPS) is an addition-reaction silicone elastomer that has been used in dentistry since the 1970s.3 Over time, it has become a standard for replicating hard and soft tissues in great detail and has been used in teaching institutions, hospitals, and dental offices for the construction of fixed, removable, implant, and maxillofacial prosthodontics.3

The literature has covered the many uses of VPS, such as impressions and border molding.1,4 VPS also has been used for sealing access of implant screws, various aspects of maxillofacial prosthodontic procedures, capturing loose tissue in a nondistorted state, establishing bite registration in
fixed and removable prosthodontics, and a blockout material for extraction sites before relining immediate dentures.°9 Dentists also may use VPS to facilitate orientation of the maxilla in a facebow transfer, to determine occlusal clearance when preparing teeth for full coverage crowns, to place attachments in overdenture situations, and to function as a blockout material for clinical impressions.°9

This article describes the technique of applying bite registration fast-set VPS to the denture border at either delivery or the follow-up appointment in order to identify length overextension and/or excessive border thickness of the denture flange. This alternative material can improve and facilitate the adjustment process.

Traditionally, dentists have used a variety of commercially available pastes and waxes to evaluate pressure areas and denture borders at the time of insertion. The bite registration fast-set VPS technique described in this article has advantages over more conventional methods (such as pressure-indicating paste or disclosing waxes).°10,11 There is less chance of false positives or areas being easily removed by insertion. The use of bite registration fast-set VPS is more efficient since the material can usually be removed in one piece prior to adjustment. The need to clean wax or paste from a bur—which can be tedious and time-consuming—is virtually eliminated. Some clinicians may consider the fast-set VPS technique as an expensive alternative to the traditional routes of evaluating pressure areas and denture borders; however, some of the benefits of this technique—such as the more assertive modifications to the denture flange and less adjustment time involved in follow-up appointments—should be considered.

**Procedure**
The procedure is very simple. First, the area in question is dried, and a sufficient length of VPS bite registration material is expressed onto the denture flange (Fig. 1). Next, the denture is placed and seated, and the border molding is performed on that particular aspect of the prosthesis. After 15-30 seconds, the denture is removed and inspected. Any displaced material is considered overextension (Fig. 2). Since no adhesive has been applied, the area of show-through is marked with a pencil in case the material peels off during the adjustment (Fig. 3). This procedure is repeated until the denture borders have adequate length and thickness, so that no material is displaced from the borders when the denture is placed (Fig. 4).

**Discussion**
This technique is suggested as an adjunctive procedure for detecting overextended borders of complete dental prostheses. As stated previously, pressure-indicating pastes and/or disclosing waxes have been used for many years with excellent diagnostic results. Painting a paste on the
intaglio surface of a removable prosthesis generally identifies soft tissue lesions associated with denture irritation by displacing the paste from the denture base in areas of tissue contact. However, the formulas of indicating paste vary between manufacturers, and these variances can affect their rate of flow under pressure.¹²

Using a disclosing wax to determine flange overextension aids in visualizing affected vestibular tissue since the material is displaced from the border areas of contact with the tissue.¹³ These materials are inexpensive and can be applied easily to removable prostheses. However, false positives may be encountered upon insertion and/or removal; as a result, the material is dragged from the prosthesis base into areas of soft tissue or bone undercuts.¹³ In addition, the interpretation of pressure areas with complete dentures can vary among individual dentists, depending on their particular technique and level of experience. Phoenix & DeFreest noted that the viscosity of some commonly marketed disclosing waxes may not be adequate for effective evaluation of the peripheral border of a removable prosthesis.¹⁵

The authors have found bite registration fast-set VPS to be helpful when instructing predoctoral dental students and postdoctoral dental residents on troubleshooting post-insertion adjustments for patients wearing removable complete or partial dental prostheses. The bite registration fast-set VPS has a heavy consistency that allows it to remain in place on the prosthesis border during manipulation. At the same time, the material is soft enough to flow and allow for partial removal when found in areas of pressure to the tissue.

Many institutions use either modeling compound or heavy body VPS to teach border molding.¹⁴ Various materials and their effects on postinsertion adjustments have been evaluated in the literature.¹⁴,¹⁶ A 2003 study by Drago examined 78 edentulous patients who underwent border molding and determined that the number of denture adjustments was the same whether modeling compound or VPS was used.¹⁴ In the authors’ experience, only conventional methods for the identification of excessive border thickness or areas of overextension tend to be covered in dental schools. The common false-positive marks inherent in these methods may lead clinicians-in-training to spend additional time with insertion and postinsertion appointments. Recent studies have shown that the majority of dental schools utilize a selective pressure technique for edentulous final impressions using a border-molded custom impression tray.¹⁴,¹⁵ Some schools have proposed a mucostatic technique for their denture patients, which usually results in a comparatively shorter flange.¹⁵ However, in the authors’ experience, the bite registration fast-set VPS technique can identify overextended as well as underextended flange length. Depending on the symptoms associated with the particular flange dimension (whether over- or under-extended), procedures could be recommended to correct such a finding.

The authors have observed removable prosthetics with inadequate denture borders in some of their patients. Upon questioning, the patient often speaks of numerous follow-up appointments with his/her previous dentist, who had then adjusted the denture in the area where the patient felt soreness. These adjustments often are performed without a systematic and thorough examination of the patient’s edentulous arch or an adequate diagnosis to facilitate the proper course of treatment and consequently may or may not alleviate the soreness. A 1995 study by Yeoman & Beyak determined that areas of denture discomfort perceived by patients usually are not actually the part of the prosthesis that requires adjustment.¹⁶

It is imperative to polish the acrylic after altering the pressure area or flange on a denture base.¹⁷ Polishing restores the material to a much smoother surface, which provides a comfortable fit for the patient. Previous studies have mentioned that denture base material left in a roughened state is prone to bacterial accumulation and plaque formation.¹⁷,²¹ Pathogens that can colonize on the acrylic include Candida albicans and Streptococcus oralis. Chairside polishing kits or pumice on a wet rag wheel can restore the denture acrylic to a smooth surface, reducing the likelihood of bacterial adhesion.

After the first or second post-delivery appointment, the cause of tissue irritation usually can be traced to some minor malocclusion. Some clinicians favor a settling period for the dentures before refining the occlusion. However, the literature has shown that performing a clinical remount procedure at the time of delivery helps minimize mucosal soreness and reduce the frequency of return visits for adjustment.²²,²³ It is implicit that this procedure will require more clinical time at the insertion appointment; however, it also allows for accurate refinement of the occlusion and ensures fewer post-insertion appointments. Intraoral occlusal adjustments are not always reliable due to tissue resilience and denture shifting, which can lead to inaccurate markings on the teeth.

Regardless of the dentist’s methodology for providing a removable prosthetic service to a patient, utilizing a bite registration fast-set VPS material to evaluate flange shape and extension can be an additional diagnostic aid during the delivery and adjustment phase of removable prosthodontics.

Conclusion
The use of bite registration fast-set VPS is an alternative technique for identifying length overextension and/or excessive border thickness of denture flanges. As with other techniques, its use has advantages and disadvantages.

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Low-shrinkage composites: an in vitro evaluation of sealing ability after occlusal loading

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The objective of this in vitro study was to compare the microleakage of a flowable low-shrinkage-stress resin composite—in a Class II fatigue-loading design when used as a 4 mm dentin replacement—to a conventionally layered silorane-based resin composite. Eighty standardized 4 mm deep cavities, divided into 4 subgroups, were restored with the 2 tested materials. Half of the restorations were submitted to mechanical loading, and all of the restorations were prepared for microleakage evaluation. The evaluation of the marginal adaptation to dentin was performed with scanning electron microscopy. The results showed that both silorane-based composite groups had higher rates of microleakage in comparison to the low-shrinkage-stress resin composite groups.

Materials and methods
Eighty intact, noncarious, unrestored, human third molars, extracted for therapeutic reasons with the informed consent of the patients and with the approval of the Serra dos Orgaos University Ethics Committee (Teresopolis, Brazil), were stored in an aqueous solution of 0.5% chloramine T at 4°C for up to 30 days. The teeth were debrided of residual plaque and calculus and then examined under an optical microscope at 20X magnification to ensure that they were free of defects.

Eighty standardized Class II mesio-occlusal-distal cavity preparations 3 mm buccolingually, 4 mm occlusally, with the proximal margins located 1-2 mm below the cementoenamel junction (CEJ) were performed. The cavities were cut using coarse diamond burs under profuse water irrigation (No. 2143, KG Sorensen). The diamond burs were changed after every 3 preparations. In order to deliver results that would be comparable to previous studies, the inner angles of the cavities were rounded, and the margins were not beveled.

The teeth were divided into 2 groups, control (without occlusal loading) and test (with occlusal loading); each group was divided into 2 subgroups according to the material used: Filtek Silorane or SDR. Table 1 lists the materials used in this study and their manufacturers.
that 650 mW/cm² was constantly delivered of the light was checked periodically with Industria e Comercio S/A). The intensity with an LED light-curing unit (Olsen oil- and dust-free air jets for 2 seconds, and 15 seconds. The solvent was removed with of the primer was applied with a brush for enamel and 15 seconds on the dentin. The phosphoric acid for 30 seconds on the water at 37°C. samples were stored for 7 days in distilled water at 37°C. that the teeth were included in the PVC section were discarded. The 2 sectioned sections were made for mechanical loading as follows. The roots were coated with melted wax up to 2 mm below the CEJ. A polyvinyl chloride (PVC) cylindrical tube (Tigre S/A), 21 mm diameter x 25 mm length, was used to contain the teeth in autopolymerizing acrylic resin (Artigos Odontologicos Classico Ltda) up to the wax level (2 mm below the CEJ). A surveyor (Bio-Art Equipamentos Odontologicos Ltda.) was used to ensure that the teeth were included in the PVC tube with the cusps parallel to the base. Thus, the load coming from the test equipment (EMIC DL 500 MF; EMIC Equipamentos e Sistemas de Ensaios LTDA) was equally distributed among the cusps. The teeth were then removed from the acrylic resin, and the wax was substituted with silicone (Express XT, 3M ESPE). The excess silicone was removed with a Le Cron spatula up to the area previously marked as the fulcrum (2 mm below the CEJ). After preparation, the teeth underwent 4000 loads at 150 N with each load lasting 1 second, using a universal testing machine controlled with a software program (TESC version 1.08, EMIC Equipamentos e Sistemas de Ensaios LTDA).

Table 1. Materials used in the restorations, manufacturers, and chemical compositions.

<table>
<thead>
<tr>
<th>Group</th>
<th>Occlusal loading</th>
<th>Material (batch)</th>
<th>Manufacturer</th>
<th>Resin matrix</th>
<th>Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>Filtek Silorane (88H)</td>
<td>3M ESPE</td>
<td>3,4-Epoxy cyclohexylethylcyclopentymethyilsloxane, bis-3, 4-epoxy cyclohexylethylphenylmethyilsilane, yttrium fluoride (15%), camphorquinone, iodine salt, stabilizers, and pigments</td>
<td>Silanized quartz particles: 50% vol, 70% weight</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>DENTSPLY Caulk</td>
<td>Modified urethane dimethacrylate, triethylene glycol dimethacrylate, and ethoxylated bisphenol-A-dimethacrylate</td>
<td>Ba-Al-F-B-Si glass and St-Al-F-Si glass</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Surefil SDR Flow (100407)</td>
<td>DENTSPLY Caulk</td>
<td>Modified urethane dimethacrylate, triethylene glycol dimethacrylate, and ethoxylated bisphenol-A-dimethacrylate</td>
<td>Ba-Al-F-B-Si glass and St-Al-F-Si glass</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After cavity preparation, the teeth were cleaned with a low-speed handpiece for 30 seconds, using a fine powder of pumice in a rubber cup. An individual metallic matrix fixed by a matrix retainer was used to create the lost proximal wall. The teeth were then restored according to the restoration material used.

**Filtek Silorane (Groups 1 and 2)**
Cavities were conditioned with 37% phosphoric acid (3M ESPE) for 30 seconds, exclusively on the enamel, as indicated by the manufacturer. The surfaces were rinsed with distilled water for 30 seconds and gently dried with oil- and dust-free air for 2 seconds. Next, the Filtek Silorane Adhesive System was applied to the entire cavity, enamel, and dentin, according to the manufacturer’s instructions. A thin layer of the primer was applied with a brush for 15 seconds. The solvent was removed with oil- and dust-free air jets for 2 seconds, and the surface was light cured for 10 seconds. SDR was then placed in a single 3 mm increment using a bulk layering technique. The increment was light cured for 40 seconds. Then a 1 mm increment of Esthet X (DENTSPLY International) was placed to complete the cavity restoration and was light cured for 40 seconds. The 1 mm increment was contrary to the manufacturer’s 2 mm recommendation. After restoration, the samples were stored for 7 days in distilled water at 37°C.

**Surefil SDR Flow (Groups 3 and 4)**
The cavities were conditioned with 37% phosphoric acid for 30 seconds on the enamel and 15 seconds on the dentin. The surfaces were rinsed with distilled water for 30 seconds and then gently dried with oil- and dust-free air for 2 seconds. The XP Bond Adhesive System (DENTSPLY Caulk) was applied according to the manufacturer’s instructions. A thin layer of the product was applied with a brush and left undisturbed for 30 seconds. The solvent was removed with oil- and dust-free air for 2 seconds. An additional layer of the adhesive was applied and immediately dried, similar to the first layer, and the surface was light cured for 10 seconds. SDR was then placed in a single 3 mm increment using a bulk layering technique. The increment was light cured for 40 seconds. Then a 1 mm increment of Esthet X (DENTSPLY International) was placed to complete the cavity restoration and was light cured for 40 seconds. The 1 mm increment was contrary to the manufacturer’s 2 mm recommendation. After restoration, the samples were stored for 7 days in distilled water at 37°C.

**Microleakage evaluation**
All of the specimens were immersed in a 50% silver nitrate dyeing solution for 4 hours. The teeth were then longitudinally sectioned with a mesiodistal cut, using a low-speed diamond saw (KG Sorensen) under irrigation. As a follow-up procedure, 2 precalibrated examiners evaluated the tooth halves to evaluate the amount of dye microleakage using 40X magnification. The microleakage was scored using the following scale: 0, no leakage; 1, leakage up to the CEJ; 2, leakage beyond the CEJ without reaching the axial wall; and 3, leakage reaching the axial wall.

**SEM evaluation**
After 7 days, a transverse section was made 5 mm below the tooth/composite interface, using the diamond saw, and the roots of the sections were discarded. The 2 sectioned halves, formed of enamel, dentin, adhesive system, and resin composite, were hand polished on wet 600 grit silicon carbide paper (Saint-Gobain Abrasives) and then finished with a felt wheel placed in a Praxis...
polishing device. An alumina polishing paste with 0.5 µm particles (AP-Paste SQ, Struers, Inc.) was used until no grooves were observed at 50X magnification. The sections were then conditioned in distilled water.

After 7 days, 1 section of each previously formed pair was gently decalcified using 37% phosphoric acid for 10 seconds, rinsed with distilled water, and then deproteinized with 3% sodium hypochlorite for 60 seconds. The sections were rinsed with distilled water, placed on aluminum stubs, and sputter-coated with gold (Edwards Coater S150B, Edwards Limited).

The samples were then evaluated under an LEO 1450VP scanning electron microscope (Carl Zeiss Microscopy). Microphotographs of the hybrid layers were taken at 1000X magnification.

Results

Microleakage scores were evaluated using the Kruskal-Wallis test (95% significance level). There was a statistically significant difference between the groups ($H = 18.015$, with 3 degrees of freedom; $P = 0.000$). Score values were then treated by Dunn’s multiple comparisons test (95% significance level). The mean scores of each group are shown in Table 2.

The Dunn test showed that there was an important statistically significant difference between Groups 1 and 2 and between Groups 1 and 4. There was no statistically significant difference between groups 3 and 4. Thus, the final microleakage evaluation was Group 2 > Group 1 > Group 4 = Group 3.

When evaluated under SEM, the hybrid layer images in Group 4 were compatible with other study images and were considered of good quality. However, Group 2 presented images of bond failures and a lack of resin tag formation. Figures 1 and 2 are images of specimens from Groups 2 and 4, respectively.

Discussion

The objective of this study was to evaluate the sealing ability of 2 low-shrinkage composite restoration systems, before and after occlusal loading, using a microleakage test and an SEM evaluation. As shown in Table 2, greater microleakage scores were found in the samples restored with Filtek Silorane both with and without occlusal loading (Groups 2 and 1, respectively). Although the adhesive system of Filtek Silorane promotes good bond strength, nanoleakage remains a characteristic problem of this system. In a previous study, the Filtek Silorane adhesive system provided a tight, stable, and water-resistant adhesion to dentin. However, those same authors could not see resin tags in the hybrid layer formed by this adhesive system, as found in the present study and other studies. With regard to the SDR resin flow system, the results were satisfactory, showing low microleakage scores in the occlusal loading group (Group 4) and the absence of microleakage in the group without occlusal loading (Group 3) (Table 2). These results agree with those obtained in another study that revealed the adhesive effectiveness and marginal integrity for enamel and dentin when compared with 5 other restorative systems.

When evaluated with SEM, the hybrid layer was considered uniform and regular. These results are in accordance with the results of other authors, who stated that the combination of SDR with a final layer of conventional resin composite apparently showed no lack of adhesive performance in terms of marginal quality to enamel and dentin and presented with good internal dentin adaptation.

The Dunn test showed that the Filtek Silorane microleakage was statistically greater than the microleakage observed with the SDR. Therefore, there was a statistically significant difference between the 2 materials, even when analyzed after occlusal loading, meaning that the first null hypothesis was rejected. When the authors of this study evaluated the influence of occlusal loading in groups treated with the same composite, a statistically significant difference was found between the groups, indicating that the second null hypothesis was also rejected.

Table 2. Mean microleakage scores for the groups in this study.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean score</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2.26</td>
</tr>
<tr>
<td>2</td>
<td>2.97</td>
</tr>
<tr>
<td>3</td>
<td>1.20</td>
</tr>
<tr>
<td>4</td>
<td>1.43</td>
</tr>
</tbody>
</table>

Fig. 1. Absence of hybrid layer and resin tags in a specimen restored with the Filtek Silorane system with occlusal loading.

Fig. 2. Portion of the hybrid layer and resin tags in a specimen restored with Surefil SDR Flow and Esthet X with occlusal loading.

Table 2. Mean microleakage scores for the groups in this study.
interesting fact observed by the analysis of Table 2 is that the microleakage of Group 3, SDR Flow with occlusal loading, was significantly lower than that of Group 1, Filtek without loading, indicating that SDR Flow tends to be more resistant to this occlusal challenge than Filtek Silorane. The SDR was covered by a layer of regular RBC—as directed by the manufacturer’s instructions and also as depicted in other studies that determined that the manufacturers’ indication to finish a bulk-fill RBC restoration by adding a capping layer made of regular RBCs is a necessity, since the values of the indentation moduli and hardness of particular materials (such as SDR) were considerably below the mean values measured for regular nanohybrid and microhybrid RBCs. Therefore, there was no means of actually comparing the tested resins. In fact, the authors of this study compared the restorative techniques using the tested materials.

The authors of this study agree with the findings of other studies that asserted that—although clinical trials remain the gold standard in evaluating the performance of dental materials—clinicians must take into account the fact that individual products under investigation may not prove useful once clinical data are collected. This situation is exacerbated by the delay between the points at which clinical results are obtained and at which they are published in peer-reviewed journals. Thus, preclinical screening via laboratory tests is still an important tool for the evaluation of dentin adhesives, allowing for the evaluation of many experimental groups, unlike clinical studies, in which the number of variables must be kept small. However, real clinical practice in actual restorations and their respective evaluations are required for the final assessments of actual results. In the same manner, evaluations with other types of bulk-fill composites would be helpful to give a better baseline to compare new materials in order to evaluate if a new material is an actual improvement over older generations of materials.

Conclusion

Based on the results obtained in this study, the silorane-based composite Filtek Silorane has higher rates of microleakage, requiring verification of the effectiveness of the adhesive system indicated for use with this composite by the manufacturer. The best microleakage results were found with Surefil SDR Flow. However, randomized clinical trials are necessary to verify the clinical use of this new material.

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Manufacturers

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