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**Coming next issue**

**In the January/February issue of General Dentistry**
- p53 expression in oral lichenoid lesions and oral lichen planus
- Local anesthetic calculations: how to effectively treat pediatric patients
- Effect of imaging powders on the bond strength of resin cement

**In the November issue of AGD Impact**
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- Redefining Case Presentation

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Joao Carames, DMD, PhD
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Jeff Brucia, DDS
Dental Materials Update 2015
Johan Figueira, DDS
Communication Protocols with Photography
Edmond R. Hewlett, DDS
Lifelike Composites – It’s not Complicated
Brian P. LeSage, DDS, FAACD
CADCAM and Composite Layering
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Technical Diagnostic and Esthetic Approach
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Outcome-based Preparation Design

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Perry Klokkevold, DDS, MS, FACD
Interdisciplinary Implant Treatment in the Aesthetic Zone
Baldwin Marchack, DDS, MBA
Successful Implant Prosthetics: Avoiding Failures and Complications
Peter Moy, DMD
Guided Approach to Implant Dentistry: From work-up to Delivery
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Prosthodontics-related topics:
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California Implant Institute
The memories and relationships of a long professional career have their high and low points. Hopefully, we remember the former and let the latter fade with time. Our professional growth is attributed to the relationships we developed along our path toward wisdom. As Louis L’Amour wrote, “The best of all things is to learn. Money can be lost or stolen, health and strength may fail, but what you have committed to your mind is yours forever.”

It has been said that the largest room in the world is the room for improvement.

Nature has a beautiful way of illustrating the growth process. There is an inspirational story about how a Chinese bamboo tree seed is planted, watered, and fertilized, yet no growth is visible for the first 4 years. This all changes in the fifth year when the bamboo tree grows 90 feet in 6 weeks. The lesson from this story is that even though no growth is visible, the tree’s root system grew and flourished in the first 4 years, giving the tree a strong and sturdy base on which to grow. In many ways this story is a parable for dental school.

On our journey as dental professionals, character is determined by what we accomplish when the excitement of beginning a career is gone. We must maintain the energy to keep growing because our patients deserve nothing less. As B.C. Forbes stated, “It may be all right to be content with what you have, never with what you are.” It has also been said that of all the human resources, the most precious is the desire to improve. Most people want to improve themselves, but not too many are willing to pay the price to work at it.

We are all born with abilities, and we are given a number of opportunities to develop them. Life is like a game of cards. We dentists must accept the cards dealt to us, but once those cards are in our hands, we alone decide how to play them to win the game of life. We must decide whether to take a risk and act. Nothing in life provides more opportunities for growth than new experiences, and our lives have the power to touch other lives in either positive or negative ways.

Have you ever been “caught in the doldrums?” The doldrums near the equator abound with everything from thunderstorms to squalls to light variable winds. During sailing times, restless crews on ships often felt helpless waiting for the wind to blow. Sometimes as professionals, we may get caught in the doldrums. We wait for an external force to create change; if nothing presents itself, we may become dispirited and uninspired. Well, personal and professional growth does not suddenly manifest itself. We need to take a conscious step out of the doldrums in order to reach our goals.

David Jordan wrote, “Wisdom is knowing what to do next, skill is knowing how to do it, and virtue is doing it.” Claude Pepper observed that, “Life is like riding a bicycle; you don’t fall off unless you stop pedaling.” You have the potential in you to grow as a professional; you’ve just got to work to achieve it.

Roger D. Winland, DDS, MS, MAGD
Editor

Reference
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Questions? Contact the AGD at 888.AGD.DENT (888.243.3368) or education@agd.org.
Relevance in the 21st century

Happiness is something that happens when we chase success.
—August Bruguera

It’s an honor to be asked to contribute a few words to your publication. Both the Academy of General Dentistry (AGD) and the American Academy of Cosmetic Dentistry (AACD) are dedicated to lifelong learning, and they are really more alike than different. Here are a few thoughts on our 2 academies.

What is cosmetic dentistry? For years, dentists and the public have tried to pin down this definition. In my view, every restorative procedure that I perform has an esthetic component. From posterior composites to complete dentures, as restorative general dentists, my team and I pay close attention to “making it look real.” As form follows function, if it looks real, there is a good chance that it will function properly as well. One of my mentors said, 

Cosmetic dentistry ought to be just good, restorative dentistry.
—Larry Addleson, DDS, AACD

There are several similar associations that offer an advanced award based on an examination, yet there is no American Dental Association (ADA)-recognized specialty in Cosmetic Dentistry. The world has virtually shrunk as the information age has burgeoned, and cosmetic dentistry has become more mainstream. Any dentist with a license to practice can claim expertise in the art, but the AACD’s Accreditation award is thought to be the most valid of its kind in the industry (of course I would say that!). The AACD Accreditation program is based on 3 pillars: a written examination, anonymous submission of 5 clinical case types, and finally, an oral examination in which the candidate’s cases are defended before a group of 5 seasoned examiners. Advanced recognition of one’s skill is the AACD’s Accredited Fellow award, which requires the submission of 50 documented cosmetic cases.

As you know, the AGD has 2 recognition awards as well, and many AACD members have completed the AGD’s Fellowship examination and gone on to attain Mastership. The AGD’s examinations touch on all dental disciplines. In contrast, AACD Accreditation’s 5 clinical case types are specific to disciplines that relate to restoration of maxillary anterior teeth, and it incorporates elements of prosthodontics, orthodontics, photography, and surgery, as well as dental anatomy, physiology, and occlusion.

Cosmetic dentistry is a specific prosthodontic discipline, requiring… study and practice…
—Daniel Mayeda, DDS, AACD

Although the focus of the AACD may be more limited than that of the AGD, there are many parallels between the 2 organizations.

You’re likely to find the same speakers at both AGD and AACD conferences. In fact, the Executive Directors and Executive Committees of both organizations have met formally several times to discuss collaborative efforts. Both associations offer marvelous opportunities for quality Continuing Education (CE); both have virtual learning programs. The question is, how do we sell ourselves to our future members?

The trend toward virtual CE and inexpensive online courses has challenged the efforts of both academies to hold an annual “brick and mortar”-based event. And there is a multitude of course offerings on many subjects throughout the year. It’s a challenge to pick and choose the ones that offer the most bang for the buck.

What if we looked at the problem in the same way that our dental patients of today shop for dentistry? Today’s consumer is looking for value, asking about price, and searching for quality. It’s time to stress a value-based approach to membership, one that addresses the problems facing young dentists.

According to Marko Vujicic, Chief Economist and Vice President of the ADA’s Health Policy Institute, our profession is changing more and more rapidly. In a recent presentation to some of North America’s most respected clinicians and researchers, Dr. Vujicic said that 46% of dentists under the age of 35 are employees. This trend is not likely to level off, either.

In the face of staggering student loan debt (averaging more than $240,000 for 2013 graduates), it often makes sense for a new graduate to “get a job,” free of management headaches. So why not just get a job and go to work? Can you say, “paid vacation”?

There will always be a percentage of new dentists who “know that they don’t know” and who are willing to invest their time and hard-earned money to learn. For both organizations, this is the core of our target market for new members. What have you done to help your academy? Do you mentor, do you enthusiastically support its efforts, do you encourage other professionals to join?

Your academy is YOU, and you are an ambassador. For the health of our profession, help someone to grow as you have been helped. We’re all in this together!

James H. Hastings, DDS
President, American Academy of Cosmetic Dentistry

Acknowledgments
Mr. Bruguera is a renowned dental laboratory technician from Barcelona, Spain. Dr. Addleson is an Accredited Fellow and Past President of the AACD (2004-2005), who resides in Kahului, Hawaii. Dr. Mayeda is an Accredited Member and Past President of the AACD (1995-1996), who resides in San Diego, California.

References
Learn More About Advocacy Issues!

The AGD recently upgraded its online advocacy platform using CQ Roll Call’s (CQRC) Engage.

The site, www.cqrcengage.com/agd/home, provides information on the key issues impacting general dentistry today, including:

- Barriers to care
- Oral health literacy
- Student debt
- Midlevel providers
- Insurance coverage
- State dental boards

Also, you can visit the AGD Engage site to track legislative activity, read about the AGD’s most recent advocacy efforts, learn how you can advocate for general dentistry in your state, and more.

Visit www.cqrcengage.com/agd/home today!
The AGD Member Savings & Offers program works with various organizations to provide AGD members with special savings and exclusive offers on high-quality products and services, including insurance products, practice management services, and more. These savings and offers have been selected especially for you by the AGD Group Benefits Council and are exclusive to each category. The Group Benefits Council performs due diligence by vetting all companies included in this program. To learn more about available products and services, visit www.agd.org/savings.

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The AGD Member Savings & Offers program is subject to change without notice.
Perpetuating old myths

I read with dismay the column by Mr. Thomas Viola, “Co-administration of oral contraceptives and antibiotics used in dentistry,” in the May/June 2014 issue of General Dentistry. Mr. Viola is a pharmacist, not a pharmacologist. I question his expertise in advising dentists on prescribing, as he is neither qualified nor licensed to prescribe.

My 2012 continuing education course, “Pharmacological Aspects of Dental Practice,” through Daniel E. Becker, DDS, refutes the concerns raised in this article. We have enough issues to deal with as practitioners that we do not need these old myths to be perpetuated in your journal.

Robert D. Frey, DDS, MAGD
Swanton, OH
(with enclosures)

Response from Mr. Viola

I read with equal dismay the respondent’s critique of my column in the May/June issue of General Dentistry. A fair examination of the respondent’s comments leads me to question his acumen in evaluating the information as presented in such clinical literature without reader bias.

The respondent’s concern stems from his contention that my article “perpetuates old myths” and that these “myths” were refuted by Dr. Daniel Becker’s work in his 2012 text “Pharmacological Aspects of Dental Practice.” The respondent highlighted a section which states “To date, rifampin (an antituberculosis agent) is the only antibiotic having a confirmed interaction with oral contraceptives” and “To date, all human studies measuring the influence of antibiotics on estrogen and progesterin serum concentrations have found no interaction with antibiotics other than rifampin.” With all due respect to Dr. Becker and his work, while the text of antibiotics and oral contraceptives concomitantly and who may be intolerant of any risk of contraceptive failure,” let me remind him that my role in authoring these articles is not to advise dentists on how to prescribe, but to merely present the information as discovered through my research of the applicable clinical literature. Once again, I must question the respondent’s acumen in evaluating the information as presented without reader bias.

I take issue with the respondent’s statement that, as a pharmacist, I have “questionable” expertise in advising dentists, since I am not “qualified nor licensed to prescribe” myself. To make such a statement clearly undervalues and disqualifies the valuable and life-saving work performed every day by pharmacists in monitoring drug therapy, evaluating clinical drug literature, performing drug utilization reviews for interactions and contraindications, and, yes, even advising prescribers when clinical interventions are necessary, even though pharmacists are not licensed to prescribe.

In conclusion, let me state that it appears the respondent’s intention was to imply that if I were a “pharmacologist,” I might finally possess the necessary qualifications to advise dentists on prescribing. If this is the case, I find it necessary to inform the respondent that pharmacologists, on the basis of that credential only, are also not licensed to prescribe, unless, of course, they possess some other credential that entitles them to prescriptive authority in their jurisdiction.

References

Only informed patients can decide what serves them best

Mark Malterud, DDS, MAGD

Minimally invasive biomimetic dentistry (MIBD) can cover the gamut of the dental spectrum. When we review how to best care for a patient, we need to pay close attention to what is desired by the patient and then come up with a treatment plan that will satisfy their desires without compromising our values or ethics in the delivery of care. Educating the patient about the process, procedures, outcomes, and long-term effects of their decisions is the least we can do to help them decide. The following case documents the presenting wishes of a patient and the minimally invasive options that were delivered to satisfy her desire for a nicer smile.

A 27-year-old woman contacted our office upon referral from a friend, who indicated that our office could help with the patient’s smile. The patient was very concerned about the discoloration of and spaces between her teeth, both of which created what she considered to be a less than ideal smile. She wanted to have a consultation to begin the process of having veneers created by our office. She informed us that she had been saving for a while and wanted to have a smile of which she could be proud.

A consultation was scheduled for the patient, along with a review of her records to help determine the best treatment. During the consultation, the patient indicated that she disliked the color of her teeth and the white spots on them, as well as the space between her front maxillary incisors. Her desire was a quick fix of veneers on her 6 front maxillary teeth. During the consultation, she also indicated concerns about her overall health and that she really didn’t want to have her teeth prepared in any particular way, but was unaware of any other options to meet her esthetic needs.

As is evident in her initial photo, the patient’s concerns were valid as she had discolored teeth and an obvious diastema between teeth No. 8 and 9 (Fig. 1). The white spot lesions seemed to indicate fluorosis during the development of the teeth. There were no other restorative needs noted as the patient had just finished her semiannual exam and hygiene appointment; at that point, small lesions on teeth No. 12 and 13 were diagnosed and fillings were completed. The occlusal view of the maxillary arch shows that there was some wear and tear of the posterior teeth as well as restorations on teeth No. 12 and 13 (Fig. 2). Some erosion was noted on the occlusal surfaces of the posterior teeth, so a discussion of habits and health was initiated and the patient disclosed that she frequently drank carbonated soft drinks. A frank discussion ensued about the effects of home care, diet, and oral habits on restorations or any dental treatments we might provide. Upon further discussion, the patient indicated that since childhood, she had frequent medically diagnosed migraines for which she was taking “breakthrough” medications. As shown in Figure 3, her posterior occlusion was well-aligned, and areas on the buccals of the molars indicated where the caries process had likely began. Those areas now showed hard, glassy, smooth, stained remineralization.

Multiple treatment options were presented, but they all began with utilizing an anterior midpoint splint to evaluate the muscle activity and determine whether the years of migraines could have been caused by parafunctional habits, such as primary clenching. Once we determined the efficacy of splint therapy, we could then proceed with other aspects of the patient’s care.
With a focus on minimally invasive dentistry, the following treatment options were presented to the patient:

- The first treatment option would begin with diagnostic splint therapy, followed by teeth whitening, orthodontics to reduce the deep bite, closing of the diastema, then straightening the upper and lower teeth. With clear aligner therapy proposed, it was estimated that the treatment would be finished in <1 year, and she would not need to have any restorative work done on her teeth unless the tooth whitening didn’t blend the white spot lesions in well enough to accomplish her esthetic desires.

- An alternative option involved splint therapy, teeth whitening, and then closing the diastema with bonded resin restorations utilizing virtually no preparations; this would take mere weeks to accomplish.

- A third option—the one the patient initially requested—was to veneer the teeth.

We suggested starting with splint therapy, followed by whitening to try to keep the veneers to a minimum number of teeth and to match the color of the lower anteriors to her upper veneers. This treatment would be completed in <2 months, depending on the success of the whitening process.

Once presented with these options, it was reiterated to the patient that each treatment would begin with diagnostic splint therapy followed by a whitening process; at that point, she could make a final decision as to how she wanted to proceed once the whitening effects became evident.

After accepting the initial part of her treatment plan, the patient had impressions taken to fabricate her anterior midpoint stop splints and to fabricate whitening trays that would be used for at-home bleaching after the in-office whitening treatment. An initial shade was taken to use as a baseline to determine the efficiency of both whitening processes (Fig. 4). After the in-office whitening, the patient followed up with home trays for use with a 15% whitening solution for 2 hours/day for an estimated 2 weeks. The immediate results of the in-office whitening were quite dramatic (Fig. 5). However, some regression of the shade shift is a reality, so the follow-up trays for home use were used to complete the whitening process.

Once the patient saw how well the whitening process worked, we sat down to discuss the subsequent treatment alternatives and costs. It became apparent to the patient that, for her personal goals, the treatment involving orthodontics was an excellent and cost-effective option to align her teeth, close the space between her 2 front teeth, and reduce her deep bite.

Orthodontic records were taken and a very detailed vinyl polysiloxane (VPS) impression was taken to submit for digitization to Align Technology, Inc. for their computer-generated ClinCheck, which allowed the patient to visualize the stages of movement that were proposed for her care. The ClinCheck was returned in <2 weeks, and the patient presented for her final decision on which treatment she would choose. After seeing how her teeth were aligned in the final trays of the aligner treatment she decided to pursue the treatment with clear aligner therapy. Her treatment progressed with only a minor midcourse correction due to the bell shape of her natural teeth, which didn’t allow the mesioincisal contacts between teeth number No. 8 and 9 to contact far enough gingivally to keep from potentially...
creating a midline black triangle or interproximal gingival void (Fig. 6). Therefore, teeth No. 8 and 9 were treated with a very mild enameloplasty to reshape them in an effort to move the contact closer to the crest of the bone between them, to allow a full fill of soft tissue. A new VPS impression was taken and the final aligners were created to take the case to its final position. The final alignment satisfied the patient’s desire for closure of the gap between her 2 front teeth, along with reducing the deep bite that was present at the start (Fig. 7). Following a minimally invasive philosophy, this treatment created a beautiful smile that the patient can enjoy for a lifetime. To keep the smile stable will require retainers, and in this case—the patient being a migraine sufferer—the retainers were in the form of custom-fabricated anterior midpoint stop splints that were worn only at night (Fig. 8). These splints not only retained the teeth in their proper positions and prevent the wear and tear of her parafunctional activity, but they also reduced both the frequency and intensity of her migrainous episodes.

MIBD is often considered as dentists diagnose and treat tiny lesions with small preparations or save as much tooth structure as possible while restoring teeth back to their full form, function, and esthetics; but it goes much deeper than that. Often when following a MIBD approach, treatment can be completed in a way that requires little or no restorative care. This case is an illustration of what can be accomplished without destroying large amounts of tooth structure and consequently setting the patient up for a lifetime of maintenance and re-restorations. If the patient in this case had received her desired 6 veneers across her front top teeth, she might have embarked upon a lifetime of repair and replacement of these veneers. With the patient being 27 years old, there are many years of wear and tear that will occur on even her natural teeth. Hopefully the chosen course of treatment will allow her to enjoy her own teeth for years to come; and we know that should she have any issues, there are many options that will allow us to bring each individual damaged tooth back to full form, function, and esthetics with minimal treatment.

As dentistry moves forward, there will always be better materials, equipment, and techniques developing that will allow us to restore teeth more conservatively and predictably. A well-informed patient is the only person that can make the proper decision as to what is best for their given situation and desires. Educating them on the long-term consequences and outcomes of their choices in treatment is our duty as dentists.

**Author information**
Dr. Malterud is in private general practice in St. Paul, Minnesota. He has practiced some form of MIBD for over 30 years and has been lecturing and publishing on MIBD for more than 18 years.

**Manufacturer**
Align Technology, Inc., San Jose, CA 408.470.1000, www.aligntech.com
Local anesthesia for restorative dentistry

Roger A. Solow, DDS

Dentists must be proficient in multiple routes of local anesthetic (LA) administration so that profound anesthesia can be achieved in a variety of clinical situations. LA for intraoral procedures consists of either nerve blocks that place the anesthetic at the nerve trunk, or infiltration where the anesthetic is placed near the nerve terminus at the root apex. Nerve blocks provide the most intense and longest anesthesia; however, they are more technique-sensitive and incur the risk of direct needle damage, intravascular placement, muscle trismus, hematoma, and delayed onset.

The choice of the type of anesthetic depends on several factors: level and duration of anesthesia desired, tooth site, pulp or soft tissue infection, and the patient’s physical and emotional status. LA for the restorative treatment of healthy, asymptomatic teeth may not demand the same level or duration as other procedures, such as endodontic treatment of painful teeth. This article presents the author’s rationale for LA selection with adult restorative dentistry.

Routes of anesthesia
Maxillary teeth are covered by porous facial bone that is <1 mm thick at the root apices. These teeth can be predictably anesthetized by buccal infiltration (BI) without the risk of injury from a posterior superior alveolar nerve block if the needle is placed too distal into the vascular plexus. Additionally, 28% of patients have the first molar mesiobuccal root innervated by the middle superior alveolar nerve, thus requiring separate infiltration after the nerve block.

Mandibular anterior teeth and bicuspids can be similarly anesthetized with BI. Thicker buccal cortical bone is the main reason that conventional inferior alveolar nerve blocks (IANB) are used for mandibular molar LA. However, Robertson et al and Jung et al found that BI at the mandibular first molar was faster and more successful than IANB. El-Kholey reported a 93% success rate using BI at the first molar to remove impacted third molars. BI avoids the failures of IANB that may be related to a broad sphenomandibular ligament medial to the mandibular foramen, accessory innervation, retromolar foramina, or rare bifid mandibular nerves.

Four percent articaine with epinephrine 1:100,000 (A100) is the most diffusible LA and has been shown to be superior to 2% lidocaine with epinephrine 1:100,000 for BI alone, as well as a supplement to IANB. Robertson et al and Jung et al found that BI at the mandibular first molar was faster and more successful than IANB. El-Kholey reported a 93% success rate using BI at the first molar to remove impacted third molars. BI avoids the failures of IANB that may be related to a broad sphenomandibular ligament medial to the mandibular foramen, accessory innervation, retromolar foramina, or rare bifid mandibular nerves.

Four percent articaine with epinephrine 1:100,000 (A100) is the most diffusible LA and has been shown to be superior to 2% lidocaine with epinephrine 1:100,000 for BI alone, as well as a supplement to IANB. Meechan et al demonstrated that BI is much more effective than lingual infiltration for mandibular teeth. Meechan attributed the effects of mandibular BI to anesthetic diffusion through the mental foramen as a type of mental/incisive nerve block. Patients in studies using 27- and 30-gauge needles for BI were unable to sense a difference. BI is placed in loose tissue with no large vessels present, and the rate of positive aspiration is negligible. Delgado-Molina et al found no difference in positive aspiration between 27- and 30-gauge needles during IANB. Thirty-gauge needles penetrate the mucosa more easily than 27-gauge and slow the flow of anesthetic, which is important for comfort; however, both 27- and 30-gauge needles are acceptable for BI.

The BI of 1 carpule A100 is typically successful for all maxillary and mandibular anterior teeth or premolars. A BI of 1.5-2 carpules A100 is appropriate for mandibular molars at the first molar site. If the anesthesia is deemed not sufficient (usually when a mandibular molar is involved), then additional BI can be given or
alternate routes can be used: periodontal ligament (PDL), crestal, conventional IANB, or a higher nerve block (such as Gow-Gates or Vazirani-Akinosi). Lingual infiltration of A100 at the mandibular molar has not been shown to be effective.23

**Technique**

First, determine if LA is needed. Many minimally invasive restorations on older patients can be done with a light touch, new bur, and water spray. If the dentin is sensitive to a sharp explorer, then LA is indicated. There are some patients who seldom require LA. If LA is needed, dry the mucosa and place a 20% benzocaine topical gel for 2 minutes. Stretch the mucosa fully and rapidly penetrate the surface at the depth of the vestibule with a 30-gauge extrashort needle so only the bevel is submerged. Topical anesthesia extends several millimeters subsurface, so this critical step is typically painless. Express a single drop of A100 so that the membrane forms a bleb and wait 10 seconds without moving.24 Repeat this step with another drop. Advance the needle several millimeters apically staying within the anesthetized bleb, aspirate, and express the rest of the carpule over 1 minute. Stop at any time that the patient has any discomfort. Proper placement of the needle approximates the root apex, and the A100 is highly diffusible, so little advancement is needed (Fig. 1). Allow 5 minutes of absorption time before the procedure. If soft tissue anesthesia is needed on the lingual or palatal surface, sequentially introduce A100 in the interdental papilla and then the lingual or palatal. Allow enough time so that each injection occurs into tissue that is already anesthetized, as evidenced by blanching. In most cases, 60-75 minutes of pulpal anesthesia allows most restorative procedures to be performed.2

Multiple teeth can be anesthetized sequentially instead of using IANB. The author prefers a 30-gauge extra-short needle because it is less unwieldy than a long needle, which may inadvertently touch the lip or tongue. The extra-short needle can also be used for PDL or crestal anesthesia, if needed, without switching needles. Computerized delivery and vibration devices are effective but not required, as patients often volunteer that they “didn’t feel the injection at all” with this slow approach.2,25

Both PDL and crestal injections place a small amount of anesthetic (0.2 ml) in a confined space so that it is forced through the small foramina of the nutrient canals in the crest and cribiform plate of the alveolus (Fig. 2). The path of anesthetic is not through the PDL to the apical nerve terminus; it travels through the marrow spaces.26 These are highly effective injections without the need for perforation of the cortical bone with an intraosseous injection. Proper placement of the needle to obtain resistance during injection is a prerequisite for success.27,28 For the PDL injection, the needle is vertically aligned with the long axis of the tooth and advanced with the bevel toward the root until resistance is felt (Fig. 3 and 4). In cases of crestal anesthesia, the needle is placed at 45 degrees to the bone crest and advanced until the interproximal bone crest is felt (Fig. 5).
Giffin defined crestal anesthesia as a subperiosteal injection where the needle is adjacent to bone.29 Malamed described intraosseal anesthesia as similar, but the needle is advanced 1-2 mm into bone.3 Kaemmerer et al found that injection of anesthetic into the soft tissue papilla remained in the soft tissue and was inferior to PDL injection for pulpal anesthesia.40 Malamed reported 100% success with PDL injection for tooth extraction and periodontal procedures, and 88% success for restorative procedures using a conventional syringe.27 Giffin reported a 99% success for periodontal procedures, and 88% success for restorative treatments of each patient and procedure.

“Currently, dentists have a variety of materials and routes for predictable LA that can match the requirements of each patient and procedure.”

**Author information**

Dr. Solow is in private practice in Mill Valley, California, and a member of the visiting faculty at the Pankey Institute, Key Biscayne, Florida.

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Clinicians are faced with esthetic dental problems every day. Broken ceramic restorations in the anterior region are a common problem that can occur in general practice. Presently, many porcelain restorations are used to restore the human dentition. Many tooth-colored restorations have been placed over the last 20 years, whether they be porcelain-fused-to-gold (PFG), feldspathic porcelain, porcelain (aluminous) jacket crowns, lithium disilicate or zirconia-based ceramic restorations. Therefore, it would be prudent to realize that many of these restorations will need to be replaced in the years ahead. Further, it is important to have an understanding of how to predictably replace these tooth-colored restorations so that optimal blending of the new restorations can be attained.

For cases in which there is recurrent decay under an existing ceramic restoration, or the majority of the porcelain is broken and the remaining porcelain restoration is compromised, a full replacement of the porcelain restoration should be considered (Fig. 1). Replacing a single porcelain restoration can be more difficult than repairing it with a conservative composite resin.1,2 Therefore, careful assessment should be taken before considering replacement of a ceramic restoration. However, if a new porcelain restoration is determined to be necessary, there are several important factors that need to be considered.

Porcelains from different manufacturers have subtle characteristics that make them unique in appearance, so it is important to know the type of porcelain restoration you are replacing.3 For instance, PFG restorations will appear more opaque than lithium disilicate restorations due to the masking that needs to be done over the metal base of the PFG. By conveying this information to your lab you have an optimal chance of getting the best match and increased success the first time around. If you’re not sure, at the very least take preoperative photos of the tooth being restored—as well as the adjacent teeth—using shade tabs with the closest colors to the failing porcelain restoration and the adjacent teeth you are trying to mimic (Fig. 2). The author has found the Vita 3-D MASTER guide (Vident) to be the easiest to match most tooth shades. Sending photos will give your dental laboratory the best chance to analyze the shades needed to match the area being restored.

Whether color matching to a natural adjacent tooth or blending the new restoration to existing porcelain restorations, proper shade selection must be approached first.4 Through a series of high-resolution photos, the hue, value, and chroma of the restoration are conveyed to the ceramist. Be sure to use a camera that takes at least 2 MB digital files so the lab can fully assess the shades needed to be mimicked. The author uses a Canon 60D camera body with a macro-lens and dual source flash (Canon USA, Inc.).

During removal of the existing restoration, ceramic pieces should be carefully removed, saved, and submitted to the laboratory for shade analysis along with the case (Fig. 3). Having an experienced dental technician is important so that the right color blend, as well as the correct size, contour, and characterization, can be attained in the new restoration.5

If the restoration is a bonded ceramic such as a lithium disilicate- or feldspathic-type restoration, it is also important to include a photo of the prepped tooth with an internal stumpf shade (Fig. 4). With these types of porcelain restorations, the chromacity of the internal dentin shade can influence the final external
shade (Fig. 5). Submitting all this information along with the final impression and a detailed lab prescription can lead to predictable and consistent success with porcelain replacement restorations.6

Case report
A 56-year-old woman presented with an extensive fracture in her existing porcelain restoration on her left central incisor (Fig. 6). The porcelain restoration was a feldspathic porcelain veneer. First, by using a shade guide, the best shades were selected to match the existing restoration and the surrounding teeth. Digital preoperative photos were taken of the area being restored. Additional photos were taken with matching shade tabs against the teeth (Fig. 7).

During treatment, the remaining broken porcelain pieces were removed and sent to the lab. Although larger porcelain pieces are desired, even small porcelain pieces are helpful when trying to match variations of color, value, and incisal characteristics.

After the tooth preparation was complete, photos of internal shades were taken with reference stump shade tabs. All of these were submitted along with a detailed prescription and a color map.

After receiving the new porcelain restoration from the lab, the color was checked on the prepared tooth with water (glycerin may be used, as well). A visual inspection is important prior to final placement to ensure the external shade matches the surrounding dentition. Using this method, it is the author’s experience that 95% of the time, no modifications are needed to adjust for color. The final bonding of the porcelain restoration was accomplished using a total-etch technique.7 After etching with 37% phosphoric acid (Etch-37 Semi Gel w/BAC, Bisco, Inc.), a dental adhesive (ALL-BOND 3, Bisco, Inc.) and a light-cure luting resin (Choice 2, Bisco, Inc.) was used to bond the porcelain restoration. Next, the restoration was finished with a series of fine finishing diamond burs (Porcelain Finishing Kit, Komet USA, LLC) and polishers (Intraoral Diamond Polishing Kit, Komet USA, LLC). Finally, a micro-diamond polishing paste (Ultradent Products, Inc.) was used to give a final polish (Fig. 8).

Conclusion
There are many different types of porcelain restorations that have been placed throughout the last several decades. In the years to come, many of these existing porcelain restorations will need to be replaced. In order to attain the best esthetic outcomes, a methodical approach to treatment is important. Predictable clinical results can be achieved using the method of porcelain replacement treatment described in this case report.
Author information
Dr. Okuda is an international speaker on the topic of cosmetic and restorative dentistry and the founder of the Okuda Educational Institute for Innovative Dentistry in Honolulu, Hawaii, where he also has a private practice.

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Manufacturers
Bisco, Inc., Schaumburg, IL
800.247.3368, www.bisco.com
Canon USA, Inc., Melville, NY
631.330.5000, www.usa.cannon.com
Komet USA, LLC, Rock Hill, SC
888.566.3887, www.kometusa.com
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888.230.1420, www.ultradent.com
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800.828.3839, www.vident.com

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Well, it's that time of year again for gifts. We exchange them with just about everyone we know: family, friends, staff, colleagues, and business associates. It is rare that we exchange gifts with patients; however, it is quite common for patients to bring gifts to the dental office for the doctor and staff.

There are some ethical considerations to explore regarding the acceptance of gifts from patients. The following case will examine these.

Ava enjoys her visits to her dentist, Dr. Oliver. He is kind, considerate, and very gentle. Ava is one of those "unlucky" dental patients. Despite pretty good oral hygiene, something always seems to go wrong with her oral health. When she was 12, she fell off her bike and fractured her 2 maxillary central incisors and some other teeth. This led to numerous dental problems. Bonding, root canals, crowns, and veneers have all been performed on various teeth at appropriate times over the years by Dr. Oliver. Now it seems there is another problem brewing—resorption. Ava doesn't exactly know which dental treatments will be required in the future, but Dr. Oliver has told her that it will not be a simple fix. They will continue to monitor the teeth over time and intervene as needed. Dr. Oliver warned Ava that she may eventually lose her 2 front teeth.

When Ava looks back on her dental history, she cannot recall how many times she had to visit Dr. Oliver on an emergency basis for issues related to the teeth affected by her accident. She is grateful for every time Dr. Oliver was able to “squeeze her in” to his busy schedule. Fortunately, Ava has always had the financial resources to be able to pay for her treatment. First her parents’ insurance covered costs; now that she is older with a good job, she is able to pay for her own treatment.

Last November, a new problem occurred. Ava developed a large popcorn kernel sheath was lodged in the gingival sulcus adjacent to tooth No. 3 on the lingual side, and the area had a small abscess. Dr. Oliver removed the kernel easily with an instrument, drained the abscess, and ensured Ava she should be fine in 1-2 days. Ava was not only embarrassed but upset with herself for asking Dr. Oliver to come in on a holiday for something so trivial. She paid her bill, and as she left the office, she decided she for asking Dr. Oliver to come in on a holiday for something so trivial. She paid her bill, and as she left the office, she decided she didn't want to insult Ava by not accepting it, as she was a long-standing patient and hopefully would be for years to come.

What should Dr. Oliver do?

Dr. Oliver is faced with a dilemma that forces him to decide whether to accept the gift from Ava or not, and to consider the following questions:

• How does the acceptance or denial of gifts from patients affect the dentist-patient relationship?
• Should dentists accept gifts from patients at all?
• If so, what level of gift acceptance from patients is appropriate?
• Should a monetary limit be placed on gifts from patients?
• What level of gift acceptance from patients is appropriate?

The giving and receiving of gifts is a cultural phenomenon. It can also be a very emotionally charged experience on both ends. When someone doesn’t like or appreciate a gift we give, particularly when a lot of thought and effort went into its selection, we may become offended. Conversely, when we receive a gift we really don't want, it is just as difficult to deal with. We don't want to hurt the giver’s feelings and appear disappointed, yet we don't want to keep the gift, and fear the giver may find out if we return it to the store or give it to someone else. How much money was spent on a gift or how much work went into making it adds another layer of complexity to the situation. In a strictly social context, these circumstances are awkward and difficult enough to deal with. Adding to it the element of patient care in a clinical setting makes it a much more challenging problem.

In this particular scenario, we cannot look directly to the American Dental Association Principles of Ethics and Code of Professional Conduct (ADA Code) for specific guidance. The Code does not offer a specific advisory opinion on this topic. However, under the principle of Nonmalificence (Section 2.G), the ADA Code does address personal relationships with patients. Although not directly addressing the exchange of gifts with patients, the Code does require dentists to avoid any relationships with patients that may “impair their professional judgment.” The acceptance of a gift, depending on what it is and the dentist’s perceived value of the gift, as well as the patient's motivation for giving it, may have the potential to alter the professional relationship.
Dentists are also obligated under the ADA Code to be nondiscriminatory in the selection of patients; therefore, most dental offices will probably see patients from many different ethnic and cultural backgrounds. Gift giving and receiving in some cultures is a very common and meaningful occurrence. When presented with gifts, dentists need to balance cultural sensitivity with maintaining professional boundaries.

In the context of the dentist-patient relationship, Ozar & Sokol advocate an interactive model, in which the relationship is one of equality, mutual respect, and shared decision making. This model implies that while the dentist has the expertise in the science of dentistry and the provision of care, the patient's values, autonomy, and goals are equally important. If the giving of gifts is significantly important to a particular patient, the dentist may need to consider how the acceptance or refusal of a gift will affect the relationship with that patient before making a decision about the gift. How the dentist can ascertain that poses another challenge.

The medical profession has dealt with this question specifically in the Code of Medical Ethics of the American Medical Association (AMA Code). Under Section 10.017, Gifts from Patients, there is a statement on how physicians must balance cultural sensitivity with professional obligations. It states that in cases of gifts given in gratitude or as part of a cultural tradition, the doctor-patient relationship may actually be enhanced. Physicians must be cognizant, however, of patients giving gifts with the expectation that they will receive preferential care. This is problematic and could also occur in dentistry. The seeking of preferential care in exchange for a gift could damage the integrity of the relationship and potentially compromise the ethics of both parties.

The AMA Code does not offer any specific guidance, however, with regards to the appropriate cash value of gifts or exactly when it's appropriate to accept gifts, except that "the gift's value relative to the patient's or physician's means should not be disproportionately large." One criterion suggested is that "the physician should determine individually if he/she would be comfortable disclosing acceptance of the gift to colleagues or the public." Dentistry may benefit from approaching the subject of patients giving gifts in a similar manner.

The reality of accepting gifts from patients is that it does change the nature of the relationship whether it happens consciously or not. When a dentist accepts a gift, especially a substantial one, the dynamics of the relationship may shift. Going forward, the dentist may treat the patient differently than other patients. For instance, when the waiting room is full, and the dentist is running behind schedule, how might he treat the gift giver differently than other patients also waiting to be seen? Dentists should be cognizant of the potential for bias or favoritism in such cases. On a different note, by offering a gift, the patient may not necessarily be looking for preferential treatment but might instead be hopeful that the relationship may become more social. Relationship boundary violations could potentially occur as a result.

Andereck states there are 3 possible motives for patients to offer gifts to their doctors: influence, pure beneficence, and appreciation. Since there is no real way to know the intent of the patient presenting the gift, paying attention to previous or subsequent behavior may help. The author also states that some people are just "generous by nature" and advocates for the acceptance of gifts as long as "the patient's motives seem well placed."

Resolution
Dr. Oliver must weigh all of these issues and make a decision as to whether to accept the gift from Ava or not. Since there are few ethical guidelines governing this topic and there was no breach of the law, common sense should prevail. If Dr. Oliver examines this quandary closely, he will find that:

- Ava's intentions appear sincere. She is grateful for the years of care Dr. Oliver has provided to her and is especially thankful it's available for her last Thanksgiving. There is no history of challenges to their dentist-patient relationship.
- The gift was something Ava could afford. It was not disproportionately expensive relative to her or Dr. Oliver's salaries and life circumstances.
- Dr. Oliver feels that rejecting the gift may hurt Ava's feelings.
- Dr. Oliver would not be embarrassed to tell his colleagues, family, or staff about the gift.

All things considered, Dr. Oliver should accept the gift and thank Ava for her kindness. According to Krupa:

"Gifts are cherished keepsakes that help remind doctors why they went into medicine in the first place—for the connections they have with patients. In most cases, gifts are wonderful ways of showing appreciation. In a very human way, it is the way we express gratitude."

Author information
Dr. Roucka is a fellow of the American College of Dentists, president of the American Society for Dental Ethics, and has an MA in Bioethics from the Medical College of Wisconsin. She is currently the associate dean for Academic Affairs at Southern Illinois University School of Dental Medicine, Carbondale.

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Conservative cosmetic dentistry post-trauma

Nicholas Marongiu, DDS  •  Todd Cochran, AAACD

Traumatized teeth can bleed internally, causing discoloration over time. When this occurs in the smile zone, masking the dark colorations can present challenges when attempting to practice conservative cosmetic dentistry. Implementing nonvital bleaching can significantly improve the dark colorations of the traumatized teeth and support very conservative cosmetic dentistry. Effective communication with the ceramist is essential to ensure the desired results. This article presents a case involving trauma with delayed root canal therapy on tooth No. 9, which produced a very dark front tooth, and the conservative treatment plan chosen to correct it through the use of nonvital bleaching and feldspathic veneers requiring zero or minimal preparation.

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Treatment of only 1 or 2 teeth in the smile zone can present cosmetic challenges in blending with the natural dentition.1 When treating traumatized dark teeth, the balance between cosmetics and practicing conservative dentistry amplifies these challenges. Historically, dark teeth have been aggressively prepared to allow for restorative materials to block out the dark color. This article will present a case with nonvital bleaching and the fabrication of feldspathic veneers requiring zero or minimal preparation in order to conserve as much healthy tooth structure as possible while producing an excellent cosmetic result.

Case study
A 20-year-old woman presented with a single dark upper front tooth (Fig. 1). She reported that the tooth (No. 9) had been fractured after a fall at age 10 while playing softball. Over the following 10 years, she reported having the tooth filled 4 times, and a root canal completed 6 years after the incident.

Tooth No. 9 presented with evidence of previous internal bleeding due to trauma and was much darker in color than the natural dentition.2 Additionally, tooth No. 8 presented with a discolored facial composite and a gingival defect in the enamel producing asymmetrical gingival architecture. The incisal edges of the 2 teeth were uneven and the widths were not equal (Fig. 2).

The patient requested a longer lasting cosmetic dental treatment to address the discoloration of tooth No. 9, as well as correction of the asymmetrical gingival architecture of teeth No. 8 and 9.

Clinical evaluation
Complete intra- and extraoral examinations were completed that included an evaluation of the hard/soft tissues, temporomandibular joint, caries risk, periodontal health, occlusion, attrition, orthodontic class, crowding, and condition of existing dental restorations.

Radiographs were obtained to evaluate supporting structures and existing dental restorations, to assess caries, and to verify the integrity of the existing root canal of tooth No. 9 (Fig. 3). A cosmetic photo series was acquired with study models for records of preoperative conditions and evaluation with the ceramist (Fig. 4).

Tooth No. 9 presented with an existing root canal without any obvious pathology and a mesial incisal lingual facial composite with a chipped mesial incisal corner. The existing shade of tooth No. 9 was D-3 (VITA Classical shade guide, Vident), relative to the remaining natural dentition of B-1 (Fig. 5). The existing facial composite on tooth No. 8 was stained and breaking down along the margins. The mesiodistal widths and edge positions of the 2 teeth were asymmetrical. No mobility was observed. Periodontal pockets were

Fig. 1. Photograph of smile at initial consult showing darkened teeth No. 8 and 9.

Fig. 2. Retracted close-up view showing discolorations and chipped composite.

Fig. 3. Preoperative radiograph of teeth No. 8 and 9.
2-3 mm. All other existing restorations were in good condition. The patient was in class I molar and canine occlusion and presented with postorthodontic lower anterior crowding with wear on tooth No. 24 (Fig. 6).

Given the mandibular crowding and signs of wear, the patient was scheduled initially to correct the crowding and prevent traumatic occlusion. Tooth No. 9 needed to be treated with nonvital bleaching prior to the final restoration to determine the minimum restoration thickness needed to conserve as much natural tooth structure as possible, to preserve natural enamel strength, and to provide full enamel bonding. Lastly, the final restorations on teeth No. 8 and 9 needed to be fabricated in porcelain and bonded to recreate proper incisal edge position, symmetry, and color, as well as to provide the needed strength for long-term predictability.

Treatment planning
The anterior mandibular crowding was discussed with the patient and a limited orthodontic treatment vs enameloplasty of the lower incisors was proposed. Treatment options to address the patient's chief complaint of discoloration were proposed as a more aggressive preparation to block out the dark color as opposed to nonvital bleaching and a more conservative preparation. The replacement of composite on teeth No. 8 and 9 instead of porcelain veneers was discussed, as well as the advantages and limitations in treating only tooth No. 9. Treating both central incisors would produce symmetry in edge positions and tooth widths. The patient elected to correct the mandibular anterior crowding and proceed with nonvital bleaching and porcelain veneers on both teeth No. 8 and 9.

According to the treatment plan, the correction of the mandibular anterior crowding would be completed with a minor interproximal reduction of the lower incisors and the use of a series of Essix ACE thermoplastic aligners (DENTSPLY International). The nonvital bleaching of tooth No. 9 would be achieved with Opalescence Endo 35% hydrogen peroxide (Ultradent Products, Inc.). Then, the existing composite would be removed from teeth No. 8 and 9 and feldspathic veneers (Creation CC, Creation Willi Geller International GmbH) requiring zero or minimal preparation would be fabricated.

This treatment plan addressed the patient's chief complaint while being as conservative as possible, thereby maintaining the strength of the natural enamel to provide long-term predictability. The Essix aligners were chosen to minimize the cost of the anterior crowding correction. The nonvital bleaching was selected to bring tooth No. 9 closer in color to the natural dentition, while minimizing the reduction of the natural tooth structure. Feldspathic porcelain was chosen for its optical characteristics, strength upon enamel bonding, and ability to fabricate very thin restorations.

Clinical technique
After correction of the mandibular anterior crowding, nonvital bleaching was initiated on tooth No. 9. Septocaine (4%) with 1:100 k epinephrine (Septodont, Inc.) was administered, and a rubber dam was placed to isolate tooth No. 9. The existing lingual composite access fill and the gutta percha were removed from the chamber and canal to a depth 2 mm below the crestal bone. The canal was sealed up to the crestal bone with a resin-modified glass ionomer, Ketac Nano (3M ESPE). Opalescence Endo was placed in the chamber along with a small cotton pellet. The lingual access was temporarily sealed.
with Ketac Nano (3M ESPE). Two rounds of nonvital bleaching were completed for 3 days each cycle to achieve the desired whitening; this brought tooth No. 9 from shade D-3 to A-1, as measured by the VITA Classical shade guide (Vident). The stained composite on the facial of tooth No. 8 was also removed (Fig. 7).

The lingual access was then restored by administering the Septocaine and placing a rubber dam to isolate tooth No. 9. The chamber was cleaned out to the previously placed Ketac Nano level, rinsed, and dried. Scotchbond Etchant 35% phosphoric acid (3M ESPE) was applied to the enamel around the lingual access for 5 seconds, then applied to the chamber for an additional 15 seconds, rinsed, and blotted dry with cotton to remove excess water. Two coats of Adper Single Bond Plus Adhesive (3M ESPE) were applied and agitated with a microbrush for 15 seconds. The Single Bond was air-thinned for 5 seconds and light-cured for 10 seconds using an Elipar S10 (3M ESPE) curing light. B1B Filtek Supreme Ultra nanocluster composite (3M ESPE) was layered in 2 mm increments to full contour with incremental curing times (20 seconds each).

On the day of preparation for the veneers, a preoperative cosmetic photo series was acquired along with shade photos of the hydrated teeth for the ceramist. The shade B1 from the VITA Classical shade guide was photographed with higher and lower valued shade references (Fig. 8). Local anesthetic was not needed due to the nonvital bleaching of preparation of teeth No. 8 and 9. A preoperative impression was acquired with a plastic impression tray and Star VPS vinyl polysiloxane (Danville Materials). The existing class IV composite was removed and tooth No. 9 was prepared for a veneer using a coarse round end taper friction grip high speed diamond bur (799.11, Premier Products Co.). The stump shade of tooth No. 9 was recorded and photographed as ND1 using the IPS Natural Die Material shade guide (Ivoclar Vivadent, Inc.) (Fig. 9).

An Expasyl gingival extraction system (Kerr Corporation) was placed in the gingival sulcus of teeth No. 8 and 9, and a small cotton pellet was used to tamper the Expasyl down. After 2 minutes, the Expasyl was rinsed, and the teeth dried. Imprint 3 light body vinyl polysiloxane (3M ESPE) was injected into the sulcus of teeth No. 8 and 9 and around the other anterior maxillary teeth. A metal full arch impression tray loaded with Provil Novo Putty Fast Set (Heraeus Kulzer) was seated in the patient’s mouth for 5 minutes. Upon removal of the preoperative impression, the excess temporary material was removed, the impression was occlusion-verified, and then polished with Sof-Lex polishing discs (3M ESPE).

The impressions, interocclusal bite record, all pre- and perioperative photos, and Kois Dento-Facial Analyzer records were sent to the ceramist.
Laboratory fabrication

Prior to beginning the case, the clinician and ceramist met to discuss the projected treatment plan and options—including materials and techniques—that could achieve the best result. The photos reviewed included the preoperative full cosmetic photo series, shade photos with multiple shade references (to illustrate chroma, value, and internal characterization), and stump shade photos.

The models were poured in Type IV GC Fujirock EP stone (GC America, Inc.) and mounted for review. This case involved the fabrication of a no-preparation veneer on tooth No. 8 and a minimal preparation veneer on tooth No. 9. Feldspathic porcelain was chosen for the desired esthetics. The refractory veneer technique was used to build this case, a Gellar model was fabricated, and dies were duplicated with Polypour (GC America, Inc.), a pourable vinyl polysiloxane duplicating material. The refractory dies were then poured using Nori-Vest (Kuraray America, Inc.) and cured under pressure. The dies were processed strictly according to the manufacturer recommendation, then seated back into the Gellar model.

Willi Gellar Classic Creation (Creation Willi Geller International GmbH) was the chosen porcelain type for the case. The first "bake" was carried out using a 50% mixture of CL-O and HT-51 as a bonding layer to the refractory and was fired 30°C higher than the typical temperature, which is 920°C, to ensure a smooth bond to the refractory material.

The next bake was an opacious dentin layer to mask the line of the preparation and to begin mimicking the adjacent tooth shade (Fig. 10). The firing temperatures were increased 15°C to accommodate the mass of refractory material. The third bake was California White Dentin and E-57, CL-O, TI-4, and TI-2 (Creation Willi Gellar International GmbH). Mamelon characterization was created by mixing MI-61 with INN-1 and INN-2 and fired. E-57, TI-1, TI-2, HT-51 and SI-02 were layered on the incisal and mid facial areas and HT-51 and HT-52 were layered in the cervical area (Fig. 11). A slight halo was added using a mixture of California White Dentin and E-57 on both restorations for a perfect match. The final firing was a slight correction firing that added slight white stain characterizations to mimic the natural dentition.

The restorations were completed on the refractory dies using diamond impregnated silicone wheels (Axis Dental) and Legabril diamond polish paste (Metalor Technologies USA Corporation) (Fig. 12). The veneers were divested using glass beads for the bulk of the material and finished with aluminum oxide at very low pressure—less than 1.5 bars. After divesting, the internal surface of the veneers were etched with IPS Etching Gel 5% hydrofluoric acid (Ivoclar Vivadent, Inc.) for 20 seconds then placed in an ultrasonic cleaner for 10 minutes (Fig. 13-15). The case was then packed and sent to the clinician.

Final cementation

Septocaine was administered to ensure patient comfort during delivery and finishing of veneers. The temporary veneer was removed from tooth No. 9 by making a vertical cut through the veneer with the 799.11 diamond bur and using a crown spreader to remove the material. Teeth No. 8 and 9 were then cleaned with pumice and a slow speed rubber cup. The 2 veneers were initially tried in one at a time to verify fit, and then tried in together to verify passive seat and proximal contacts. Once verified, the restorations were tried
in with Rely X Translucent Try-In paste (3M ESPE) to verify incisal edge position, symmetry, midline, hue, chroma, and value (Fig. 16). The veneers were then removed, thoroughly rinsed with water spray, then cleaned with Ivoclean (Ivoclar Vivadent, Inc.) for 20 seconds.

A fourth generation etch-and-rinse bonding system was used for optimal bond strength.18,19 A single coat of silane RelyX Ceramic Primer (3M ESPE) was applied to the internal surface and allowed to evaporate. Adper Scotchbond Multi-Purpose Adhesive (3M ESPE) was applied to the silane-treated surfaces and air-thinned. Scotchbond Etchant was applied to teeth No. 8 and 9 for 15 seconds, then rinsed with water spray. Excess water was blotted away from teeth No. 8 and 9, leaving the tooth surface moist. Adper Scotchbond Multi-Purpose Primer (3M ESPE) was then applied to teeth No. 8 and 9 and gently dried for 5 seconds. Two coats of the Adper Scotchbond Multi-Purpose Adhesive were applied to teeth No. 8 and 9, and gently air-thinned. The veneers were then loaded with RelyX Translucent Veneer Cement (3M ESPE) and seated with gentle pressure. A small diameter tacking tip was used on the Elipar S10 curing light to spot-cure the veneers in place on the facial surface. The excess cement was removed with micro-brushes. The regular curing tip was reapplied to the curing light and each veneer was light-cured for 10 seconds. Glycerin was applied to margins to eliminate the air-inhibited layer and each veneer was then light-cured for an additional 20 seconds. A No. 12 scalpel blade was used to remove excess cement under microscope and Sof-Lex polishing strips and discs were used to finish the margins. The occlusive, excursive, and protrusive movements were checked.

The patient returned 2 weeks later for follow-up, at which point a postoperative cosmetic photo series and radiographs were taken (Fig. 17-19).

**Conclusion**

Through use of nonvital bleaching, very conservative cosmetic treatment can be used to treat dark teeth. Following proper protocol to seal the canal space is essential to provide for the long-term health of teeth undergoing nonvital bleaching. Communication with the ceramist and understanding of material options is crucial in providing beautiful, natural looking restorations. Conservative tooth preparation allows for complete enamel bonding, maximizing long-term predictability while conserving natural tooth structure.
Author information  
Dr. Marongiu currently serves on the Board of Directors of the American Academy of Cosmetic Dentistry. He has a private practice in La Jolla, California. Mr. Cochran is an accredited member of the American Academy of Cosmetic Dentistry. He owns Horizon Dental Studio in San Diego, California.

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www.agd.org General Dentistry Special Cosmetic Dentistry Section 31
Shade evaluation of ceramic laminates according to different try-in materials

Lawrence Gonzaga Lopes, DDS, MS, PhD • Maysa Magalhaes Vaz, DDS • Ana Paula Rodrigues Magalhaes, DDS
Paula Carvalho Cardoso, DDS, MS, PhD • Joao Batista de Souza, DDS, MS, PhD • Erica Miranda de Torres, DDS, MS, PhD

The porcelain laminate replaces the visible portion of enamel with a ceramic, which is attached to the dental surface. To enhance cosmetic results, a preliminary color matching procedure is performed prior to cementing the veneers. This procedure can be performed using water, water-soluble gel, or try-in paste. The different shades of cement and try-in pastes are intended to obtain better color and esthetics of the final restoration. This study sought to evaluate the shade of ceramic veneers produced by different try-in materials. Forty bovine teeth and 40 ceramic discs (0.6 mm thick) were prepared. The samples were divided into 4 groups (n = 10). For Group 1 samples, no material was used between the tooth and the ceramic, Group 2 interposed samples with water, Group 3 used a water-soluble gel, and Group 4 used try-in paste (value 0). The color was measured with a spectrophotometer, obtaining $L^*$, $a^*$, and $b^*$ values to calculate the color difference ($\Delta E^*$). The data were subjected to normality tests and 1-way ANOVA. No significant statistical differences were found among the groups, indicating that the different try-in materials had similar effects on the color of the ceramic laminates.

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Key words: dental veneers, color perception tests, resin cements

D

ental ceramics stand out due to their excellent optical properties, biocompatibility, durability, and close resemblance to the natural appearance of teeth. The porcelain veneer replaces the visible portion of enamel with a ceramic laminate, which attaches itself securely to the dental surface. New ceramic systems offer esthetics and high resistance, because they are reinforced with leucite and lithium disilicate, which allow for the development of minimally invasive ceramic laminates. This technique utilizes thin ceramic veneers (0.3-1 mm thick) with little or no preparation of the tooth structure necessary. The color of the cement used when placing these translucent ceramics may compromise the final esthetic result. In this context, the resin cements offer several different colors and opacities. The adhesive systems and resin cements allow for an effective interaction between the ceramic and the tooth structure, as described in the literature. The success of a ceramic restoration depends primarily on the durability of the bond between the ceramic and resin cement, as well as that between the cement and tooth structure. The resin cements used specifically for luting ceramic veneers usually are activated by visible light. Advantages of these cements include their color stability and longer working time, compared to chemically cured and dual-cured resin cements. To enhance esthetic results, the ceramic is placed over the substrate prior to cementing the veneers, at which point the color obtained is evaluated. This placing can be done with water, glycerin gel, or try-in. According to Al Ghazali et al, the try-in pastes that accompany resin cements allow dentists to predict the final esthetic result before cementation. The purpose of the different shades of resin cements and try-in pastes is to improve the color and esthetics of the final restoration. The correct correlation between try-in and resin cement colors under ceramics is critical, especially when using extremely thin and translucent ceramics.

This study sought to evaluate the shade of ceramic veneers resulting from different try-in materials. The null hypothesis was that there were no differences among the ceramic colors obtained with the try-in materials tested.

Materials and methods

Teeth preparation

Initially, a wax pattern was made (11 mm wide x 8 mm thick). Forty ceramic discs (IPS Empress, Ivoclar Vivadent, Inc.)—color ETC0—were injected to obtain a ceramic block. Next, the blocks were polished with 800- and 1200-grit abrasive paper (3M ESPE) to obtain a thickness of 0.6 mm each. The thickness standardization was registered using a digital electronic caliper (Mitutoyo America Corporation).

Try-in application

The 0.6 mm ceramic discs were placed on the prepared dental substrate. The try-in materials were placed between the ceramic discs and the tooth substrate. A pilot study was conducted to standardize the application of the try-in materials.

Samples were distributed among 4 groups (n = 10). In Group 1, no material was used between the substrate and the ceramic. For Group 2, the try-in material was 0.2 ml of water, measured with a disposable syringe. Try-in material for Group 3 was a water-soluble gel (KY Jelly, Johnson & Johnson) while a try-in paste (Variolink...
Table 1. Mean values and standard deviations (SD) of ∆E* for all groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>∆E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.03 (2.59)</td>
</tr>
<tr>
<td>2</td>
<td>10.57 (3.14)</td>
</tr>
<tr>
<td>3</td>
<td>10.40 (1.97)</td>
</tr>
<tr>
<td>4</td>
<td>11.90 (5.87)</td>
</tr>
</tbody>
</table>

∆E* indicates change in color
Similar letters denote no statistical difference (P > 0.05).

Veneer, Ivoclar Vivadent, Inc.) was used for Group 4; for both Groups 3 and 4, the materials were placed between the substrate and the ceramics and pressed in a special appliance developed for this study to standardize the thickness of the materials with a pressure of 1 kg. Although not measured directly, it was assumed that the film thickness was relatively uniform after the pressing due to the uniform loading conditions.

Color measurements
All color measurements were performed with an spectrophotometer (Vita Easyshade Spectrophotometer, Vident). According to the International Commission on Lumination (CIE), color measurements make it possible to evaluate the degree of perceptible color change based on 3 coordinates: L*, a*, and b* (known as the CIE-L*a*b* system). Color was measured in this study using the CIE-LAB system parameters, with L* indicating the lightness from 0 (black) to 100 (white), while a* and b* indicate the hue (a* represents the saturation in the red-green axis and b* in the blue-yellow axis). The color readings on each specimen were performed against a white standard background.

The measurements were performed twice: once in the tooth substrate (L0*, a0*, and b0*) and once with the ceramic in position over the substrate (L*, a*, and b*). Three measurements were made in each instance and the mean of the coordinates obtained were considered for statistical analysis.

The color change (∆E*) is used commonly to represent the difference in color between 2 measurements. A ∆E* was obtained between the substrate and the try-in values to evaluate the color difference obtained with the try-in materials and the ceramics over the substrate. The color change can be calculated using the formula:

\[ \Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \]

where ∆L* is the variation of L*, ∆a* is the variation of a*, and ∆b* is the variation of b*.

Statistical analysis
Data were organized in a database for statistical analysis with software SPSS 17.0 for Windows (IBM Corporation) with a significance level of 0.05. A Shapiro-Wilk test was used to evaluate the normality of parametric data distribution. One-way ANOVA was used to make comparisons between groups, while a paired t-test was used to make comparisons within groups.

Results
The data obtained for the different groups tested are shown in Tables 1 and 2. There was no statistical difference among the substrate measurements, no statistical significant difference was found for L0*, a0*, and b0* (P = 0.294, P = 0.372, and P = 0.795, respectively). A comparison of the same coordinates obtained from the try-in materials among the groups showed a statistically significant difference in L* values only between Groups 1 (control) and 3 (water-soluble gel) (P = 0.02). Finally, the comparison between L0* vs L*, a0* vs a*, and b0* vs b* showed a statistical significant difference for all pairs (P = 0.000, P = 0.006, and P = 0.000, respectively).

Discussion
According to O’Brien et al, the color selection process is complex, due to the different characteristics of the color components, types of lighting used (that is, natural or artificial), and the subjectivity of the viewer’s perception and experience. Color selection also involves an assessment of dental shape, gloss, surface texture, translucency, gingival color, adjacent teeth, and tooth position in the arch.

Until recently, color selection by visual perception with standardized scales was the most common method used in dental clinics. However, this method of color selection has some disadvantages, such as the scales differing by manufacturer, resulting in a lack of systematization. In addition, earlier color scales were built in materials that are different from the restoratives now.

Table 2. Mean values and standard deviations (SD) of all color values obtained before and after the test using spectrophotometry (P = 0.05).

<table>
<thead>
<tr>
<th>Group</th>
<th>L0*</th>
<th>L*</th>
<th>a0*</th>
<th>a*</th>
<th>b0*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>98.69 (1.34)a</td>
<td>97.43 (1.77)abc</td>
<td>-0.47 (0.55)abc</td>
<td>-0.57 (0.33)abc</td>
<td>22.68 (3.31)abc</td>
<td>12.00 (1.50)abc</td>
</tr>
<tr>
<td>2</td>
<td>97.69 (2.68)abc</td>
<td>95.08 (2.37)abc</td>
<td>-0.09 (0.78)abc</td>
<td>-0.53 (0.44)abc</td>
<td>24.02 (4.03)abc</td>
<td>14.19 (2.75)abc</td>
</tr>
<tr>
<td>3</td>
<td>97.77 (2.12)abc</td>
<td>92.54 (2.57)abc</td>
<td>-0.51 (1.18)abc</td>
<td>-0.93 (0.71)abc</td>
<td>23.3 (2.99)abc</td>
<td>14.42 (2.68)abc</td>
</tr>
<tr>
<td>4</td>
<td>95.47 (6.68)abc</td>
<td>94.85 (3.08)abc</td>
<td>-0.36 (1.91)abc</td>
<td>-0.8 (0.79)abc</td>
<td>24.41 (5.72)abc</td>
<td>13.06 (1.75)abc</td>
</tr>
</tbody>
</table>

L* indicates lightness
a* indicates hue (saturation in the red-green axis)
b* indicates hue (saturation in the blue-yellow axis)

Similar uppercase letters denote no statistical differences for comparisons between columns for the same coordinates and similar lowercase letters denote no statistical differences for comparisons between lines for the same coordinates (P > 0.05).
used, and the thicknesses of the teeth used in the guides did not simulate clinical conditions. These disadvantages have led researchers to discontinue using this method as a model of comparison.6,17

Color was measured and compared in this study using the CIE-LAB system and a spectrophotometer. Spectrophotometers have been used industrially and in research to measure the colors of materials and substrates and also to determine the reflectance and transmittance factors of an object, as a function of the wavelength and electromagnetic radiation.17 According to van der Burgt et al, spectrophotometry showed significant differences among the materials used, which confirmed the effect of porcelain opacity on the resultant shade of veneer and substrate systems, and concluded that porcelain veneers provide a masking effect when luted with resin composite cements.15

Considering the L* value, the highest values were observed in Group 1 (mean L* = 97.43 ± 1.77). This group interposed no material between the porcelain veneer and the substrate; as a result, the color measured was that of a dry laminate over enamel. It is likely that the absence of try-in material decreases the color interaction between tooth and porcelain veneer, which may suggest that the high L* obtained was due to the brightness of the laminate. Groups 2-4 had lower L* values, possibly because the interposed material between laminate and substrate produced some color interaction.

According to Xing et al, ΔE* values higher than 2 may be considered a noticeable color change.14 A 2010 study by Al Ghazali et al found that 3.3 units of color difference had not been noticeable for 50% of the observers using the visual method.13 A recent in vivo study reported that a ΔE* of 5.5 units was necessary for the color difference to be perceived by the human eye.19 Nevertheless, when observing the mean ΔE* values for all groups, the present study reported an apparent difference in color between the substrate and the tested groups in all cases. This concurs with other studies that showed ceramized veneers can be used for color correction.8,11,20

Conclusion
In all cases, the different try-in materials (try-in paste, water, water-soluble gel, and no material at all) produced similar color changes in the ceramic veneers.

Author information
Dr. Lopes is a professor, Department of Prevention and Oral Rehabilitation, School of Dentistry, Federal University of Goias, Goiania, Brazil, where Drs. Souza and Torres are professors, Drs. Vaz and Magalhaes are master’s students, and Dr. Cardoso is a doctor, School of Dentistry.

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Achieving highly esthetic anterior restorations with ideal assessment, communication, and technique

Scott Finlay, DDS, FAGD, FAACD • Nelson Rego, CDT, AAACD

Although all cases should be approached comprehensively, restoring a limited segment in the esthetic zone presents challenges particularly related to microesthetics. Microesthetics are those criteria related to the subtle intricacies of shade, textures, translucencies, and surface effects that make teeth look like teeth. These are the criteria that aid dentists in fooling the eye and allowing restorations to blend invisibly into the smile. Completing a comprehensive assessment of a patient ensures that the restorative foundation will remain biologically and structurally predictable, durable, and above all, esthetically pleasing. Starting esthetic treatment without first doing a comprehensive assessment will result in a compromised result. Within the criteria of microesthetics, the utilization of a common nomenclature and quantitative means of communication between the restorative dentist and the laboratory ceramist are at the core of success. The use of prototypes during the provision-alization phase and progressive techniques in digital photography are invaluable tools. Along with traditional techniques in acquiring proper shade selection, the use of cross-polarization filters has been proven to be an effective way to eliminate spectral artifacts typically found in flash photography. Additionally, the use of a color-corrected master die system provides the ceramist a method to calibrate shades on the lab bench by capturing images—via the cross-polarization filters—that are similar to what is observed clinically.

One of the most challenging clinical situations in dentistry is the restoration of a limited segment in the esthetic zone. Often complicating this task is varying hybrid restorative preparation designs that require differing laboratory modalities to create restorations that blend into the surrounding dentition. Ceramic systems that utilize a common veneering ceramic offer a great advantage in harmonizing the restorations with the full smile. An ideal material replicates natural tooth characteristics through a combination of opalescent, translucent, and light diffusion properties; and replicates the polychromatic optical properties observed in natural teeth. These restorations also require a material that exhibits biocompatibility, high strength, and durability. Although restorative success primarily hinges upon proper prosthetic design, it behooves the clinician and the ceramist to utilize the advancements in modern materials to ensure a predictable, durable, and beautiful result.

The clinician’s desire to emulate nature and the patient’s expectations of enhanced esthetics have raised the bar on what is considered a successful restoration. The foundation of a successful result lies within the ability of the restorative team’s evaluation and the interpolation of essential criteria related to smile design with a common vision and nomenclature. The American Academy of Cosmetic Dentistry (AACK) is the largest cosmetically focused dental academy in the world. The AACK offers a credentialing program that defines a platform for evaluation of smile design based upon commonly accepted standards as supported by the preponderance of literature. The credentialing process provides a common nomenclature when assessing and communicating criteria related to smile design. A smile design analysis is divided into 3 sections to conceptually guide the pretreatment evaluation. The analysis begins with the broadest strokes of smile design, then progressively narrows the focus to each individual tooth in order to replicate nature. This analysis starts from the perspective of global esthetics, an approach that focuses on those criteria that are observed in unretracted smiles and how the smile orients to the face. As the analysis narrows, the focus narrows on the elements of macroesthetics. Macroesthetics relates to the shapes and contours of teeth and their relationship to each other. The final phase of analysis focuses on microesthetics, which are those criteria related to the subtle intricacies of shade, textures, translucencies, and surface effects that essentially make teeth look like teeth. These are the criteria that aid the practitioner in fooling the eye and allowing restorations to blend invisibly into the smile.

Although the intended restorative focus may be limited in many cases, the final diagnosis must be comprehensive in evaluating the biological, structural, functional, and esthetic needs of the patient. The assessment begins with the evaluation of the temporomandibular joint (TMJ), which provides a precise location from which the design process can begin. The understanding of this sophisticated system allows for the optimization of esthetics by beginning with the end in mind, but with a focused discipline and an understanding that allows the clinician to modulate the desired contours to be in harmony with such functions as occlusion. Failure to comprehensively evaluate the system will not only put restorations in harm’s way, but also detrimentally affect the prognosis and success of the case.

The vision of the restorative dentist and ceramist team needs to be synergistic. They need to continually find new ways to creatively communicate in a progressive and quantitative way to optimize function and esthetics in order to take advantage of the advancements in contemporary materials. Predictability can only be achieved with mutual accountability and the adherence to an effective protocol.

Evaluating and communicating case specifics
Restorations are provided to the patient in what can easily be categorized as an...
incredibly hostile oral environment. Any restoration will be subjected to thermal changes, staining agents, and hundreds of pounds of force. Careful evaluation and diagnosis of risk assessment are essential to a treatment plan in order to manage these etiologies of dental deterioration.

Diagnostic photographs are an essential tool in documentation and communication between the clinician and the laboratory. Image composition needs to be reproducible from different perspectives: angle, magnification, and exposure. Digital photography enhances laboratory communication and brings to life the stone models on the lab bench. A variety of photographic techniques can enhance the evaluation of shade comparisons to the surrounding dentition, intensity of characterization, degrees of translucency and opacity within the incisal edge, as well as the incisal edge position as it relates to provisional prototypes and the intended final restorations.⁴⁻⁵

Determining the proper shade requires an understanding of the science of color, including the influences of surface finish and texture.⁶ In the experience of this restorative dentist/ceramist team, cross-polarization filters provide an invaluable tool for shade calibration. This photographic technique enhances the visual detail of enamel defects and eliminates specular reflections that can be caused by saliva, or a surface finish that was created by the illumination source. It involves the use of polarization filters that are oriented on the flash and lens at 90 degrees to each other.⁷ These specular reflections are essentially artifacts in the image that mask the underlying idiosyncrasies of the tooth. Eliminating these artifacts provides a unique opportunity to calibrate the shade from the operatory to the lab bench. In the lab, the ceramist can extend this application with the utilization of a color-corrected die system and a cement simulator to recreate what is observed clinically.

Accurately mounted diagnostic wax-up models are an attempt to implement the desired changes to the patient’s smile from a 2-dimensional perspective to a virtual 3-dimensional simulator—the articulator. From the modulated contours of the diagnostic wax-up, stents can then be fabricated to guide conservative preparations and the creation of prototypes. These prototypes are the most important quality control step relative to functional and global/macro esthetics in the restorative process.⁸ These prototypes are tested and detailed clinically to ensure that they meet the functional, phonetic, and esthetic needs of the patient. These refined contours are then communicated to the dental laboratory with an impression and the creation of an approved provisional model. From this approved provisional model, the laboratory technician can create 2 key indices to ensure functional success: the incisal edge matrix and a custom incisal guide table. These indices will clearly define the exact incisal edge position of the final restorations and a guidance that is in harmony with the envelope of function.⁹

Case report
A 34-year-old woman presented with discolored direct composite restorations on teeth No. 8 and 9 (Fig. 1). The patient reported damaging her anterior teeth 10 years earlier when she fell after fainting at work (Fig. 2). She had composite restorations placed to repair teeth No. 8 and 9 at that time, with additional endodontic treatment on tooth No. 9 (Fig. 3). The patient also presented with interproximal resin restorations placed to restore previous caries. She desired to improve the appearance of her anterior teeth with the most durable option possible.

Treatment planning
The clinical examination included hard and soft tissue evaluations, complete radiographic survey, diagnostic photographic series, TMJ exam, occlusal survey (T-Scan, Tekscan, Inc.), and mounted diagnostic models. It was determined that the patient was in generally good oral health, with adequate oral hygiene and a healthy periodontium. The patient demonstrated a full range of motion. The joints loaded incrementally without symptoms, and there was a slide from centric relation (0.5 mm horizontal and 1 mm vertical) to centric occlusion.

Although proposed as an ideal treatment option, the patient declined orthodontics to better position her teeth. Any shortcoming in the treatment recommendations introduces a level of compromise; however, the resulting consequences of this particular limitation were deemed insignificant by the study clinician.
After dental prophylaxis, the patient’s teeth were whitened using a tray system. Accurately mounted diagnostic study models were evaluated on a semi-adjustable articulator. Treatment options were then explored to achieve the desired improvements to the patient’s smile, which included an equilibration to optimize and balance occlusal forces and meet the requirements for a stable occlusal design, as well as a diagnostic wax-up to simulate the intended changes in contour for teeth No. 8 and 9 (Fig. 4).

The diagnostic wax-up was used to fabricate a Siltech matrix (Ivoclar Vivadent, Inc.) that the clinician used—along with a clear .020 inch tray—to create the new provisional and to properly evaluate the amount of reduction (Fig. 5).

The restorative treatment plan included a conservatively prepped lithium disilicate (IPS e.max, Ivoclar Vivadent, Inc.) layered veneer on tooth No. 8. A core repair and a lithium disilicate layered porcelain jacket crown was planned for tooth No. 9. Provisionalization for teeth No. 8 and 9 would be accomplished utilizing the “lock-on technique” and a self-curing composite (Telio, Ivoclar Vivadent, Inc.).

The final restorative shades should be determined prior to preparation in order to avoid dehydration of the tooth surfaces (Fig. 6). The clinician in this study observed the natural shade under a variety of light sources and intensities, being sensitive to the properties of metamerism. After viewing the shade in ideal daylight, a color rendering index near 95% was also employed to observe the natural shade. The initial shade value was first selected, the clinician taking care to control the level of light reaching the rods by squinting. Brief glances of 5 to 7 seconds helped to avoid oversaturating and desensitizing the cones of the clinician’s eyes. An 18% grey card was used as a “middle grey” reference to reset the color balance and minimize the “blue fatigue” effect of the eye. A limited field of view also helped eliminate visual distractions that may have interfered with the interpolation of the shade.

A cross-polarization device was utilized to eliminate spectral reflections and artifacts in the images used to communicate color, and multiple shade guides were compared to avoid distraction from the shade variations (Fig. 7). A spectrophotometer (Vita Easyshade, Vident) was also used to provide additional information and verification of the ideal shade.

After shade selection, the preparation design was driven by the need to cover the surfaces of the teeth in order to meet the functional and esthetic needs of this case while minimizing the removal of
tooth structure. A conservative preparation of 0.3 mm was created for the veneer on tooth No. 8. The preparation shade was then recorded to facilitate the selection of the color-corrected die material in the lab to assist in the calibration of the final shade (Fig. 8). The completed equilibration was verified in the diagnostic models prior to treatment, to ensure the balance of the occlusal contacts and ensure occlusal stability.

**Provisionalization**
The mounted models and diagnostic wax-up provided a blueprint for the smile design changes and fabrication of the provisional matrix. The provisional matrix intimately captured all of the wax-up details and contours—as well as the relationship to the opposing arch—by creating indexing on the intaglio surface of the matrix. When creating this matrix, the putty was placed on the upper member of the articulator prior to the final set. The articulator was then closed to engage the opposing arch, which recorded an indexing of the mandibular teeth on the bottom of the provisionalization stent. This feature of indexing ensured the complete seating and even distribution of the hydrostatic pressure of the composite material as the stent was re-introduced to the patient’s mouth, allowing the patient to close and engage these indices.

Spot etching was used on the incisal aspect of tooth No. 8 to help retain the provisional, and the etchant was kept several millimeters away from the cavosurface to prevent interference with the seating of the final restoration. A bonding agent (ExciTE F DSC, Ivoclar Vivadent, Inc.) was placed on this etched area prior to the seating of the provisional matrix. A bilaminar technique was used to establish a natural gradation of shade: A1 for the cervical half and BL3 for the incisal half. Once the matrix was inserted, the lighter shade of Telio provisional material was injected into the incisal half, and the warmer chroma was injected into the cervical half. The bisacryl was left in place for 3 minutes to allow for a complete cure, with the intention of enabling the provisional to lock into place. The matrix was then removed and any flash was eliminated.

Additional characterization of the provisional was accomplished utilizing several shades for characterization (IPS Empress Direct Color, Ivoclar Vivadent, Inc.). Blue tint was diluted with an unfilled resin and then applied to the incisal aspect to simulate translucency; white opaque was similarly diluted to create the milky hypocalcification observed in the adjacent teeth. A final glaze was then placed (Fig. 9).

The patient was instructed to use peroxyl, a Waterpik (Water Pik, Inc.), and a toothbrush. The patient was scheduled for another appointment 48 hours postinsertion, at which time the prototypes were re-evaluated for esthetics and function, and an impression was taken to record the approved contours of the provisional.

**Laboratory fabrication**
The model of the approved provisional was mounted on a semiajustable SAM articulator (SAM Prazisionstechnik GmbH) and used to create a custom incisal guide table (PATTERN RESIN LS, GC America, Inc.) that accurately replicated the lingual surfaces of the provisional, ensuring that the envelope of function would not be adversely affected (Fig. 10).

The final restorations were fabricated based on the approved provisional restorations, incisal edge matrix, and custom incisal guide table. The models were scanned into the digital articulator (3Shape A/S) (Fig. 11). After the digital protrusive and excursive movements were
calculated based on the mounted cases, the final restorations were milled in wax using a 4-axis milling machine (Wieland Mini Mill, Ivoclar Vivadent, Inc.) (Fig. 12). The waxed units were marginated, sprued, and pressed using IPS e.max lithium disilicate (Ivoclar Vivadent, Inc.) in a No. 2 shade. After a careful inspection of the marginal integrity, the restorations were cut back and layered with multiple shades of veneering ceramic, contoured, and layered with final incisal powders (Fig. 13-15).

Color correct dies (IPS Natural Die Material, Ivoclar Vivadent, Inc.) were used to calibrate the shade, as the new restorations were very thin (0.3 mm) and the underlying shade of the remaining tooth structure influenced the final perceived shade. The study ceramist selected a natural die material to virtually assist the clinician chairside. The restorations were photographed on the natural die material with glycerin, and the images were then captured with and without the cross-polarization filters and the respective shade tabs (Fig. 16). These images were compared to those captured by the clinician in order to verify the final shade.

The incisal edge matrix created from the approved provisional was used to verify the incisal edge position of the final restorations in both a vertical and horizontal component (Fig. 17 and 18).

**Final restoration try-in and cementation**

The restorations were returned to the study clinician. The provisional were removed, preparations cleaned, and restorations tried-in in order to evaluate fit, esthetics, and contacts. A neutral try-in paste was utilized as a cement simulator, and the shade was evaluated clinically and photographically. Both methods were used with and without a cross-polarization filter.

Once approved, the restorations were cleaned with Ivoclean paste (Ivoclar Vivadent, Inc.), and a priming agent (Monobond Plus, Ivoclar Vivadent, Inc.) was applied. The preparation surfaces were cleaned and etched. A light-curing veneer cement (Variolink Veneer, Ivoclar Vivadent, Inc.) was applied to tooth No. 8, as the restoration thickness was deemed conservative enough to not require a dual-curing luting material. An alternative cement (Variolink II, Ivoclar Vivadent, Inc.) was applied to tooth No. 9, as the restoration thickness benefited from a dual-cure luting agent. The restorations
were seated and light-cured according to the manufacturer’s instructions. Excess cement was removed, and the occlusion was checked and verified (Fig. 19). The patient was satisfied with the new esthetics and function of her smile (Fig. 20).

Conclusion
There are many challenges when managing restorations in the smile zone. The keys to success involve the proper assessment, technique, and communication to ensure a common vision for both the restorative dentist and the ceramist. In this case, the patient required 2 independent, highly esthetic restorations with differing restorative requirements. It was only after a complete exam and an agreement to a set protocol for diagnosis and treatment planning—utilizing photography, mounted models, and a diagnostic wax-up—that a dental blueprint was created that ensured a predictable outcome. Many of the elements of microesthetics and shade determination that allow restorations to invisibly dissolve into the smile zone can be challenging; however, the use of a deliberate shade-matching protocol—including color-corrected lighting, cross-polarization filters and color-corrected master dies—has proven to be invaluable. Precisely contoured prototype restorations are the key to predictability for functional esthetics. The use of a versatile ceramic system allows not only the conservation of tooth structure, but also the harmonization of different preparation designs to create a functional, durable, and esthetically pleasing result.

Author information
Dr. Finlay is in private practice in Annapolis, Maryland. Mr. Rego is in private practice in Santa Fe Springs, California.

Disclaimer
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A minimally invasive smile enhancement
Fred H. Peck, DDS

Minimally invasive dentistry refers to a wide variety of dental treatments. On the restorative aspect of dental procedures, direct resin bonding can be a very conservative treatment option for the patient. When tooth structure does not need to be removed, the patient benefits. Proper treatment planning is essential to determine how conservative the restorative treatment will be. This article describes the diagnosis, treatment options, and procedural techniques in the restoration of 4 maxillary anterior teeth with direct composite resin. The procedural steps are reviewed with regard to placing the composite and the variety of colors needed to ensure a natural result. Finishing and polishing of the composite are critical to creating a natural looking dentition that the patient will be pleased with for many years.

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The phrase minimally invasive dentistry has been around for many years in our profession. The trend toward conservative treatment has gained momentum in recent years, and preserving tooth structure should be of the utmost importance in the daily treatment of our patients. Aggressive removal of tooth structure is detrimental to the long-term health of the tooth and, ultimately, the patient, and should only be chosen when other options are not available. Each patient should be presented with all options prior to any dental treatment, especially those which are elective. The following case report portrays how one can be conservative in both diagnosis and treatment when restoring a smile.

Case report
The patient was a 22-year-old man who was dissatisfied with his smile (Fig. 1). Specifically, he did not like the spaces between his upper anterior teeth; however, he was content with their color (Fig. 2 and 3). A complete dental examination was performed including photographs, full mouth X-rays, as well as periodontal, occlusal, and restorative evaluations. It was determined that joint loading was normal, there was no tooth mobility, no signs of wear, and no occlusal issues. The patient had moderate gingivitis, no decay, and structurally sound teeth. His primary concerns were the diastemas between his anterior teeth, and the size and shape of these teeth.

Several options were discussed with the patient. Orthodontics would align the teeth, but not solve the size discrepancies. Other options included porcelain veneers or direct resin bonding. After reviewing the options, the decision was made to restore teeth No. 7-10 with direct resin bonding. The position of the patient’s teeth appeared to allow for a no-prep type of restoration; this would be verified after a diagnostic model evaluation. Diagnostic models were taken utilizing an alginate substitute material (Algin-X Ultra, DENTSPLY Caulk), ensuring the ability to obtain excellent gingival margins. A Kois facial analyzer (Panadent Corporation) was used to mount the models on an articulator (Panadent Corporation). A diagnostic wax-up was completed on the plaster models and a full arch putty was made, along with an incisal edge putty matrix (Template, Clinician’s Choice Dental Products, Inc.). The patient was scheduled to try in the proposed treatment shape for contour and incisal edge position (Fig. 4 and 5). The patient approved the provisional workup and was scheduled for treatment.

The goal of the treatment was to increase the width of the 4 incisors to impart a more natural look with the correct proportions of width to length ratios. The height of the gingival levels were also discussed with the patient. Ideally, the gingival heights should be even with the central incisors and cuspids. The lateral incisor gingival free margins can be equal to the central incisors or slightly lower. The gingival discrepancies were discussed with the patient, but he was content to leave the tissues as they were. Evening out the free gingival margins
would have required a combination of periodontal crown lengthening and the orthodontic extrusion of tooth No. 7 to lower the margin. It is important that these discussions take place prior to any treatment to avoid patient dissatisfaction.

The patient returned for a multi-hour appointment. The composite chosen was Estelite Omega (Tokuyama Dental America, Inc.), which, in the author’s opinion, has excellent handling properties.

The desired color was selected after a quick mock-up of the color layers over the unetched tooth surface. Trying out the proposed colors before final selection is highly recommended to avoid ending up with the wrong color combination at the end of treatment (Fig. 6). A shade map was then made of all the proposed colors for future reference (Fig. 7). The teeth were isolated with cotton rolls, and a Premier Comfort View small retractor (Premier Products Co.) was used. A retraction cord was placed in the sulci of the teeth that were to be restored. A size 0 retraction cord (Ultradent Products, Inc.) was dipped in ViscoStat Clear 25% aluminum chloride gel (Ultradent Products, Inc.). Using a clear retraction gel helps prevent discoloration of the final composite restorations.

The teeth were air-abraded with a Danville Prep Start (Danville Materials) utilizing 27 µ aluminum oxide, then lightly roughened with a coarse Sof-Lex disk (3M ESPE). The central incisors were treated first. Each tooth was isolated with a Mylar strip to keep the phosphoric acid off of adjacent teeth. Then the tooth was etched with 37% phosphoric acid. A bonding agent (ALL BOND UNIVERSAL, Bisco, Inc.) was used over the prepared tooth surface. At this time, the Mylar strip was removed. The putty matrix was held against the lingual surface. A very thin layer of composite was placed in the lingual putty matrix as the lingual shell (Fig. 8). The selected shade was MILKY WHITE (Tokuyama Dental America, Inc.). Prior to curing, a 12B Bard-Parker surgical blade (Aspen Surgical Products) was utilized to cut between the uncured composite and the adjacent tooth, along the matrix. This prevented the thin lingual shelf from bonding to the adjacent tooth and fracturing when detached from the tooth surface. If the lingual shelf is too thick, it can be thinned with a bur, then the bonding protocol can be repeated before proceeding (Fig. 9). In order to fill in the appropriate width of the diastema and to simulate the dentin shade while blocking out the darker appearance from the back of the mouth, a more opaque shade was used (DA-1, Tokuyama Dental America, Inc.) over the MILKY WHITE shade (Fig. 10).
The cervical area was covered with a more translucent enamel shade (EB-1, Tokuyama Dental America, Inc.) to impart some chroma and simulate a more intense color at the marginal area. The cervical portion was built out to full contour for 2-3 mm from the margin, then beveled toward the incisal. The middle and incisal thirds were covered with the enamel shade BL-2 (Tokuyama Dental America, Inc.).

Prior to curing the composite in the incisal third, indentations were placed to simulate the developmental lobes that are seen in natural dentition (Fig. 11). The composite was cured and a translucent shade (Tokuyama Dental America, Inc.) was placed in the depressions and cured. The final color placed was MILKY WHITE, which acted as a value-modifying layer over the incisal third to slightly reduce the value (Fig. 12).

The goal of adding composite should be to place just enough composite without too much bulk and overcontouring. It is always better to add small increments at a time. If each shade is overbulked, then the final shape would be too large. Excess reduction will then be necessary and this will result in removal of the outermost shades, with a resultant loss in color variations. The tooth will then appear monochromatic in color.

The last step of applying the composite was the final cure. It is very important to cure the oxygen-inhibited layer. This was accomplished in this case by covering the composite with a water soluble glycerin gel that easily washed off.

The initial contouring was started on the central incisor. Ideally, the only time a bur should be used in the initial stages is to smooth the cervical margins adjacent to the retraction cord. If too much composite is placed, then a fine diamond bur can be used to remove the excess. A thin (.001 inch) Tofflemire band was placed on both interproximal surfaces to prevent damage to the adjacent teeth while polishing (Fig. 13). A coarse Sof-Lex disk was used with the cutting surface facing the back of the contra-angle handpiece. This prevented the mandrel from scratching the tooth. A pencil line was drawn on the facial surface toward the mesial and distal where the line angles were desired. The facial aspect between the lines was adjusted first, and excess composite was removed from the lingual. This stage of adjustment is necessary to ensure that the lingual/incisal and facial/incisal line angles are lined up with the desired shape in the putty matrix from the diagnostic wax-up.

After the tooth was contoured to a proper outline shape with the coarse disk, medium and fine disks were used for further polishing. Any overhangs were removed with the surgical...
Bard-Parker blade No. 12B. The speed of the electric handpiece—set at a contra angle—was 40,000 rpm. The finishing of a composite restoration takes precision and time. One must ensure that all surfaces are polished completely and no sharp angles or overhangs are present. Dentists who are new to restoring anterior teeth with direct resin veneers may make the mistake of not giving the finishing stage a high priority, when it is at this critical stage that close attention to detail produces a final restoration that appears as a natural, polished tooth.17

Additional lines were drawn on the tooth to begin placing the facial anatomy (Fig. 14-17).7 The tooth was divided into thirds from cervical to incisal, and a triangular line was placed where ridges and depressions were desired. The facial anatomy was placed with a Brasseler 8888.012 diamond bur (Brasseler USA). The electric handpiece was then turned down to 2500 rpm and the corrections were done with a very delicate touch, in an effort to avoid gouging the composite. When viewing the final restoration, the light should be reflecting off of the line angles and other highlights of the tooth, known as reflective areas. The depressions on the facial surface of the tooth do not reflect any of the light, and are known as deflection areas. It is very important to remember when placing the facial anatomy of a central incisor that teeth No. 8 and 9 should be mirror images of each other.

After the depressions were placed in the facial surface, additional faint lines were placed in the surface which served to break up the light reflections and make the finished tooth look more natural. A super fine disk was then used to put a smoother surface on the majority of the tooth. The finished interproximal surfaces will also prevent the bonding of the adjacent tooth from sticking to the finished tooth.

Attention was then turned to restoring the opposite central incisor. The central incisors are the cornerstone of the smile and should always be completed first. Determining the length of the interproximal area is always addressed after both central incisors are completed. According to the 50-40-30 rule, the length of the connector between the centrals should be 50% of the height of a single central, assuming both central incisors are identical.18 So if an ideal tooth is 10 mm long, the interproximal connector size would be 5 mm. This can be increased to simulate an older smile, or less with a more youthful smile. The incisal embrasure can be altered for the desired length. The connector size between the lateral and central would then be 40%, and 30% for the lateral incisors and cuspids. The incisal embrasures increase as one progresses to the posterior.

The lateral incisors were then completed, knowing that the gingival heights were going to be uneven, based on the patient’s decision not to work on the tissues. Laterals do not need to be mirror images of each other, but optimally should be similar. In this patient’s case, the author would have liked the tissue heights to be closer in size. That is why it was so important that everything was explained to the patient in advance so there were no unrealistic expectations.18

The final disk polishing was completed and photos were taken to evaluate the shape and other details of the restorations.19 The patient was scheduled to return to the office approximately 3 weeks later, after the tissues had healed from the placement of the retraction cords. At the follow-up visit minor modifications were made to the incisal embrasures and the facial anatomy (Fig. 18). The final step in completion of the composites was polishing the teeth with a Cosmedent FlexiBuff wheel utilizing Enamelize composite polishing paste (Cosmedent) (Fig. 19).20 The author has found that only small amounts of this polishing paste are needed to get a high gloss shine. The patient returned a few weeks later for final photos (Fig. 20).

Discussion
The patient received a treatment that drastically improved not only his smile, but his self-confidence. His existing tooth structure was maintained, which was especially important due to his young age. Leaving the enamel intact, the treatment ensured that the teeth remain strong with minimal flexure during masticatory forces.21 Any future repairs, if necessary, could be readily accomplished.

Composite resin veneers can have the esthetics of natural teeth, be minimally invasive, and provide an excellent treatment for many patients. Composite resin veneers have several advantages as an esthetic treatment over porcelain restorations. For instance, when these veneers are applied over dark or tetracycline-stained teeth, the control of color rests solely in the hands of the dentist.

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Porcelain veneers rely on a laboratory technician using only a description and photography. The result may be multiple visits in order to match the final colors needed. With composite veneers, the dentist can easily visualize and apply the exact colors necessary to achieve the desired outcome. The matching of adjacent teeth is accomplished easier and more accurately when using multiple colors and tints in the restoration. Shape and contour can also be determined with the surrounding lips and facial features.

The restoring dentist has a variety of restorative materials of which to choose. Many brands of dental resin composites exist that have similar properties, but their ease of handling and color shades can be very different. The dentist must find the composite he/she is most comfortable with and understand the interaction of the various colors in order to achieve an optimal result. There is no simple way to accomplish this task, but an understanding of the material strength, and the color interaction of the materials under the existing tooth color is a great start. Further skills in contouring the zone with excellent results. There are many situations in which direct resin is the best treatment modality, especially in the cases of younger patients—such as teenagers—who should not have tooth structure removed if there is a way to avoid it. There is only a fixed amount of enamel in permanent teeth, and dentists as a profession must respect that. Banking tooth structure for the patient’s future is essential. Today’s dentists should be thinking about being minimally invasive in all treatments.

Author information
Dr. Peck is in private practice in Cincinnati, Ohio.

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Comparison between visual and instrumental methods for natural tooth shade matching

Welson Pimentel, DDS, MSc • Rodrigo Tiossi, DDS, PhD

Tooth shade matching in daily clinical practice is still a cause of discomfort for many professionals due to the subjectivity of the process and the need for advanced training; this discomfort may lead to unsatisfactory results for the clinician and the patient. Instrumental methods were developed to simplify daily color matching procedures and to provide better esthetic outcomes. This study compared the accuracy of shade matching by both visual and instrumental methods to determine whether the instrumental method would significantly improve the process. Visual shade matching was performed by 4 dentists using a classic shade guide; instrumental shade matching was performed with a spectrophotometer by a previously calibrated examiner. Shade matching was conducted in a dental clinic under controlled illumination on the middle third of the right central incisor tooth of 30 subjects. Data were analyzed by Cohen’s Kappa inter-rater agreement and by the equality of 2 proportions test ($\alpha = 0.05$). Results showed statistically significant differences between the groups (76.7% ± 11.1% and 32.4% ± 7.8% for the instrumental and visual methods, respectively). Shade matching by clinicians using the instrumental method presented more agreement, and was more effective than shade matching by clinicians using the visual method.

Dental shade matching is a challenging and difficult task for clinicians. Unlike dental shape, size, proportion, and texture, dental shade selection is affected by environmental light conditions, age, variable viewer interpretation, previous eye exposure, and eye fatigue. Even experienced clinicians can erroneously select and evaluate the color of teeth and restorations. Visual shade selection relies on the clinician’s interpretation of color and the communication of the selected color to the technician. Visual shade guides and spectrophotometers were developed to facilitate and standardize the communication between dentists and technicians.

The correct tooth color selection is essential for the successful esthetic outcome of a restoration. The use of commercially available visual shade guides is the standard for tooth color matching of prosthetic restorations. However, visual color assessment is subjective and relies on a series of visual evaluations that are communicated between 2 or more professionals using shade guides that do not always represent the entire gamut of natural teeth. The variable of viewer interpretation is another difficulty of visual shade matching for oral rehabilitations.

Other factors that could compromise the esthetic outcome and the final shade of ceramic restorations include differences between the dental shade guides and the dental porcelain, nonuniform porcelain layer thickness, porcelain processing variables, wrong shade interpretation, and uncontrolled environmental light conditions. Spectrophotometers and colorimeters have been developed in an attempt to overcome the difficulties and complexity of visual shade matching. Instrumental measurements can quantify color and enable communication to be more uniform, more rapidly obtained, and more precise than visual measurements. However, instrumental shade matching is not error-proof. Translucent optical differences between teeth and dental ceramics can modify the standardized illuminating light used for color determination. The software used during instrumental shade matching is capable of predicting some of the optical differences, but complete compensation is difficult to achieve and could lead to errors. The color database that is available in the chosen software also influences the accuracy of shade matching.

This study evaluated the accuracy of both visual and instrumental tooth shade matching in an effort to determine whether the instrumental method would provide significant assistance in the color selection process. The tested null hypothesis was that there would be no significant differences between the visual and instrumental methods.

Materials and methods
The trial protocol for this study was approved by the ethics committee of the Sao Leopoldo Mandic School of Dentistry, Brazil (Protocol No. 2007/0145). Four dentists with different levels of experience (3 professors, 1 master’s candidate) voluntarily participated in this study for the visual selection method. Each participant was screened for color deficiencies using Ishihara’s plates for color blindness. The study sample consisted of 30 volunteer dental students from the Sao Leopoldo Mandic School of Dentistry who presented with a sound right central incisor and without any severe enamel anomaly or pigmentation.

Visual shade matching was performed separately on each patient by each dentist that participated in the study. The 4 dentists were classified as D1, D2, D3, and D4. The visual assessment of tooth shade was done under a corrected light source with a color temperature of 5500 K. Dentists were instructed to use the middle third of the tooth for color selection with the aid of a shade guide (VITA VITAPAN Classical Dental Shade & Color Guide, Vident) (Figure). A previously calibrated examiner performed the instrumental measurement. Three measurements (SP1, SP2, and SP3) were performed on each patient, on the same incisor, for the instrumental

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shade matching with a dental spectrophotometer (SpectroShade Micro, MHT S.r.l. A Socio Unico).

Data were collected and submitted for statistical analysis. Cohen’s Kappa inter-rater agreement and the equality of 2 proportions test compared the visual and instrumental tooth color assessment ($\alpha = 0.05$).

**Results**

Table 1 presents the proportion distribution of the tooth colors that were selected by the different examiners using the visual method. The selection of the tooth color A2 was different between examiners D1 and D3 and examiners D2 and D4. Table 2 presents the colors selected in the consecutive instrumental measurements. No significant differences between the consecutive instrumental measurements were found and the agreement between measurements was determined to be significant ($P < 0.001$). The agreement found for the different instrumental measurements was higher than that found for the different examiners using the visual color assessment ($P < 0.001$) (Table 3).

**Discussion**

The accuracy of dental shade matching between visual and instrumental methods for tooth color selection was evaluated in this study. The results support rejection of the tested null hypothesis, since the instrumental method presented significantly better agreement than the visual method. Accurate color selection is a complex and significant aspect of successful esthetic outcomes for dental restorations. Small color differences will lead to dissatisfied patients and dentists. Shade matching has always been a source of challenge for the clinician. Despite not presenting the entire gamut of natural tooth color, the Vita classical shade guide used in this study was selected because of its widespread use in dental clinics.

With the introduction of new technologies comes speculation about reliability. A 1998 study by Okubo et al found that the chosen colorimeter was precise in 50% of shade matching cases, whereas the visual method showed a precision rate of 48% with no significant differences between the methods. The differences between the results found by Okubo et al and the present study could be due to the fact that the instruments used were different. However, other studies found results that were similar to those of the present study,
with significant differences between the visual and instrumental methods. A study by Paul et al used 3 operators that independently assessed the best match to the middle third of unrestored maxillary central incisors of 30 patients. The same tooth color was measured 3 times by a reflectance spectrophotometer. The agreement between the operators was only 26.6%, whereas the agreement between each spectrophotometric assessment was 83.3%. Another study compared conventional visual and spectrophotometric shade assessment for porcelain-fused-to-metal crowns in 10 patients. The shade evaluation matched for all 3 visual shade selections in only 2 cases. By comparison, the spectrophotometric shade selections matched in 9 of 10 cases. Two studies compared the reliability of shade-matching instruments. All the tested devices presented high reliability, with values ranging from 85% to 99%. This further supports the use of spectrophotometers for dental shade matching.

The shade matching between the 2 methods that were tested also found a better agreement when lighter (more value) or darker (less value) colors were present. These results are in agreement with a study by Lagouvardos et al, which found that darker shades presented more reliable and valid shade matching results, and that intermediate shades were less distinguishable between each other. Individual color perception and variable viewer interpretation influence the reproducibility of a dental restoration. A successful tooth shade selection relies on adequate knowledge of color science and control of the variables that influence the visual color assessment. The perception of color is subjective and different between viewers, and is also affected by environment light conditions.

The instrumental analysis with the spectrophotometer can be a valuable aid to the clinician, providing better color agreement and standardization to contribute to a better aesthetic outcome of a dental restoration. It should be stated that the use of only 1 visual shade guide was a limitation of this study. Future studies are recommended to compare differences between other visual shade guides and different instrumental equipment.

**Conclusion**

Within the limitations of this study design, and based on the results that were found, it can be concluded that dental shade matching using an instrumental method was more reliable and repeatable compared to the visual method. The use of an instrumental method is therefore recommended for adequate tooth color selection.

**Author information**

Dr. Pimentel is a director, Advanced Education Program, Implantology and Implant Prosthodontics, Brazilian Dental Association, Sao Goncalo, Rio de Janeiro, Brazil. Dr. Tiossi is an assistant professor, Department of Prosthodontics, School of Dentistry, Fluminense Federal University, Niteroi, Rio de Janeiro, Brazil.

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Diagnosis, treatment, and risk management for a victim of domestic abuse: a case report

Richard W. Featherstone, DDS, AAACD, FAGD, AFAAID

A 37-year-old woman was referred to the author by the American Academy of Cosmetic Dentistry’s “Give Back a Smile” program. The program helps facilitate dental treatment and support services for adults who have suffered dental injuries to the smile zone as a result of domestic or sexual violence. The woman presented with a broken jaw and fractured teeth. This case report describes the treatment planning decisions and a successful outcome.

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Key words: diagnosis, treatment, implants, GBAS, bridges

A 37-year-old woman was referred for treatment by the American Academy of Cosmetic Dentistry’s (AACD) “Give Back a Smile” (GBAS) program, which is designed to provide treatment and support services at no charge to adults whose smiles have been damaged as a result of domestic abuse.1 The patient’s chief complaints were partial edentulousness and the discoloration of her remaining teeth (Fig. 1). While many of the patient’s dental problems were a result of several instances of blunt force to the face, the patient also reported bruxing in times of stress and that she had a 10 cigarettes/day smoking habit. She was 3 months pregnant and not taking any medications. Cold stimulation to the teeth produced pain. The patient also reported occasional pain in the right jaw, with no joint sounds.

Diagnosis and risk assessment

A panoramic radiograph strongly suggested a Type VI intracapsular fracture as described by Spiessl & Schroll (Fig. 2).2 This was considered to be a result of the patient receiving a blow to the jaw. Healing of the fractured condyle shortened the right ramus by approximately 8 mm; as a result, the bite was collapsed on the right side (Fig. 3). Complications in the treatment plan were expected due to the multiple missing teeth, the impacted condylar fracture, and the lack of research guidelines on treating occlusion after fractures.

Additional photographic, radiographic, and clinical records were made, along with impressions, face-bow, and bite registrations for diagnosis and for creating a wax mock-up with an articulator (Artex, Jensen Dental Incorporated). An outline of diagnostic information and risk assessments was derived by examining 4 key elements: temporomandibular joint (TMJ) disorder, periodontitis, caries and structural defects, and esthetics.3

TMJ disorder and functional issues

Examination of the TMJ and masseter muscles revealed no discomfort. Slight anterior pressure in the ear canal upon jaw opening revealed joint clicking on the right side. The jaw opening was normal at 54 mm but was accompanied by deviation. An attempt to place the joints in centric relation with bimanual manipulation revealed interference at tooth No. 12. Upon closure, the jaw moved markedly to the left and forward 2 mm to a more centered position. There was discomfort (described by the patient as “tension”) in the right side during joint loading with bimanual manipulation.4

Periodontal disease

The initial examination revealed 6 mm periodontal pockets between the maxillary left molars and 5 mm pockets between the maxillary premolars, with bleeding on probing. The diagnosis was moderate periodontitis.

Caries and structural elements

Caries was severe. It was determined that teeth No. 7, 10, 13, 15, 27, and 28 were nonrestorable due to decay or fracture. Pulp testing revealed that teeth No. 7, 9,
10, and 27 were nonvital. The radiograph revealed a periapical lesion on tooth No. 10. The patient’s susceptibility to caries could further compromise the treatment plan (Fig. 4 and 5).

**Esthetics**
The patient’s upper lip rose to 2 mm below the gingival margins when forming the “e” sound. This was an acceptable level, requiring no treatment.

**Treatment plan**
The goals of treatment were to improve the patient’s long-term quality of life and social confidence, preserve maxillary and mandibular bone mass, and provide both adequate function and a high level of esthetics. The challenge was to employ treatment that would serve the patient’s interests while conforming to GBAS guidelines. The patient had 6 structurally sound teeth remaining in the mandible. Only 7 teeth would remain in the maxilla after the necessary extractions were performed. It was determined that treatment would involve placing maxillary fixed prostheses and a mandibular immediate hybrid implant prosthesis with tilted implants.

**Maxilla**
Teeth No. 7, 10, 13, and 15 were extracted and endodontic therapy was performed on teeth No. 9 and 14. Bridges were made for teeth No. 3-8 and 9-14, to provide the maximum amount of bone preservation, esthetics, and function. The patient’s periodontal health and foundational bone level were manageable.

High caries risk required the patient to be able and willing to maintain the bridgework. The patient responded well to hygiene instructions, and it was felt that she would continue long-term maintenance. Another concern was the use of a cantilever at the tooth No. 3 position. Upon review, it was determined that the risk for fracture or stress on anterior abutments would be low, because the cantilever would be attached to 4 strong teeth, none of which had root canal fillings or posts. The bridge extended to the central incisor, providing 24 mm anteroposterior and 15 mm mediolateral support, as measured at the long axes of teeth No. 8 and No. 4, thus providing an ample amount of resistance to cantilever forces.

**Mandible**
Treatment involved extracting the remaining teeth, performing a 5-7 mm vertical reduction alveolectomy, and placing 4 implants and an interim fixed appliance in a single visit. This approach provided the patient with immediate function and long-term bone maintenance from that time forward. The longer posterior implants (16 mm) were angled so that the 30 degree multi-unit attachments would exit the tissue near the same position as a molar vertical implant, which negated the need for a long cantilever. There has been impressive documentation on the success of immediately restored fixed hybrid dentures in edentulous mandibles. This treatment plan was proven to be effective in a 2012 review article documenting 462 patients in 10 studies. Other retrospective/longitudinal studies reviewed cases involving 410 patients, with success rates comparable to other implant-supported prosthetic procedures. This is particularly impressive as the majority of these cases used NobelActive prostheses with a miniscule 15 Ncm of torque on very small screws to retain the prostheses. Misch expressed serious misgivings regarding this technique and the low torque in 2011; however, the cases have proven successful.

The author of this case report has had previous experience with this operation, including managing another fixed hybrid implant patient who functioned successfully with 3 implants for 9 months while bone grafting healed around a fractured facial plate at the right posterior position.

The only treatment obstacle remaining for the patient was finding donors for the mandibular implants, the 2 prosthetic appliances, and the maxillary fixed prostheses in order to reduce costs of this pro bono case. The 3 donors listed in the Acknowledgments section agreed to donate materials and labor.

**Treatment options and considerations**

**Full or partial dentures**
The options of full or partial dentures—including 2 implant-retained mandibular overdentures—were rejected because of the resultant edentulism which would eventually lead to ≤60% bone loss. At 37 years old, the patient was determined to be too young to risk that amount of bone loss.
Reconstruction
One viable option involved selective extractions followed by crowns and bridges on implants and natural teeth. This would involve at least 7 implants, crown lengthening, and placing crowns on every tooth. It was the most complicated, risky, and time-consuming option; in addition, the scope of this treatment plan went well beyond GBAS guidelines, which state: “The program is designed to focus on standard of care smile-zone dentistry, not full mouth reconstruction.”

Implant-supported dentures
Treatment of edentulism with implants and prosthetic appliances has been documented in the literature. These studies reveal that implants protect bone over the long term, which helps preserve bone mass. Many options are possible for bone preservation, such as cantilevered bar overdentures, overdentures or bridges without cantilevers, overdentures attached to individual implants/mini-implants, and immediate maxillary and mandibular temporary hybrid implant prostheses, followed by fixed milled bar hybrid dentures. These options would have fulfilled the treatment plan’s objectives. Some are complex and time-consuming, and some require long-term maintenance, such as replacing worn removable attachment apparatuses. Other options that involved cantilevers were more prone to restoration fracture and screw loosening/breakage.

One option that was considered for the mandible involved adding implants posterior to the mental nerve. This procedure would have been risky since the left mandible was resorbed already. Figure 6 shows a narrow implant (10 mm in length) in this position, which was very close to the mylohyoid depression. In addition, the crest was too narrow to allow 2 mm of bone on the buccal and lingual sides. As a result, it was decided that placing long, tilted implants following the ostectomy was the simplest and best solution.

Another option involved extracting the 7 remaining viable maxillary teeth and placing an implant-supported hybrid denture similar to that planned for the mandible. However, this procedure would require an invasive reduction of bone height; in addition, there is evidence that implant-supported maxillary prostheses do not fare as well as mandibular prostheses. Studies using machined Branemark implants showed that the denser bone of the mandible is more amenable for long-term implant success compared with the softer Type III or IV bone common to the maxilla.

The plan of treatment used in this study went beyond the GBAS-suggested treatment protocol regarding the esthetic zone and constituted reconstructions. However, the author found it difficult to compromise the patient’s long-term health and well-being while staying within those guidelines, and thus chose the more appropriate, less complex treatment.

Treatment
Extractions, crown buildups, and endodontic therapy were performed over 2 visits. Two months after extractions in the esthetic zone, 2 maxillary bridges were prepared for teeth No. 3-8 and No. 9-14. Teeth No. 13 and 15 were extracted. Prototype resin bridges created from a wax mockup (Yeti Dentalprodukte GmbH) were placed.

The intaglio surfaces of the pontics were shaped into a modified oval with a flattened bottom to maximize papillae support. Seven months after initial presentation, the patient returned for treatment of the mandible. Impressions were made for an immediate denture. A bite relation was created with a Jankleson Myomonitor (Myotronics) to record myofunctional occlusion since the fractured right condyle was painful in the retruded, manipulated centric relation. A computed tomography scan was deferred until after the patient delivered her baby. The scan provided information used in the planning positions, lengths, and angulations of the implants. Following extractions and an ostectomy, 4 implants—measuring 4.7 x 16 mm with 4.5 mm platforms (Implant Direct, LLC)—were placed using an
All-on-4 surgical guide (Nobel Biocare USA, LLC) to aid with angulations. Two 30-degree and 2 15-degree angled abutments were screwed into the posterior and anterior implants, respectively. An impression was made of the mandibular implants and sutured ridge to fabricate the implant replica model. The mandibular appliance had been prepared by a technician from impressions of the mandible made at a previous office visit. The denture was hollowed out in the implant temporary abutment areas, attached to the implants with resin, and removed so that resin could be added and trimmed by the attending technician. Following the implant manufacturer's instructions, the mandibular hybrid, all-acrylic denture was screwed in at 30 Ncm and adjusted for occlusion to the prototype maxillary bridgework.

One month later, the impressions and bite registration were made for the final maxillary prostheses. An image of the bite stick was sent to the laboratory to confirm horizontal alignment. That same month, the mandibular hybrid denture was removed; at that time, it was observed that the implant tissue around the implants was very healthy. The patient's home care regimen included a Water Flosser (Water Pik, Inc.). She had been diligent about cleaning along the intaglio surface of the denture (giving special attention to the implant sites) and maintaining the prototype maxillary bridgework (Fig. 7 and 8). Bleeding on probing was nearly nonexistent.

The following month, the bridges and teeth No. 3-8 and No. 9-14 were seated, with only minor adjustments made to the acrylic mandibular teeth. At a follow-up visit the next month—9 months after initial presentation—the patient's periodontal health remained excellent. Four months later, the patient returned for an oral hygiene checkup and to have impressions made for the final mandibular prosthesis. The patient continued to maintain her oral health.

Results
A panoramic radiograph of the completed case shows prescribed implant angulation and no bone loss (Fig. 9). Fig. 10 shows the patient with an improved smile, and Fig. 11 shows the before and after anterior views of the patient's mouth.

Summary
This article describes the diagnosis, treatment plan, and options considered for a patient whose fractured jaw and super-erupted broken teeth complicated the planning. The risks outlined for caries and periodontal disease were mitigated by the patient's willingness to perform oral hygiene functions on a daily basis, and therefore were reduced to “low risk.” The risk of future TMJ disorders in the patient will continue to be moderate due to the fractured ramus.

This case establishes the fact that, when given the opportunity, people can recover from facial damage due to domestic abuse.
Acknowledgments
The author would like to thank Dr. Gerald Niznick and Implant Direct for donating the implants and prosthetic parts; Dr. Robert Winter and The Winter Laboratory for donating the wax-up, provisionals, and porcelain-fused-to-metal prostheses; and George Savage and Implant Bars for donating time and materials, including the milled bar.

Author information
Dr. Featherstone is a general dentist in Henderson, Nevada.

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Direct or indirect composite veneers in anterior teeth: which method causes higher tooth mass loss? An in vitro study

Alessandra Nunes Machado, DDS • Fabio Herrmann Coelho-de-Souza, DDS, MSD, PhD • Juliana Nunes Rolla, DDS, MSD, PhD
Maria Carolina Guilherme Erhardt, DDS, MSD, PhD • Flavio Fernando Demarco, DDS, PhD

There is little information in the literature regarding the relationship between preparations made for direct and indirect veneers and the loss of tooth structure required for each technique. This in vitro study sought to quantify the different mass losses from preparation techniques used for direct and indirect veneers. Thirty artificial teeth were weighted using a digital balance and placed in a dental manikin in the position corresponding to the right maxillary central incisor. Five clinicians—all experts in esthetic dentistry—were asked to perform conventional preparations for both a direct composite resin veneer and an indirect ceramic veneer. After preparations, specimens were weighted again in the same digital balance. Teeth undergoing veneer preparations demonstrated a statistically significant mass loss compared to unprepared teeth. Indirect ceramic veneer preparations produced more mass loss than direct composite veneer preparations ($P < 0.01$).

Keywords: dental veneers, dental cavity preparation, tooth structure, esthetics, ceramic, composite resin

Modern dental patients are increasingly concerned about esthetics, alignment, and whiter teeth without discolorations or surface alterations. Anterior teeth play a crucial role in facial esthetics. In some clinical situations, more conservative techniques (such as dental bleaching or conventional composite restorations) are unable to produce a satisfactory esthetic result, and veneer preparations may be required. Although veneer placement has the potential for esthetic benefits, their preparation requires removing sound tooth structure. According to the concept of minimally invasive dentistry, the preservation of sound tooth structure is important and techniques that result in greater preservation of dental structure may be preferred.

With the evolution of adhesive systems and photo-activated composite resins, less invasive adhesive restorative techniques can be developed that remove comparatively little sound dental structure. The main disadvantages involved in these adhesive restorations include the need for highly sensitive techniques, the complex application of materials, and the need for correct marginal sealing against deleterious factors that could compromise longevity. Direct composite veneers are a popular adhesive technique for improving esthetics in discolored, decayed, or fractured anterior teeth. Direct composite veneers involve a buildup of sequential layers over the buccal tooth surface. This technique may be performed in a single session, without the need for laboratory work, and involving a reduced removal of sound tooth structure when compared to indirect ceramic veneers. This technique also offers both restoration longevity and satisfactory esthetic results.

Indirect ceramic veneers are another esthetic restorative technique available for anterior teeth. This technique traditionally requires some preparation that includes tooth structure loss, such as removing contact points and incorporating the incisal edge to allow adequate space for taking an impression and veneer adaptation. To preserve the maximum amount of tooth structure, some authors have advocated a minimal preparation even for indirect ceramic veneers. For young patients with large pulp chambers, the preparation of conventional ceramic veneers could damage the pulp dentin complex. However, the esthetic results obtained with ceramic veneers is excellent and the longevity of this treatment tends to be higher than that for direct veneers.

Both techniques (direct and indirect veneers) have been described in the literature. However, there is a paucity of information regarding the amount of tooth structure that must be removed during these clinical procedures. This study sought to quantify the amount of tooth loss needed for direct composite veneers and indirect ceramic veneers, and to detect if there were significant differences in tooth loss between both techniques.

Materials and methods
To perform this study, artificial right central incisors were selected and divided in 2 groups according to the veneer technique preparation: direct (Group 1) or indirect (Group 2).

Sample size calculation
A pilot study was performed to define the sample size. Three samples for each group were prepared to identify the mean and standard deviations, with a 95% confidence interval. With an estimated error of 15% and a standard deviation of 0.029 g, a sample size of 14.3 teeth per group was obtained.

Specimen selection
Thirty artificial teeth corresponding to the right maxillary central incisor were selected, numbered, and weighted in a digital balance. Before weighting, the specimens were stored at 37°C for 24 hours. Fifteen specimens were allocated randomly to both groups.
**Specimen preparations**

The veneers were prepared for 5 previously calibrated experts in esthetic dentistry with similar clinical experience. The experts were blinded in relation to the objectives of the study. Each dentist prepared 6 artificial teeth, 3 for each group.

The specimens were prepared with the teeth mounted in a dental manikin (P Oclusal Produtos Odontologicos Ltda ME) to better simulate clinical conditions. For specimen preparation, each dentist received the same preparation kit, including a high-speed turbine, a low-speed micromotor, mirror, explorer probe, and diamond burs (KG Sorensen), Soflex disks (3M ESPE), polishing strips (3M ESPE), silicone points, and a manual instrument for finishing margins.

When the dentists received the specimens and instrument kits, a hypothetical clinical situation was explained to them: “A patient who has stated a desire for improved esthetics has a nonvital right maxillary central incisor, well-aligned in the arch. The tooth shows a moderate discoloration and it is not responding to bleaching treatment.” Two restorative options were offered to the dentists: a conventional direct veneer preparation for composite resin, and a conventional indirect veneer preparation for ceramic.

After direct and indirect preparations, the teeth were collected, washed, dried with a paper towel, and maintained at 37°C for 24 hours; at that point, they were weighted again in the same digital balance. The structure loss was determined by comparing the weight before and after preparations.

**Statistical analysis**

A paired t-test was used to compare differences between groups, with the confidence level set at \( P < 0.01 \).

**Results**

Data related to the weight in different groups are listed in the Table, along with mass loss and statistical analysis. The results showed that unprepared artificial teeth had similar weights \( (P = 0.208) \). Differences were observed between unprepared teeth and prepared teeth in both groups \( (P < 0.001) \), with the indirect veneer specimens exhibiting the highest mass loss \( (P < 0.001) \).

**Discussion**

This study showed that both veneer preparations resulted in a significant loss of tooth structure; the loss increased when an indirect ceramic veneer was prepared.

Different methods have been described to measure the amount of tooth structure removed for indirect ceramic preparations. The present study employed a methodology that had been used previously to determine the loss of tooth structure when preparing different esthetic treatments for anterior teeth. Hussain et al evaluated mass loss in naturally extracted canine and incisor teeth that were submitted to different endodontic and restorative treatments. It is important to note that the use of naturally extracted teeth is becoming more difficult not only because of ethical concerns, but also because the concept of preventive dentistry has caused a significant decrease in the need to extract teeth. Artificial teeth appear to be a reliable alternative for this kind of study. At present, no study has used a similar approach to compare mass loss for veneer preparation.

Tooth discoloration was the only criteria used in this study to indicate the need for a veneer preparation. Other criteria that could influence the preparation (such as tooth decay or bad alignment) were not included, because it would be difficult to reproduce and standardize them in a manikin.

The preparations were performed using an air/water spray, as resin is a material that can absorb water. Before weight measurements were performed, teeth (prepared and unprepared) were stored for 24 hours at 37°C. According to Edelhoff & Sorensen, weight stabilization for artificial teeth is obtained after storage for 24 hours in similar conditions.5

Stappert et al measured differences in the amount of tooth loss between different veneer preparations in terms of deepness in millimeters.15 Representing tooth loss in mm can allow for better visualization, using the top of the burs as a guide. However, the analysis of mass loss, while not feasible clinically, is useful for research purposes, as it allows for the quantification of the necessary amount of tooth structure that needs to be removed with the different veneer preparations.

Measuring mass loss is quite simple and can be reproduced easily in different laboratories for testing similar conditions. To ensure standardization, only 1 tooth type was used (right maxillary central incisor).

The main reason for the difference in weight observed is due directly to the more aggressive designs required for ceramic restorations. When an indirect veneer was prepared, the incisal border was removed and proximal contacts were invaded also; such steps were not necessary for direct composite preparations. There are several advantages to preparing a direct composite veneer instead of a ceramic veneer, including lower cost, immediate results, reduced time required for the preparation/restoration, good clinical performance, and the elimination of laboratory work. A deeper preparation—such as those commonly found in ceramic veneers—can also cause pulpal problems and postoperative sensitivity. However, the more aggressive preparation with a ceramic restoration is associated with better esthetics and higher longevity.

This study’s ability to determine mass loss precisely reinforces the need for more conservative preparations whenever possible, to avoid removing additional tooth structure, which may weaken the teeth in the long term.

**Table. Mean weight and standard deviation (SD) for unprepared and prepared teeth (in grams).**

<table>
<thead>
<tr>
<th>Group (n = 15)</th>
<th>Unprepared teeth</th>
<th>Prepared teeth</th>
<th>Mass loss rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (direct veneer)</td>
<td>0.688 (0.003)\textsuperscript{a}</td>
<td>0.607 (0.012)\textsuperscript{b}</td>
<td>11.8</td>
</tr>
<tr>
<td>2 (indirect veneer)</td>
<td>0.690 (0.004)\textsuperscript{a}</td>
<td>0.561 (0.027)\textsuperscript{b}</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Different uppercase superscript letters indicate statistically significant differences between columns \( (P < 0.01) \). Different lowercase superscript letters indicate statistically significant differences between rows \( (P < 0.01) \).
Conclusion
Within the limitations of this in vitro study, it was possible to conclude that both preparation types caused tooth mass loss, and that the loss was greater for the indirect veneer preparations.

Author information
Dr. Machado is in private practice in Porto Alegre, Rio Grande do Sul, Brazil. Drs. Coelho-de-Souza, Rolla, and Erhardt are adjunct professors, Department of Conservative Dentistry, College of Dentistry, Federal University of Rio Grande do Sul, Brazil. Dr. Demarco is a professor, Department of Operative Dentistry, Federal University of Pelotas, Brazil.

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Approaches to managing asymptomatic enamel and dentin cracks

Samer S. Alassaad, DDS

Asymptomatic enamel and dentin cracks can pose a risk for multiple pathological and undesired consequences if intervention is postponed. This article reviews asymptomatic enamel and dentin cracks, and presents current management approaches utilized by a sample of general dentists. Becoming familiar with all forms of asymptomatic enamel and dentin cracks is crucial to adopting a proactive approach of prevention, early diagnosis, and intervention to control the potentially detrimental effects of these cracks on the dentition.

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An incomplete tooth fracture, also known as a tooth crack, is a fracture without visible separation of the segments along the plane of the fracture.1 Incomplete tooth fractures can be subtle and difficult to diagnose, especially when asymptomatic. However, they pose a risk for multiple pathological and undesired consequences that can eventually render the tooth unsavable.

The pathological consequences can range from caries to pulpal and periodontal involvement to complete tooth fracture.2-8 Walker et al demonstrated that enamel cracks provide caries-producing bacteria access to the dentin-enamel junction, thus leading to caries progression inside the tooth without any externally visible evidence.2 Abou-Rass suggested that asymptomatic crack lines are precursors to the symptomatic cracked tooth syndrome.3 Krell & Rivera found a 9.7% incidence of cracks in all teeth referred to an endodontic practice within a 6-year period, excluding cusp fracture, vertical root fracture, and split teeth.5 In their study, 20% of the cases diagnosed as cracked teeth with reversible pulpitis and treated with full crown restorations nevertheless progressed to irreversible pulpitis or to necrotic pulp within 6 months.5 Pitts & Natkin described periodontal involvement associated with tooth cracks as bone loss produced by chronic inflammation along the fracture line, causing a narrow isolated pocket and radiographically linear bone loss along the root surface.6 In a study of cusp fracture in restored posterior teeth, Bader et al concluded that incomplete fractures are a predictor of complete cusp fractures, which have been found to have an incidence of 69.9/1000 persons each year.7,9 Finally, Braly & Maxwell concluded that fractures are the third most common cause of tooth loss behind caries and periodontal disease.10

Based on the evidence that incomplete tooth fractures can lead to major complications, and taking into consideration that the incidence of fractures increases with age, a more proactive approach, in which asymptomatic cracks are addressed early—before major complications occur—should be considered. This is especially relevant with the current aging population.7,10,11 However, there has been less agreement among dentists on which teeth are at risk for fracture, and which teeth require intervention for the prevention of fracture.12 A recent literature review concluded that there is no universally accepted restorative protocol to treat cracked tooth syndrome.13 Consequently, this author conducted a literature review of managing asymptomatic enamel and dentin cracks, and conducted a survey using clinical images during multiple presentations to determine how general dentists currently manage these cracks in their general practice.

Materials and methods

The author gave presentations on managing incomplete tooth fractures to 4 different groups of dental professionals in Northern California between March 2012 and March 2013. A total of 71 dental professionals—54 general dentists, 15 dental specialists, and 2 dental hygienists—attended these presentations. At the beginning of the presentations, clinical photographs of asymptomatic enamel and dentin cracks in posterior teeth were projected on a screen to ensure uniformity in the referenced cases. Enamel and dentin cracks were classified according to their direction (vertical or oblique).
and the presence of stain. Enamel cracks were additionally classified based on their detection by tactile examination with an explorer, transillumination, and staining with methylene blue dye. All attendees were then asked to answer multiple choice questions regarding the approaches they utilize in their practice to manage the projected asymptomatic enamel and dentin cracks, such as when and what they recommend for intervention. To preserve anonymity, participants were asked not to write their names on their answer sheets. Some of the dental specialists who attended the presentations limited their practice to their specialty and did not directly treat asymptomatic cracks. Seven dental specialists and 2 dental hygienists did not complete the survey. Therefore, only responses from general dentists were included in the results. Of the 54 responses from general dentists, 3 were excluded as their answers were incomplete; descriptive statistics of responses from the remaining 51 general dentists were then computed.

Survey results
The majority of the general dentists (73%) would recommend to their patients the removal of intracoronal restorations in order to explore the extension of asymptomatic vertical enamel cracks in posterior teeth when these cracks were both stained and detectable by an explorer, even though the restorations were not compromised and the teeth had no evidence of decay (Fig. 1). This was followed by 62% of the general dentists who would recommend to their patients the removal of intracoronal restorations to explore for oblique enamel cracks originating from the corner of restorations and detectable by transillumination (Fig. 2). Twenty-nine percent would recommend removal for vertical enamel cracks that were unstained but accepting methylene blue dye (Fig. 3); 25% would recommend removal for vertical enamel cracks that were stained but undetectable by an explorer (Fig. 4); and 12% of the general dentists surveyed would recommend the removal of intracoronal restorations to explore for unstained vertical enamel cracks that were detectable by transillumination but were not accepting methylene blue dye (Fig. 5). Twenty percent of participants would not recommend the removal of intracoronal restorations to explore for asymptomatic enamel cracks.
With regard to asymptomatic dentin cracks, 86% of general dentists in the sample would recommend treatment for stained vertical dentin cracks (Fig. 6) and 84% would recommend it for stained oblique dentin cracks in posterior teeth (Fig. 7), followed by 65% for both unstained vertical dentin cracks and for unstained oblique dentin cracks (Fig. 8 and 9). Eight percent of the general dentists surveyed would not recommend any treatment for asymptomatic dentin cracks.

Participants were then asked to rank their treatment approaches (restorative and/or occlusal) for asymptomatic vertical and oblique dentin cracks noted after restoration removal, regardless of the relationship between isthmus width and cusp-to-cusp distance. Participants were able to give the same ranking to multiple treatment approaches if they would recommend them simultaneously, such as occlusal treatments in conjunction with a restorative approach. The treatments of choice (TOC) for the 47 general dentists who treat asymptomatic dentin cracks are presented in the Table. The majority of participants were in favor of occlusal coverage restorations, such as full crown and onlays. Protective occlusal hard bite plates and occlusal adjustments of opposing and cracked teeth were the primary TOC when used in conjunction with restorative treatments.

### Literature review

#### Diagnosis of asymptomatic cracks

Asymptomatic enamel and dentin cracks can be very subtle and difficult to diagnose. They can be evaluated by transillumination, staining with dyes such as methylene blue dye, and tactile examination with a sharp explorer.\(^{14,16}\) Visual examination can also be enhanced by magnification with tools such as magnifying loupes, intraoral photography, and microscopes.\(^{14,15,17}\)

#### Management of asymptomatic enamel cracks

The traditional classifications of cracks placed less emphasis on the possibility of underlying pathologies of enamel cracks.\(^{17}\) Fortunately, more modern approaches are taking asymptomatic enamel cracks into consideration. Clark et al classified asymptomatic enamel cracks based on the risk of underlying pathologies such as dentin cracks, decay, and severely undermined enamel that allow microleakage.\(^{17}\) According to their analysis, cracks with wedge-shaped enamel ditching and cracks that either detour from or do not follow anatomic grooves have a moderate risk of underlying pathology.\(^{17}\) Diagonal cracks, cracks that house debris, and cracks with a brown, gray, or white corresponding "halo" have a high risk of underlying pathology.\(^{17}\) The greater the risk, the more strongly it is recommended to remove the restoration for further evaluation, followed by treatment of any underlying pathology as needed, even if the tooth is asymptomatic.\(^{17}\)
In their study of cusp fracture in restored posterior teeth, Bader et al concluded that external fracture lines that are detectable with an explorer should be considered strong indicators of elevated risk of complete fracture. However, it has been emphasized that even dramatic enamel cracks may not necessarily indicate the presence of any underlying pathology.8,17 Ratcliff et al classified posterior enamel cracks based on the presence of stain and restorations, and suggested that stained cracks are most likely to be treated due to their appearance.11 The authors also concluded that equilibrating the occlusion for maximum intercuspsation and eliminating excursive interferences may prevent the propagation of asymptomatic cracks.11 Walker et al also suggested that stained cracks should be considered as permeable or permeated by cariogenic bacteria, and that cracks displaying a shadow under transillumination indicate the presence of caries.2 Intervention is recommended for these cracks to block bacterial invasion and stop the progression of caries.2

**Management of asymptomatic dentin cracks**

Taking a more proactive approach of assessing enamel cracks based on the possibility of underlying pathologies—such as dentin cracks—brings another dilemma to practitioners regarding what to do when an asymptomatic dentin crack is discovered.2

Dentin cracks should be considered structural cracks and therefore protection from occlusal forces to minimize fracture propagation is indicated.3,8,17 However, Clark et al speculated that intracoronal restorations and occlusal adjustments might be proven insufficient to stop structural breakdown associated with cracks, and that occlusal coverage is mandatory.17 Replacing an asymptomatic cracked cusp with a restoration when 1 cusp is involved has been recommended.8 When more than 1 cusp is involved or there are asymptomatic vertical cracks, placing a full crown restoration is recommended.3,8

Currently the literature—including clinical trials—focuses mainly on the treatment of symptomatic cracks. However, the principles used to treat symptomatic cracks can be applied to the treatment of asymptomatic teeth predisposed to cracking; this includes the treatment of asymptomatic cracks to limit their progression and thus prevent any subsequent undesired consequences.4 Occlusal adjustment has been recommended as an initial treatment for cracked tooth syndrome.4 Although there is no universally accepted restorative protocol in the treatment of symptomatic cracks, it is generally agreed that the aim of restorative therapy is to immobilize the segments of the tooth that tend to move during loading.13 Opdam et al found that direct composite restorations maintained the pulp vitality of >90% of cracked, painful teeth, resulting in a complete elimination of pain in 75% of the affected teeth over a 7-year period.18 The authors also had more success with cuspal coverage than without.19 Modern approaches advocate reinforcing resin-based restorations with leno-weave ultra high modulus polyethylene ribbon fibers in order to bridge cracks and strengthen teeth against fractures.19,20 Crown restorations were successful in maintaining pulp vitality in 80% of cracked teeth diagnosed with reversible pulpitis over a 6-year period.5 Additionally, altering traditional crown preparations (such as beveling fractured cusps), using bases and build-ups under crown restorations, and placing margins more apically were suggested to minimize external forces and prevent the propagation of fractures underneath crown restorations.21 Additional clinical trials comparing these direct and indirect treatment options are required to determine the best treatment for the various forms of incomplete tooth fractures.18,22

**Prevention of cracks**

Whenever possible, the proactive prevention of tooth cracks is the optimal treatment choice. This requires a deep understanding of the etiology of tooth cracks in an effort to control the contributing factors to their formation. The etiology of teeth cracks is complex and multifactorial; Lynch & McConnell proposed 10 factors that contribute to cracked teeth, citing 17 examples.23 The most commonly emphasized etiologic factors are the loss of dentin support due to relatively large intracoronal restorations, and traumatic occlusal forces, especially when accompanied by excursive interferences.5,7,11 The susceptibility of teeth to fracture has been measured in terms of isthmus width in relation to cusp-to-cusp distance.24 If teeth have been weakened due to wide cavity preparations, they need to be stabilized via indirect restorations, such as full cuspal coverage or bonded inlays.25 However, the isthmus width is not the only factor that needs to be considered. The depth of the restoration along the isthmus width can be a more accurate measurement of the lack of dentin support.7

Recent research has shown that the prevalence of cusp fractures in amalgam restored teeth was found not to be significantly different than resin composite restored teeth.26 These new findings may further shift the emphasis away from treatment plans that are based mainly on the choice of restoration materials, as these may result in designs that weaken the teeth. Conservative cavity preparations that preserve tooth structure without connecting multiple occlusal preparations have been advocated.17 Additionally, rounded internal line angles have been recommended over sharp line angles to avoid stress concentrations.25 Nonrestorative approaches have also been recommended to prevent cracks. Occlusal adjustment of nonfunctional cusps of teeth predisposed to cracking—such as teeth with excessive cuspal wear, heavy wear facets, worn restorations, or posterior malocclusion—has been recommended, especially when the patient has a history of cracked tooth syndrome.4 Although occlusal guards have not been directly linked to preventing cracks and limiting their progression, they are considered useful protectors of teeth against the damage caused by bruxism. Thus they are an option worthy of consideration in patients with a history of symptomatic cracks and evidence of bruxism.27

**Summary**

The majority of the general dentists who completed this survey would recommend intervention for some forms of asymptomatic enamel cracks, but were more proactive when it came to treating asymptomatic dentin cracks, emphasizing restorations that provide occlusal coverage. Becoming familiar with the existence of all forms of asymptomatic enamel and dentin cracks, the modern methods of
their diagnosis, and the levels of risk of underlying pathologies is crucial to adopting a proactive approach of prevention, early diagnosis, and intervention before major complications occur. In the wake of limited available knowledge, and until more evidence validates the necessity and the different modes of intervention for all forms of asymptomatic cracks, clinicians must rely on their clinical experience in weighing the benefits and risks of observation vs intervention, and then guide their patients to make informed decisions.

**Author information**
Dr. Alassaad is in private practice in Davis, California.

**Acknowledgment**
The author would like to thank the dental professionals who attended the presentations and participated in the survey.

**References**
The 15 questions for this exercise are based on the article, Approaches to managing asymptomatic enamel and dentin cracks, on pages 58-62. This exercise was developed by Daniel S. Geare, DMD, in association with the General Dentistry Self-Instruction committee. Reading the article and successfully completing this exercise will enable you to understand:

• the nature of symptomatic and asymptomatic cracks;
• the causes of symptomatic and asymptomatic cracks; and
• treatment options for cracked teeth.

Answer form is on the inside back cover. Answers for this exercise must be received by October 31, 2015.
Perspective of cardiologists on the continuation or discontinuation of antiplatelet therapy before dental treatment: a questionnaire-based study

Ruchi Banthia, MDS • Pallavi Singh • Priyank Banthia, MDS • Rajbhan Singh, MBBS, DMD • Santosh Gupta • Sapna Raje

Antipatelet and anticoagulant agents have been extensively researched and developed as potential therapies in the prevention and management of arterial and venous thrombi. These medications are associated with an increase in bleeding time and risk of intraoperative and postoperative hemorrhage in the dental office. There is some controversy regarding whether these agents should be temporarily discontinued before dental procedures. In order to gain insight into this controversy, a survey of 50 cardiologists was conducted regarding suggested guidelines for dentists in the management of patients who are taking anticoagulant medication.

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Key words: antipatelet therapy, bleeding risk, thromboembolic events, dental treatment

Platelets provide the initial hemostatic plug at the site of vascular injury. They are also involved in pathological processes and serve as an important contributor to arterial thrombosis possibly leading to myocardial infarction and cerebrovascular stroke.1 Various antipatelet and anticoagulant agents are used for the prevention and management of arterial thrombi.2 The most common of these are low-dose aspirin (75-300 mg daily), clopidogrel, dipyridamole, and warfarin.3,4 Antipatelet therapy is associated with the inhibition of platelet aggregation. When platelets are inhibited, it takes longer for primary hemostasis to occur, hence bleeding time is prolonged, leading to an increased risk of intraoperative and postoperative hemorrhage during dental procedures.5,6 Dental practitioners are encountering more and more cardiac patients taking antipatelet medications in their routine practice. A decision needs to be made whether to temporarily discontinue antipatelet therapy before performing any dental procedure on a patient with this medical history. The dilemma lies in the fact that although these medications increase the risk of hemorrhage during dental procedures, temporarily stopping them can put the patients at risk of thromboembolic events, such as stroke.7 Therefore, a medical opinion and consent is mandatory for the management of cardiac patients in the dental office, and the risk of occurrence of thromboembolic event must be weighed against the risk of hemorrhage. Previously, discontinuation of antipatelet therapy for either 3 or 7 days was recommended prior to dental procedures to avoid excessive bleeding, but with increasing concern over the thromboembolic risk, this is no longer recommended.7 There is a great deal of confusion and controversy among dental surgeons regarding this issue. This study sought to obtain evidence-based results by conducting a survey on 50 cardiologists with the goal of helping to resolve the controversy.

Materials and methods
A structured questionnaire consisting of 7 questions was prepared by 2 of the study’s coauthors (R. Banthia and P. Banthia). Verbal consent was obtained over the telephone from 72 cardiologists and the questionnaires were distributed by 2 different coauthors (P. Singh and R. Singh). The physicians were asked to respond in 2-3 days. The first 50 responses received were accepted for use in the study. The data was collected and the responses analyzed (Table).

Discussion
Antipatelet therapy agents (also known as blood thinners) are used mainly for the inhibition of platelet activation or aggregation. They are effective in arterial circulation where anticoagulants have little effect.7 Aspirin irreversibly acetylates cyclooxygenase, inhibiting the production of thromboxane A2, resulting in decreased platelet aggregation.8 Clopidogrel selectively inhibits ADP-induced platelet aggregation. Dipyridamole is an adenosine reuptake inhibitor and phosphodiesterase inhibitor with antipatelet and vasodilating activity.9

Most of the cardiologists surveyed use either aspirin as monotherapy, or aspirin and clopidogrel as dual therapy. Aspirin and clopidogrel have synergistic antipatelet effects that block complementary pathways in a platelet aggregation cascade.10,11

Dipyridamole is another antipatelet therapeutic agent. Oral antipatelet regimens vary in different institutions, but the recommendations of the American College of Chest Physicians in 2006 were that aspirin (75-162 mg) should be prescribed and continued indefinitely for all patients with stable coronary artery disease (CAD), and clopidogrel in combination with aspirin is advised for all stable CAD patients with a risk profile that indicates a high likelihood of developing acute myocardial infarction.12

The effect on primary hemostasis is minimal when antipatelet agents are used as monotherapy in patients, with no additional risk factors for impaired clotting.13 The risk of bleeding may increase in combination therapy cases.14 While aspirin can double the bleeding time, this may still be in normal range. Only 20%-25% of patients on aspirin were reported to have abnormal bleeding times. Burger et al observed that patients on an aspirin regimen have, on average, an increased (1.5-fold) risk of intraoperative hemorrhagic risk, without an increase in surgical morbidity and mortality.15 Clopidogrel, being a more potent antipatelet agent, can cause a 1.5 to 3-fold increase in bleeding times.16,17
Eighty percent of the cardiologists surveyed were not in favor of discontinuing antiplatelet therapy before minor dental procedures. However, all of the doctors surveyed were in favor of stopping antiplatelet therapy for surgical procedures. This discontinuation was recommended to avoid the risk of postoperative and intraoperative bleeding.

Ardekian et al investigated the effect of aspirin on the hemorrhagic risk in patients undergoing dental extractions. None of the patients reported any episode of uncontrolled bleeding immediately after the procedure or in the following week. Intraoperative bleeding was managed either by suturing, gauze packs, and/or use of tranexamic acid in local packing.

The pharmacological actions of clopidogrel and dipyridamole suggest that patients taking these medications will be at no greater risk of excessive bleeding than those taking aspirin. While clopidogrel has shown an increased bleeding time compared to aspirin, it has proved to be clinically more potent; and it has been established that there is no risk of

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<th>Table. Survey results</th>
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<td>Questions</td>
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<td>1. Which antiplatelet agent do you most frequently prescribe?</td>
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<td>2. Do you recommend stopping antiplatelet therapy before dental procedures?</td>
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<td>3. On which criteria did you base your decision to continue or discontinue the antiplatelet therapy?</td>
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<td>4. When ‘written medical consent’ is required by a dental practitioner, what protocol do you follow?</td>
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<td>5. Have you ever been consulted for a bleeding episode—in a patient on antiplatelet therapy—by a dental office?</td>
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<td>6. How many episodes of thromboembolic events have been reported to you in cases where discontinuation of antiplatelet therapy was recommended?</td>
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<td>7. What is your final recommendation?</td>
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excessive bleeding when using clopidogrel during dental procedures.15-19 If a patient is on a dual therapy of aspirin and clopidogrel, it is recommended that the dental procedure be performed in a hospital setting, in order to more proactively manage any severe bleeding episode, as such patients are at a higher risk of hemorrhage. Patients with underlying hepatic, renal, or bone marrow disorders often have disease-related bleeding disorders. Bleeding risk also increases with age and with heavy alcohol consumption.4

Sixty percent of the cardiologists surveyed were in favor of stopping antiplatelet therapy 5 days prior to the dental procedure. Thirty percent recommended the discontinuation of antiplatelet therapy 7 days prior to the procedures. Ten percent recommended discontinuation starting 3 days prior, continuing 2 days postoperative.

All patients on antiplatelet therapy may have drug-induced alterations of platelets, the degree of which varies from person to person. Aspirin irreversibly inhibits platelet aggregation within 1 hour of ingestion, and clopidogrel does so within 2 hours. This inhibition lasts for the lifetime of platelets, approximately 7-10 days. This effect is only overcome by the production of new platelets.20 Complete recovery of platelet aggregation may occur in 50% of cases by Day 3, and in 80% of cases by Day 4 postoperative.21 Ferrari et al concluded that when aspirin (either 75 or 300 mg) was stopped in healthy patients after 2 weeks of therapy, all bleeding times returned to normal after 6 days.22 The action of dipyridamole is reversible and ceases about 24 hours after the drug is discontinued.16

Only 5% of the medical practitioners surveyed had been consulted for the management of 1 or 2 bleeding episodes. Lockhart et al suggested that postoperative bleeding is considered significant if the bleeding continues beyond 12 hours, causes the patient to call or return to the dental office or emergency department, results in the development of a large hematoma or ecchymosis within oral soft tissues, or requires a blood transfusion.23

Life-threatening bleeding after dental surgery is rare.24 According to Matocha, the incidence of postextraction hemorrhagic complications is 0.2%-2.3%.25 McGaul reported a case of sublingual hematoma in mandibular anterior teeth following periodontal flap surgery in a patient on long-term antiplatelet therapy which resolved on its own.26 Thomason et al reported severe bleeding following a gingivectomy in a patient taking 150 mg aspirin qd, which was resolved by platelet transfusion.27

Napenas et al found no differences in hemorrhages following dental treatments such as extractions, periodontal surgery, subgingival scaling, and root planing between patients receiving single or dual antiplatelet therapy.28 In a study by Partridge et al, the amount of blood loss was found to be similar in patients on antiplatelet therapy and healthy patients (controls) during dentoalveolar surgery.29 The Antiplatelet Trialists’ Collaboration concluded that long-term antiplatelet therapy caused reductions in mortality, relative risk of myocardial attack, and cerebrovascular incidents; with only a mild (0.12%) increase of spontaneous hemorrhage risk.30

All the doctors surveyed who had been asked for consent before dental therapy on their patients with antiplatelet regimens recommended bleeding time, clotting time, ECG, routine investigations, blood sugar level, and blood pressure tests. Only 10% of the doctors advised chest X-rays, and only 10% advised an International Normalized Ratio (INR) in order to know the status of coagulation. An INR is advised for all patients on warfarin or heparin therapy.31

Although there is no suitable test to assess the increased risk of bleeding in patients taking antiplatelet therapy, platelet function is normally assessed using the cutaneous bleeding time test. In a normal healthy patient, bleeding time ranges from 2 to 10 minutes.32 Prothrombin time (PT) and partial thromboplastin time have been used to evaluate anticoagulant levels. The INR was introduced in 1983 by the World Health Organization Committee on Biological Standards, who defined the INR as the ratio of the patient’s PT to a control PT, raised to the power of the International Sensitivity Index (ISI).33

The INR is a more reliable and sensitive test for determining the level of anticoagulation as it depends on both the patient’s blood and the sensitivity of the assigned ISI value. The PT alone would not be an accurate gauge in the evaluation of a patient’s anticoagulant status. A patient with a normal coagulation profile would have an INR of 1. It is recommended that a patient undergoing invasive treatment should have a PT 1.5-2.0 times the normal value (INR = 1.5-2.5 when the ISI is 1).33

In patients on antiplatelet therapy, the recommended INR is 2.0-3.0 for most procedures. This range of INR (2.0-3.0, average 2.5) minimizes the risk of both hemorrhage and thromboembolic events.34 Nevertheless, minor surgical dental procedures can safely be performed with an INR between 2 and 4, while being aware that local measures may be needed to control bleeding.35 In patients on warfarin and heparin, the INR should be checked within 24 hours prior to the procedure.31

A correlation between bleeding time test results and the rate of surgical bleeding complications has not been established.35 Shalom & Wong concluded that cutaneous bleeding tests should not be used to estimate the hemorrhagic risk in patients on anticoagulant therapy.36 Of the doctors surveyed, all reported 1 or 2 cases of thromboembolic events after discontinuation of antiplatelet therapy.

Thromboembolic events following the cessation of antiplatelet medications have also been reported in the literature. One retrospective analysis study reported that out of 475 patients admitted with myocardial infarction, 11 (2.3%) had discontinued aspirin within 15 days prior to the attack.37 Nine patients discontinued aspirin due to a planned procedure, 1 of which was a dental procedure.37 Another study by the same author reported that 5% of the patients who were admitted for acute coronary syndrome had admitted they had stopped using oral anticoagulant agents, and the authors concluded that a rebound effect occurs after an interruption of oral antplatelet medication.38 In a study by Ferrari et al, the mean delay time between aspirin withdrawal and an acute coronary event was 10 ± 1.9 days (range 4-17 days); and 13 of the patients (25.5%) who discontinued their aspirin medication did so prior to dental treatment.39 Maulaz et al reported the mean interval between treatment disruption and cerebral infarction was 9.5 ± 7 days.39 Kovich & Otley estimated that the risk of thromboembolic events associated with the withdrawal of aspirin 3-14 days prior to cutaneous surgery was approximately 0.005%.40
Management of patients on antiplatelet therapy in a dental office

According to Scully & Wolff, oral surgical procedures must be done at the beginning of the day, as it allows more time to deal with any bleeding episode.41 Procedures should also be performed early in the week so that prompt management of any delayed bleeding can be done.

Local anaesthetic containing a vasoconstrictor should be administered. Field blocks are contraindicated. If no alternative exists, local anaesthetic should be administered cautiously with repeated aspiration.42,43

Atraumatic and careful manipulation of tissues is recommended. Bleeding should be stopped by local measures, such as use of pressure packs for 15-30 minutes, packing of sockets with absorbable hemostatic dressings (oxidised cellulose, haemocollagen, or resorbable gelatin sponge), and suturing.42,43

The use of aspirin leads to increased bleeding time. If it increases to >20 minutes and surgery has to be performed as an emergency procedure, 1-desamino-8-D-arginine vasopressin can be used to shorten the bleeding time.44 This involves the enhancement of Von Willebrand’s factor which in turn acts as a platelet aggregator. It can be used at a dose of 0.3 µg/kg of body weight—not exceeding 20-24 µg— or as a nasal spray. This should be administered under a physician’s guidance as this can cause drug-induced thrombosis in older subjects.8

Paracetamol is the painkiller drug of choice for patients on antiplatelet therapy. Nonsteroidal anti-inflammatory drugs (NSAIDs) are avoided, as they carry the potential risk of increasing bleeding time by having a reversible effect on platelet aggregation and function.4 To ensure the absence of any antiplatelet effect, NSAIDs should be discontinued 5 half-lives before the procedure.45

Scully & Cawson developed the following list of instructions to be given to patients for the management of a clot in the postoperative period.46

• Rest until the local anesthetic wears off and the clot forms (2-3 hours).
• Avoid rinsing the mouth for 24 hours.
• Do not suck forcefully or disturb the socket with the tongue or any foreign objects.
• Avoid hot liquids and hard foods for the first day.

• Avoid chewing on the affected side until it is clear that a stable clot has formed.
• Apply pressure over the socket using a folded clean handkerchief or gauze pad for 20 minutes if bleeding continues or restarts. If bleeding does not stop, consultation with the dentist is advised.46

Patients with the following medical problems taking antiplatelet medications should not be treated in primary care without medical advice or should be referred to a hospital-based dental clinic: liver impairment and/or alcoholism; renal failure; hemostasis disorders; and patients currently receiving cytotoxic medication or dual antiplatelet therapy.42,43,47

A consensus opinion from American Heart Association, American College of Cardiology, Society for Cardiovascular Angiography and Interventions, American College of Surgeons, and American Dental Association recommended continuing aspirin and clopidogrel therapy for major dental surgical procedures in patients who have coronary artery stents, or delaying the treatment until the prescribed regimen is completed.48 When >3 teeth need to be extracted, multiple visits are required. Scaling and gingival surgery should initially be restricted to a limited area.49

When a definite increase in intraoperative bleeding is anticipated, or when surgical hemostasis could possibly be difficult, aspirin can be replaced for a 10-day period by a shorter-acting NSAID regimen, interrupted the day before surgery. Postoperative antiplatelet therapy should be resumed immediately after surgery (first 6 hours).49

Medical consent is mandatory in cardiac patients taking antiplatelet therapy in order to know the exact medical condition of the patient and to prevent any unwanted sequelae. Properly structured consent forms should be mandatory. Eighty percent of the cardiologists surveyed did not have printed consent forms.41

Conclusion

The Hippocratic oath states, “First do no harm.” This must be considered immediately when deciding whether or not to temporarily discontinue antiplatelet therapy before dental treatment. Careful appraisal of the type of procedure, vascular status of the patient, and chances of complications—along with a risk-benefit analysis—should be undertaken in consultation with a cardiologist to ensure the complete well-being of the patient. The dental surgeon and physician should exercise judgment based on their skill, experience, and the facilities at their disposal so as to provide the best postoperative care to the patient. Fifty percent of the doctors surveyed in this study based their decisions on whether to temporarily discontinue antiplatelet therapy before a dental procedure on both clinical experience and evidence-based research; 25% percent based their decisions solely on evidence-based research; and the remaining 25% based their decisions predominantly on their clinical experience.

Clinical experience is a critical tool in the successful management of patients, but in today’s world of ethical and lawful guidelines, clinical decisions need also to be based on evidence-based research.

Author information

Dr. R. Banthia is a professor, Department of Periodontics, Modern Dental College & Research Centre, Indore, India, where P. Singh, Gupta, and Raje are postgraduate students. Dr. P. Banthia is a professor and head, Department of Periodontics, Inderprastha Dental College, Ghaziabad, India. Dr. R. Singh is a medical officer, Employees’ State Insurance Corporation (ESIC) Hospital, Indore, India.

References

The 15 questions for this exercise are based on the article, Perspective of cardiologists on the continuation or discontinuation of antiplatelet therapy before dental treatment: a questionnaire-based study, on pages 64-68. This exercise was developed by Merlin Ohmer, 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 clinical implications of antiplatelet therapy;
• when and how to consult the patient’s cardiologist; and
• the effects of antiplatelet therapy on dental patients.

Answer form is on the inside back cover. Answers for this exercise must be received by October 31, 2015.
Mepivacaine: a closer look at its properties and current utility

William G. Brockmann, DDS, PhD

The use of mepivacaine in dentistry has remained strong since its introduction in the 1960s. It has retained its place as a valuable local anesthetic, either as a primary agent or as an alternative to lidocaine or articaine. Mepivacaine is commonly used in medically compromised patients—for whom elevations in blood pressure or heart rate are not advisable—in a formulation with a vasoconstrictor, or in pediatric populations in a formulation without a vasoconstrictor. Pharmacologically, these are the 2 groups most susceptible to side effects and toxicity, thus mepivacaine is commonly indicated. Most often the decision to use mepivacaine is based on its vasoconstrictor effect or lack thereof (depending on the formulation). However, the pharmacokinetics of mepivacaine are not well understood or assumed to be similar to that of other local anesthetics. It is important to understand the unique pharmacologic characteristics of mepivacaine in order to minimize the potential for inadvertent toxicity.

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Currently used local anesthetics and their formulations each have individual characteristics that allow them to claim clinically useful niches to validate their continued market presence. While the introduction of articaine—in 1982 in Canada and in 2000 in the US—has gained much of the market share in North America, lidocaine and mepivacaine have remained commonly used agents. In Canada, where articaine is the most used agent, a survey of general dentists showed that from 1993 to 2007, mepivacaine usage declined but remained the third most used agent. Mepivacaine’s niche has been considered by many dentists to be the “safer” lidocaine alternative, to be used in elderly or cardiovascular disease patients, because it not only comes without a vasoconstrictor, but it is available with levonordefrin, which is assumed to have less vasopressor potency and 25% of the direct beta effects on the heart. It is now known, however, that levonordefrin acts similarly to norepinephrine, as it elevates not only systolic blood pressure, but diastolic and mean arterial pressures as well. Used at 5 times the concentration of epinephrine, it possesses relatively the same or more potential for cardiac stimulation, especially elevations in blood pressure. Mepivacaine is also commonly used—in a formulation without levonordefrin—for children, as it is available without a vasoconstrictor for shorter postoperative duration, whereas articaine and lidocaine have longer durations and must have vasoconstrictors for their efficacy. Many general and pediatric practices use mepivacaine formulations exclusively with these characterizations in mind. Whereas the 2 different vasoconstrictors used in local anesthetics bear many similarities to each other with similar clinical limitations, it is worthwhile to look at mepivacaine by itself.

Rather than being a lidocaine substitute, mepivacaine possesses distinct pharmacokinetic characteristics of its own that are important for the clinician to understand. This article reviews the unique pharmacology of mepivacaine and the potential clinical implications involved with its use.

History and chemistry: pipecholyl xylidines

In the years immediately after the development of the xylidine derivative, lidocaine, there followed a series of chemical syntheses based upon the same successful 2,6-xylidine-amide structure, with emphasis on increasing the duration of action. In 1957, af Ekenstam et al synthesized (along with many other structures with anesthetic properties) mepivacaine and bupivacaine, both very similar in structure and with longer durations than lidocaine. Each preserved the 2,6-xylidine group on the aromatic ring, but each had a shortened intermediate chain, and replaced the terminal tertiary amine with a less basic methyl-piperidine ring. Homologous local anesthetics that share the mepivacaine structure, such as bupivacaine and ropivacaine, are referred to as pipecholyl xylidines due to the presence of this pipecholyl acid moiety (Fig. 1). Bupivacaine differs from mepivacaine only by substitution of the methyl group on the piperidine ring by a methylene group.

Fig. 1. Pipecholyl xylidines compared to lidocaine.
fibers, such as rabbit vagus and sciatic. Methods that measure conduction block-
to the other local anesthetics.

water) is lowest in mepivacaine compared in nonpolar solvents but only sparingly in phobicity (tendency to be readily soluble in a formulation without a vasoconstric-
tor or in a formulation with 1:20,000 levonordefrin (Neo-Cobefrin, Novocol Pharmaceutical of Canada, Inc.) which 

more lipid soluble butyl (C4H9) group. It was not until the late 1970s, however, that bupivacaine was approved for clinical use as a nerve blocker in dentistry.6-8 

Mepivacaine, being less toxic than bupivacaine, was immediately evaluated for clinical use in various types of regional and dental anesthesia and was identified as having a faster onset and longer duration than lidocaine without a vasoconstrictor.9,10 Approved by the FDA in 1960, it was subsequently studied in many dental trials, where it rapidly established its dual utility in dentistry when used in a formulation without a vasoconstrictor or in a formulation with 1:20,000 levonordefrin (Neo-Cobefrin, Novocol Pharmaceutical of Canada, Inc.) which markedly increased its duration.13,14

Lipid solubility and potency

Mepivacaine, lidocaine, and prilocaine are considered to be “intermediate” in terms of their lipid solubility and anesthetic potencies (Table).15 The correlation of lipid solubility, and the ability to penetrate membranes with increased affinity for hydrophobic binding sites are the main determinants of anesthetic potency.10 The lipid solubility and hydrophobicity (tendency to be readily soluble in nonpolar solvents but only sparingly in water) is lowest in mepivacaine compared to the other local anesthetics.

Hydrophobicity correlates with in vitro methods that measure conduction block-
ing (anesthetic) potency on isolated nerve fibers, such as rabbit vagus and sciatic.

These methods showed mepivacaine to have a correspondingly lower anesthetic potency than lidocaine or prilocaine under in vitro conditions.17 However, these measurements were derived under controlled conditions and do not directly reflect in vivo anesthetic potency. They also do not correctly reflect the clinical end-points of mepivacaine use, where success is measured by an adequate conduction block, and the physiologic variables that affect tissue concentration, diffusion, and ionization are more complex. Animal studies with live nerve blocks have shown the potency of mepivacaine to be equivalent or greater, with a faster onset time, and longer duration of anesthesia than lidocaine and prilocaine.18 Mepivacaine, lidocaine, and prilocaine have all been shown in numerous clinical studies to have similar intermediate anesthetic efficacy, regardless of differences in their lipid solubility.19-21

Effectiveness in infected tissues

The ionization constant, or pKa, of mepivacaine is also the lowest of the intermediate agents (articaine and lidocaine have the same pKa). At 36°C, the pKa’s of the intermediate-acting agents are all close enough to make onset times roughly equivalent under normal physiologic conditions.22 Estimates of the effects of acidic conditions such as those found in infected tissue—using quantitative structure-activity relationship modeling (QSAR) calculations—have shown the relative anesthetic potency of lidocaine drops 72.8% from a normalized 100 (at pH 7.4) to 27.2 (at pH 6.5).23 In comparison, the relative anesthetic potency of prilocaine decreases by 66.5%, and mepivacaine decreases by 64.7%. Theoretically, mepivacaine would lose less potency when injected into areas of reduced pH and this may be considered an advantage. However, realistically, this is a rare occurrence if a regional block is available.

Hypersensitivity and cross reactivity

For patients who are known to be allergic to sulphites, the availability of mepivacaine without vasoconstrictor and sodium metabisulphite is a highly valuable clinical asset, since articaine and lidocaine must have vasoconstrictors added for their efficacy. Allergy to mepivacaine itself, as well as any of the amide local anesthetics is very rare, but does occur.23 Most case reports of mepivacaine allergic reactions prior to the mid-1980s were related to the methylparaben used as antimicrobials in the cartridges; these were subsequently removed by FDA mandate.24

A large 2009 study that analyzed the French Pharmacovigilance database over a 12-year period (1995-2006) found 16 cases of allergic reactions to amide local anesthetics, of which 11 were immediate Type 1 reactions occurring within 1 hour with severe symptoms.25 Of the Type 1 reactions, 6 were due to lidocaine, 2 to mepivacaine, 2 to articaine, and 1 to bupivacaine. Of the other 5 reactions, which were delayed-type skin reactions, 4 were due to lidocaine and 1 to mepivacaine.25

Cross-reactivity among the amides, previously thought to be rare, was found in 6 cases (38%) and all were between lidocaine and mepivacaine. In patients with a true lidocaine or mepivacaine allergy, neither lidocaine nor mepivacaine should be used as a substitute due to very possible cross-allergenicity.25

A 2006 report in Spain published a similar case of a patient with confirmed lidocaine and mepivacaine allergies who was not allergic to bupivacaine, despite its structural similarity.26 No cross-allergenicity to articaine was found in either study. The findings in these and other studies suggest that articaine may have rare cross-allergenicity with other members of the amide class, including delayed-type reactions.27,28

<table>
<thead>
<tr>
<th>Anesthetic</th>
<th>MW base (g/mol)</th>
<th>pKa (36°C)</th>
<th>Hydrophobicity* (mol/L)</th>
<th>Lipid solubility (distribution coefficient Q7.4)b</th>
<th>Relative conduction blocking potency (in vitro, isolated nerve fibers)</th>
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<tr>
<td>Lidocaine</td>
<td>234</td>
<td>7.8</td>
<td>304 (366)</td>
<td>43 (110)</td>
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<tr>
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<td>220</td>
<td>8.0</td>
<td>129</td>
<td>25</td>
<td>1.8</td>
</tr>
<tr>
<td>Mepivacaine</td>
<td>246</td>
<td>7.7</td>
<td>90 (130)</td>
<td>21 (42)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

*aOctanol/buffer partition coefficients for unprotonated species only: 25°C. Values in parentheses: 36°C. 
bQ7.4 = (total drug/ml octanol)/(total drug/ml buffer) at pH 7.4. Includes ionized and unionized partition coefficients.

Margins of error not shown.
Systemic absorption

At therapeutic concentrations, mepivacaine has an intrinsic vasodilating activity intermediate between lidocaine and prilocaine. In various arterial blood flow studies, lidocaine markedly increased blood flow whereas mepivacaine and prilocaine tended to either maintain or decrease peripheral blood flow. This would appear to be an additional safety factor, by keeping systemic levels low. However, in maxillary infiltration studies conducted by Goebel et al, serum levels of the mepivacaine formulation without vasoconstrictors were always higher and more persistent than lidocaine. Complimentary studies by Goebel et al comparing lidocaine and mepivacaine with their respective vasoconstrictors, epinephrine and levonordefrin, also showed that mepivacaine produced significantly higher and more variable serum levels than lidocaine at all time intervals.

Medical studies comparing lidocaine and mepivacaine in regional blocks also indicate that mepivacaine, even in the vasoconstrictor formulation, produce higher and more sustained systemic blood levels on the order of 35% to 38%. Since the duration of mepivacaine without a vasoconstrictor is about 30 minutes, reinjection at that time occurs at peak serum levels. In addition, at all later time intervals, differences in mepivacaine serum levels are not significantly different whether or not a vasoconstrictor is used. Serum levels at time intervals beyond 30 minutes in maxillary infiltration studies are essentially the same regardless of whether or not the vasoconstrictor formulation was used. The mean peak (Cmax) percentage difference between plain 2% mepivacaine and 2% mepivacaine with levonordefrin was only 8%, while the peak difference between lidocaine with and without epinephrine was 29%. Systemic levels of mepivacaine decrease less when compared to lidocaine in the presence of a vasoconstrictor. A formulation with 3% mepivacaine (no vasoconstrictor) produces the highest systemic levels of local anesthetic, which are 1.5 times higher than 2% mepivacaine with levonordefrin, and thus has the most potential for chronic accumulation.

Metabolism and disposition compared to other local anesthetics

Mepivacaine, like the other amide local anesthetics, undergoes extensive hepatic biotransformation with <5% urinary excretion of the unchanged drug. Metabolism is primarily through hydroxylation of the parent compound to inactive 3-OH-mepivacaine and 4-OH-mepivacaine by CYP1A2 (Fig. 2). CYP1A2 is constitutive, and CYP1A1 is the inducible isoform which also participates in metabolism. CYP3A also contributes to the formation of 4-OH-mepivacaine. All these hydroxyl (OH) metabolites are excreted as glucuronide conjugates and comprise >50% of the total mepivacaine dose. Urinary sampling shows the 3-OH-mepivacaine to be the major metabolite earlier in the process, with the 4-hydroxy compound produced later in smaller amounts, indicating the predominance of CYP1A metabolism. Demethylation by CYP3A produces pipecoloxylidide, a minor metabolite accounting for about 1% of the urinary output.

Lidocaine metabolism involves similar enzymatic activities, but CYP3A4 plays the larger role in dealkylation to the major metabolite monoethylglycinexylidide (MEGX), an active metabolite that still retains central nervous system activity intermediate between lidocaine and prilocaine.
(CNS) toxicity. CYP1A contributes to forming MEGX in addition to generating 3-OH-lidocaine which is converted to 3-OH-MEGX.41 These are all eventually eliminated as glucuronide conjugates. MEGX is metabolized to inactive glycinexyldide (GX) and excreted for the most part renally.42 The remaining MEGX and GX is further broken down to 2,6-xylidine metabolites when the xylidine ring is removed by hydrolytic reactions involving hepatic carboxylesterases or amidases (Fig. 3).43

Prilocaine metabolism occurs in the liver and kidney by carboxylesterases and CYP3A4 that generate o-toluidine. CYP2E1 produces hydroxylated toluidine metabolites that represent more than 40% of the urinary metabolites of prilocaine. O-toluidine and its hydroxylated variants can oxidize hemoglobin to methemoglobin, a critical dose-limiting restriction for prilocaine use.44 Drug interactions with prilocaine mainly involve inducers of CYP3A4 (carbamazepine, phenytoin, rifampin), or other drugs that contribute to methemoglobinemia, such as benzoic acid, nitrates, or acetaminophen.45

Articaine has the simplest and most rapid metabolism of the amides due to its carboxyl group ester linkage. Articaine is metabolized rapidly into articainic acid by plasma carboxylesterases with a plasma half-life of 20 minutes.46 Articaine is metabolized rapidly into articainic acid by plasma carboxylesterases. 47 Articaine is rapidly metabolized into articainic acid by plasma carboxylesterases with a plasma half-life of 20 minutes.46 Forty percent to 70% is excreted as articainic acid, and 4% to 15% as articainic acid glucuronide (Fig. 4). Almost all major P450 cytochromes participate in the remaining metabolism of articaine, but only 10% of the total dose is metabolized by cytochromes, making articaine relatively resistant to pharmacokinetic drug interactions.47

Lidocaine clearance is reduced metabolically by inhibitors of CYP3A4, such as cimetidine, erythromycin, and azole antifungals. Antidepressants and benzodiazepines that heavily utilize CYP3A4 have also been associated with serious lidocaine toxicities, including sertraline (Zoloft), escitalopram (Lexapro), desipramine (Norpramin), and flurazepam (Dalmane).48 Because of the high hepatic extraction ratio of lidocaine, drugs that reduce hepatic blood flow also reduce its metabolism significantly. Beta-blockers that decrease cardiac output, especially propranolol, decrease lidocaine elimination by decreasing hepatic blood flow.49 Propranolol also prolongs mepivacaine blood levels, but mepivacaine is not as dependent on hepatic blood flow since it has a lower hepatic clearance (extraction ratio) of 0.51 compared to 0.72 for lidocaine.50-52

Pharmacokinetic drug interactions with mepivacaine are more likely to involve inhibitors of CYP1A2. Potent inhibition of CYP1A2 occurs with selective serotonin receptor inhibitors fluvoxamine (Luvox) and fluoxetine (Prozac) and moderate inhibition with paroxetine (Paxil) and sertraline (Zoloft).53 Other strong inhibitors of CYP1A2 and drugs known to interfere with mepivacaine metabolism include caffeine, grapefruit juice, fluoroquinolone antibiotics, and verapamil (Calan), mexiletine (Mexitil), and zileuton (Zyflo).54 Lastly, significant hepatic CYP1A2 levels are not present in infancy (<1 year), and may not be fully functional before the age of 3 years, which prolongs metabolism of mepivacaine in infancy, whereas fetal CYP3A7 and immature CYP3A are present at birth.54,55

The main difference in pharmacokinetic safety levels between local anesthetics is the total clearance rate (Cl tot). Local anesthetic duration of activity is determined by vascular redistribution from the local site and is only indirectly and weakly correlated with final elimination of the drug from the body. Total clearance (expressed in volume/time) is the removal of a drug from a volume of plasma in a given unit of time as the sum of all clearances by all the various elimination mechanisms, such as renal and hepatic. Of the currently used intermediate-acting agents, mepivacaine has the slowest total clearance. In comparison, the total body clearance of lidocaine is 3 times higher than that of mepivacaine (0.95-1.1 l/min vs 0.45 l/min).56 Medical studies examining systemic levels of mepivacaine after caudal or regional blocks have clinically demonstrated the drug’s relatively long persistence.56,57 The typically slower total clearance of mepivacaine is a factor that can lead to potential accumulation in cases of repetitive dosing over time or excessive doses, especially when children are involved.58-60 In neonates, the lidocaine total plasma clearance normalized to body weight is not significantly different than adults because more lidocaine is excreted renally and unchanged.61 The neonatal capacity for aromatic hydroxylation, however, is very limited, thus the total plasma clearance of mepivacaine is <50% of the adult clearance rate, coupled with a hepatic clearance that is approximately 25% that of adults.62 Concomitant drug interaction from CYP1A inhibition would also contribute to prolonged or toxic blood levels. Prilocaine has a notably fast total clearance—almost 2.5 times that of lidocaine—which not only indicates high hepatic extraction but also extrahepatic metabolism.63,64 This hydrolysis of the amide bond occurs very efficiently, considering only 5% of prilocaine is excreted.
unchanged. Articaine has the fastest total body clearance of all amide local anesthetics, ranging from 3.9 l/min for intraoral injections to 8.9 l/min for IV injections.66

In dentistry, local anesthetic toxicity occurs more frequently in children, most often with mepivacaine.65 Plain mepivacaine is favored and useful in pediatric dentistry for its shorter duration of activity, but plain mepivacaine leads to higher systemic levels which are subject to a slow total clearance rate. Even with levonorgestrel, serum levels are not decreased as they are with lidocaine and a vasoconstrictor. Mepivacaine—especially 3% mepivacaine without a vasoconstrictor—has been implicated in most reported fatalities due to excessive dosing.65,66 Factors that contribute include practitioners not understanding fully the implications of injecting additional anesthetic in low body weight children, basing the dosage on the number of caruples rather than the patient’s weight, and in many instances not understanding the synergistic effects of concomitant opioids or CNS depressants in pediatric sedation protocols. For example, opioids such as meperidine can decrease convulsant thresholds by producing respiratory acidosis and elevating arterial carbon dioxide, which increase the CNS toxicity of local anesthetics.66 All these factors can contribute to toxicity due to mepivacaine’s inherent characteristic of maintaining prolonged and relatively high serum levels even when used with a vasoconstrictor.

Conclusion

Mepivacaine is an efficacious and useful intermediate-acting local anesthetic for use in dentistry as it can be used when required and without a vasoconstrictor. The presence of a vasoconstrictor increases the duration of action but has little effect on systemic blood levels. The slower total clearance of mepivacaine makes it more susceptible to the various mechanisms that can lead to chronic toxicity, such as the lack of fully functional enzymes in infants, inadvertent excessive dosing of 3% mepivacaine, or repeated dosing in conjunction with long appointments, renal failure, or drug inhibition of CYP1A2 (in elderly patients). Children <5 years of age are most susceptible to overdose and are often also given sedation that can increase toxicity. Weight-based dosing in children should be used as a matter of course, and the maximum recommended dose should never be exceeded, especially when using 3% mepivacaine. It has been recommended by many other authors that, since the 3% formulation is potentially 1.5 times more toxic than the 2% formulation, mepivacaine use in children be restricted to smaller volumes, and that its use be limited to supraperiosteal injections whenever possible.65

Author information

Dr. Brockmann is a clinical associate professor, Department of Oral Pathology, Oral Medicine, Oral Radiology, University of Missouri-Kansas City.

References

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D. Fundamental properties of local anesthetics. II. 74      November/December 2014 General Dentistry www.agd.org

Anesthesia and Pain Control Mepivacaine: a closer look at its properties and current utility
1. Mepivacaine was first synthesized in which year?
   A. 1957  
   B. 1982  
   C. 1993  
   D. 2007

2. All of the following anesthetics are classified as intermediate for lipid solubility and anesthetic potencies. Which is the exception?
   A. mepivacaine  
   B. articaine  
   C. lidocaine  
   D. prilocaine

3. All of the following local anesthetics are considered pipiecholyl xylidines except one. Which is the exception?
   A. mepivacaine  
   B. bupivacaine  
   C. ropivacaine  
   D. lidocaine

4. Bupivacaine differs from mepivacaine by the substitution of a(n)
   A. aromatic ring.  
   B. tertiary amine.  
   C. ethyl group.  
   D. butyl group.

5. Mepivacaine loses ____% of relative anesthetic potency in infected tissues.
   A. 27.2  
   B. 64.7  
   C. 66.5  
   D. 72.8

6. Mepivacaine has the largest increase in the cardiotoxic dose. This is because it is correlated to relative potency.
   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.

7. Cross-reactivity among the amide anesthetics, though rare, was found in ____ cases, all between lidocaine and mepivacaine.
   A. 6  
   B. 8  
   C. 16  
   D. 38

8. Thirty years ago, case reports of allergic reactions to mepivacaine were due to which agent?
   A. metabisulphite  
   B. methylparaben  
   C. vasodilator  
   D. vasoconstrictor

9. Which of the following local anesthetics demonstrated a marked increase in arterial blood flow?
   A. cocaine  
   B. lidocaine  
   C. mepivacaine  
   D. prilocaine

10. Which local anesthetic has the most potential for chronic accumulation?
    A. 2% lidocaine  
    B. 2% lidocaine with epinephrine  
    C. 2% mepivacaine with leonordefrin  
    D. 3% mepivacaine

11. Prilocaine interactions with all of the following drugs may contribute to methemoglobinemia except one. Which is the exception?
    A. carbamazepine  
    B. glyburide  
    C. phenytoin  
    D. acetaminophen

12. Inhibition of mepivacaine metabolism can be accomplished by all of the following drugs except one. Which is the exception?
    A. Lithobid  
    B. Luvox  
    C. Paxil  
    D. Prozac

13. All of the following are factors that contribute to pediatric local anesthetic fatalities except one. Which is the exception?
    A. injecting additional anesthetics  
    B. number of carpules used  
    C. failing to understand synergism of opioids and/or depressants  
    D. dosing by weight

14. Among amide anesthetics, mepivacaine has the slowest total body clearance. Articaine has the fastest total body clearance.
    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.

15. Which cytochrome has the major role when metabolizing mepivacaine?
    A. CYP1A1  
    B. CYP1A2  
    C. CYP3A  
    D. CYP3A4

The 15 questions for this exercise are based on the article, Mepivacaine: a closer look at its properties and current utility, on pages 70-75. This exercise was developed by Anthony S. Carroccia, DDS, MAGD, ABGD, in association with the General Dentistry Self-Instruction committee. Reading the article and successfully completing this exercise will enable you to:

- Identify mepivacaine’s properties;
- Recognize potential clinical implications; and
- Differentiate between mepivacaine and other local anesthetics.

Answer form is on the inside back cover. Answers for this exercise must be received by October 31, 2015.
A direct approach for fabrication of a provisional restoration immediately after tooth preparation for custom cast dowel and core

Kunwarjeet Singh, BDS, MDS • Nidhi Gupta, BDS, MDS

When a tooth is fractured at the gingival level due to accidental trauma and there is insufficient coronal tooth structure to retain a crown, a custom cast dowel and core often is necessary, followed by the fabrication of a definitive crown. It is very difficult to fabricate the provisional restoration for a tooth until the custom cast dowel and core are cemented permanently. This article describes a direct procedure for fabricating a provisional restoration (with a prefabricated temporary titanium post and an acrylic resin denture tooth) immediately after the tooth has been prepared for a custom cast dowel and core. This technique produces good clinical results while being less time-consuming than an indirect approach.

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Key words: provisional restoration, temporary titanium post, acrylic resin tooth, custom cast dowel and core

The importance of provisional restorations in fixed prosthodontics has been well-documented in the literature.1-3 A variety of techniques are available—from a single unit to a complete arch provisional fixed prosthesis—depending on the patient’s needs and the clinical situation.1-3

One of the greater challenges when restoring a tooth that has been fractured due to trauma is making the provisional restoration esthetically pleasing. A particular challenge for dentists involves a tooth that is fractured at the gingival level that has already been prepared for a custom cast dowel and core, despite the fact there is little intact supragingival tooth structure for crown retention (Fig. 1).4 Only 1 technique has been described in the literature for making a provisional restoration while the custom cast dowel and core is being fabricated. This technique involves fitting an orthodontic wire into the prepared canal and fabricating a provisional crown with autopolymerizing resin, using the direct technique.3

This article describes a simple direct chairside technique for fabricating a provisional restoration by using a temporary titanium post and an acrylic tooth. This should accomplish excellent esthetic results due to the acrylic tooth’s well-polished, glazed, labial surface. An additional benefit to this technique is that the dentist can use the temporary titanium post later (after sterilization) for the fabrication of a provisional crown in another patient.

Materials and methods

This technique requires an acrylic lateral incisor tooth and a temporary titanium post; both must be the proper size (Fig. 2). The acrylic tooth (both the lingual fossa and cingulum) must be trimmed from the palatal side in order to resemble a laminate veneer. To maintain the polished glazed appearance, dentists should be careful to avoid trimming the labial surface of the acrylic tooth. The fit and extension of the post should be evaluated to ensure it fits passively into the prepared canal and extends sufficiently into the oral cavity to retain the provisional restoration.

The tooth (including the canal and surrounding soft tissues) should be lubricated by placing petroleum jelly on a small piece of cotton rolled on paper points. Next, the temporary post (with the required oral extension) should be placed in the canal. The autopolymerizing tooth-colored acrylic resin monomer and polymer can be mixed in a dappen dish. The fitting surface...
of the trimmed acrylic tooth should be wetted with the monomer, and some acrylic resin should be placed on the fitting surface of the acrylic tooth. Then the tooth should be placed over the temporary post extending into the oral cavity and held in the proper position while applying acrylic resin from the palatal side with the help of a cement carrier and Hollenbeck carver. Make sure that the acrylic resin on the palatal and proximal surfaces blends well with the acrylic tooth veneer.

The resin should still be “rubbery” 2-3 minutes after application, at this point the entire assembly should be removed. Polymerization should be monitored carefully. If the resin is allowed to become rigid, it might lock into the undercuts within the post preparation and between adjacent teeth. Removing the assembly at this later point would be both time-consuming and risk the restorability of the tooth.

To hasten the polymerization of the resin, place the assembly in warm water. The temporary post must not be disturbed while the resin is soft. Once the resin becomes hard, it should be finished, polished, and cleaned (Fig. 3 and 4). After evaluation (Fig. 5), the tooth should be cemented with a zinc oxide noneugenol cement. An example of the tooth after cementation is shown in Figure 6.

After the permanent cementation of the custom cast dowel and core (Fig. 7 and 8), the temporary titanium post should be separated carefully from the acrylic crown by using carbide burs (Fig. 9). The same acrylic crown can be used again by trimming it from the palatal side. Stabilize the crown properly on the labial side of the custom cast dowel and core, and adapt the tooth-colored autopolymerizing resin from the palatal and proximal side after applying the petroleum jelly over the core. Next, the provisional crown (Fig. 10) should be finished, polished, and cemented with a temporary cement (Fig. 11). Figure 12 shows a definitive crown with a well-established emergence profile maintained by the provisional restoration.

Discussion
Placing a custom cast dowel and core is one of the more common approaches for the functional and esthetic rehabilitation of a traumatized tooth that has been fractured at the gingival level, with inadequate tooth structure for crown retention. One of the biggest challenges a dentist faces is providing immediate esthetic rehabilitation after making the tooth preparation.
Several laboratory and clinical techniques for fabricating provisional restorations have been described, including indirect, direct, and indirect-direct techniques for both single and multiple unit fixed restorations.\textsuperscript{5,7} The indirect technique is used widely in clinical practice; however, this approach requires additional time and laboratory support. As a result, some dentists prefer the direct technique, which involves a less time-consuming procedure for fabricating provisional fixed partial dentures chairside.

Only 1 technique has been described in the literature for fabricating a provisional restoration immediately after a tooth is prepared for custom dowel and core. This technique involves fitting an orthodontic wire into the prepared canal and fabricating the provisional restoration by applying autopolymerizing resin around the wire that is extended into the oral cavity. However, the fabrication of a provisional crown is more time-consuming and offers inferior esthetics compared to the technique described in this article. Based on the authors’ experience, fabricating a provisional crown using a temporary titanium post and a prefabricated acrylic denture tooth is less time-consuming with better esthetics, greater patient acceptance, and less irritation of surrounding tissues, while allowing dentists to maintain a proper emergence profile until the definitive restoration is fabricated.

**Conclusion**
This article describes a direct approach for fabricating a provisional restoration immediately after tooth preparation for a custom cast dowel and core using a temporary titanium post and an acrylic denture tooth. This procedure achieves functional and esthetic provisional restorations with minimal adjustments and optimal esthetics.

**Author information**
Dr. Singh is an associate professor, Department of Prosthodontics, Dental Materials and Implantology, Institute of Dental Studies and Technologies, Modinagar, Ghaziabad, India, where Dr. Gupta is an associate professor, Department of Pedodontics and Preventive Dentistry.

**References**
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### Answer Sheet

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### ANSWERS

Select the best answer by completely filling in one box for each response.

**Correct ✔ Incorrect ✗ Incorrect ✗

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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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The efficacy of 2 different doses of dexamethasone to control postoperative swelling, trismus, and pain after third molar extractions

Cicero Newton Lemos Felicio Agostinho, MSc • Vanessa Camila da Silva, PhD • Etevaldo Matos Maia Filho, PhD
Maria Luiza Cruz, PhD • Eider Guimaraes Bastos, PhD

This article addresses the effect of 2 different concentrations (4 and 12 mg) of dexamethasone to control pain, swelling, and trismus after third molar surgery. A clinical study was conducted with 27 male and female patients, all presenting with bilaterally displaced mandibular third molars. The treatment protocol required the surgical removal of each tooth in 2 separate operations. The patients were given a preoperative dose of dexamethasone—4 mg for one surgery, 12 mg for the other. The choice of which side would be operated on first and which dose of dexamethasone would be taken was performed randomly, under double-blind conditions.

The trismus was assessed by measuring the interincisal distance. Pain intensity was measured both by the amount of painkillers (acetaminophen 750 mg) taken postsurgery and by the Visual Analogue Pain Scale. Data were collected 1 hour preoperative, then at 24 and 48 hours postoperative. A statistical analysis (student’s t, Wilcoxon, and Friedman tests) of the results showed no significant differences ($\alpha = 0.05$) between the analyzed variables for the 2 different doses of dexamethasone (4 and 12 mg).

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The pharmacological control of inflammatory processes after third molar surgeries has been a source of concern for oral and maxillofacial surgeons. This has led to an increased use of corticosteroids, nonsteroidal anti-inflammatories, and other painkillers to control the most involved sequelae in these surgeries—pain, swelling, and trismus—in order to provide maximum relief postsurgery.1-6 Perhaps the greatest factor in the postsurgical sequelae is the inflammatory process initiated by the surgical act.5,6

A great source of the fear and aversion experienced by some patients concerning oral surgery is the postoperative pain associated with these procedures. Thus any preoperative technique that is able to prevent or decrease pain postsurgery is strongly recommended. Numerous procedures have been used preoperatively to assure postsurgical comfort, such as the use of corticosteroids, antihistamines, and other painkillers, as well as the application of ice to the affected area.7

Some characteristics are peculiar to the inflammatory pattern, such as swelling, leucocytosis, an increase in vascular permeability, and hyperalgesia with its subsequent alteration of blood flow. The association of these inflammatory factors culminates with plasma extravasations, an increase in the chemical mediators of inflammatory response, and increased peripheral nervous pressure; all of which promote pain.7 It is important to stress that this sequelae is not observed immediately after the surgical procedure. It is gradually triggered, hitting its peak at approximately 48 hours postsurgery.8

Glucocorticosteroids are known as the most powerful anti-inflammatory available for clinical practice and are classified as pleiotropic hormones. They are responsible for the prevention (or suppression) of the inflammatory process and other immunologically mediated processes. According to Boumpas et al, these hormones must be administrated within certain pharmacological patterns in order to achieve ideal dosage.9 According to Kingery et al, the role corticosteroids play on the postoperative process is still controversial.10 This is because it is not well known whether such compounds act more on decreasing postsurgery swelling or actually function as a painkiller.10

Glucocorticosteroids, such as dexamethasone, stop the inflammatory cascade at its initial steps.8 The administration of these steroids before third molar surgery is commonly done preoperatively in a single dose. However, the authors of this study have not found a protocol in the literature that clearly defines patient selection, optimal surgery time, which corticosteroid to use, and the best administration route for this type of drug.8

The present study is a comparative evaluation of the effects of 2 different doses of dexamethasone (4 and 12 mg) on controlling postoperative symptoms of pain after surgical extraction of displaced third molars.

Materials and methods

This study was approved by the Ethics Committee of the Federal University of Maranhao-UFMA, Sao Luis, Brazil (Protocol No. 23115 006060/2009-87). The patients consent included the option to quit the research at any time, with no consequences to their treatment. Thirty-four patients were initially selected. Of these, 1 became pregnant after the first surgery, 2 did not show up at their postoperative appointments, and 4 did not return after the first surgery. The final study group included 27 male and female patients, with an age range of 15 to 41 years.

This study was a randomized, paired, and double-blinded, longitudinal clinical trial. The patients’ indicated treatment was for the removal of bilateral misplaced mandibular third molars, all in similar positions, without any manifestation of a local or systemic disorder that could counterindicate the surgery or choice of drug treatment.

Exclusion criteria were any surgeries that lasted >1hour and/or presented any type of complications during and after the operation, patients who used postoperative painkillers other than acetaminophen,
patients whose 2 surgical times varied more than 5 minutes, and patients who did not show for the 2 postoperative evaluations (at 24 and 48 hours).

**Surgical procedure**
The order in which the selected patients were submitted to the surgical procedure was randomized. For each patient, the left mandibular third molar was extracted first, then the right mandibular third molar was extracted 15 days later. After each extraction, the patients were examined 2 times (at 24 and 48 hours) for pain, swelling, and trismus.

Dexamethasone was administered 1 hour before surgery; the doses were randomized and different for each extraction—for example, if the patient was given 4 mg before the first surgery, he/she would be given 12 mg before the second surgery.

Before the first surgery, certain areas of the patient’s left side of the face—mandibular angle, tragus, external eye corner, nose wing, buccal commissure, and soft pogonion—were marked by a dermographic pen. Taking the mandibular angle as a reference and using a silk thread (Ethicon, Inc.), the linear distances from the mandibular angle to the other points were measured. These distances were registered in the patient’s clinical file, and used as a reference for swelling. The superior-inferior interciscal distance (ID) was also measured with a paquimeter as a reference for trismus. All preoperative swelling and trismus measurements were done in triplicate and noted on the patient’s clinical record.

The presurgical treatment started with an intraoral antiseptic 0.12% chlorhexidine digluconate mouthwash (Periogard, Colgate-Palmolive Company). The inferior alveolar nerve was anesthetized on the lingual and buccal sides of the tooth with 2% mepivacaine and adrenalin, 1:100,000 (Mepiadre 100, DFL Industrio e Comercio). An incision was made with a scalpel to expose the surgical site and mucoperiosteal detachment, then an ostecotomy and odontosection was performed with surgical spherical burs (No. 4, FGM Produtos Odontologicos) and surgical conical burs (No. 702, FGM Produtos Odontologicos). The sites were irrigated with 0.9% sterile saline solution. Bone regularization, alveolar ridge cleaning, and suture with 4-0 silk thread (Ethicon, Inc.) were performed postextraction.

The patients received postsurgical instruction: semiliquid foods for the first 48 hours, bed rest, and avoidance of ice packs so as not to interfere with the postoperative swelling assessments. Each patient was medicated immediately for postsurgical pain with an oral administration of acetaminophen (750 mg) (Cetafrim, Luper Industria Farmaceutica Ltda). Acetaminophen was given to each patient with instructions to take 1 pill every 6 hours only if pain was present. Each patient then informed the researcher at the 24- and 48-hour postoperative evaluations how many pills he/she had taken. Pain was also measured using the Visual Analog Pain Scale (VAS) as indicated by the patient within the same 2 intervals.

To assess postoperative swelling, new measurements of the facial points were done at both 24 and 48 hours. The same was done for the trismus assessments. Suture removal was performed at postoperative Day 7. The surgery, data collection, and suture removal were all performed by the same researcher.

To avoid the patients knowing the amount of the administrated dose of dexamethasone, and to maintain the double-blind conditions of the research, both doses of the drug (4 and 12 mg) were manipulated so that all the pills were the same size and color, with no listed specifications.

**Postoperative evaluations**
Each patient returned for 24- and 48-hour postoperative evaluations. The clinical measurements of maximum interciscal opening and facial contour, for the evaluation of trismus and swelling, respectively, were noted in the patient’s file.

The mouth opening and facial points that were measured at 24 and 48 hours postoperative were substracked from the preoperative measurements with the same dexamethasone dosage. To evaluate whether there were differences in trismus and swelling on postoperative Days 1 and 2, the measurements taken at the 48-hour evaluation were substracked from the measurements taken at the 24-hour evaluation. The collected data was analyzed using SPSS Statistics Package (version 17.0, SPSS, Inc.). The tests performed were t-test, Wilcoxon, and Friedman (α = 0.05).

**Results**
The study population consisted of 27 patients: 17 women (63%) and 10 men (37%), ages 15-41 (21.7 ± 6.37). Patients treated with 4 mg of dexamethasone had a mean surgical time to remove the impacted teeth of 24.2 minutes; the patients who received a 12 mg dose had a mean surgical time of 25.6 min.

The most prevalent position for the displaced mandibular third molars was vertical (51.9%), followed by mesioangular (33.3%), horizontal (11.1%), and distoangular (3.7%). Using the Pell and Gregory system, almost half of the sample was Class III (48.1%) with more than half in the C position (51.9%), followed by Class II (40.7%) with approximately 33.3% in the B position, and Class I (11.1%) with 14.8% in the A position.

**Trismus**
The ID for the preoperative dose of 4 mg dexamethasone ranged from 39 to 59 mm (49.48 ± 5.06). The ID at 24 hours postoperative ranged from 19 to 58 mm (39.48 ± 10.96); the ID at 48 hours postoperative ranged from 20 to 55 mm (38.92 ± 10.71).

For the class of patients who received the 12 mg dexamethasone dose, the preoperative ID ranged from 39 to 58 mm (48.40 ± 4.87); at postoperative 24 hours, the ID ranged from 15 to 50 mm (38.77 ± 9.65); and the ID at postoperative 48 hours ranged from 14 to 56 mm (37.92 ± 11.25). For the patients who received a 4 mg dose, the preoperative ID was the same as the patients who took a 12 mg dose; the ID at 24 hours postoperative ranged from 19 to 58 mm (39.48 ± 10.96), and the ID at 48 hours postoperative ranged from 20 to 55 mm (38.92 ± 10.71).

**Swelling**
The paired t-test analysis of the relationship between facial swelling—at 1-hour preoperative and 24- and 48-hour postoperative—and the doses of dexamethasone (4 and 12 mg) showed no significant difference between the 2 doses of dexamethasone at either postoperative time (P = 0.68 at 24 hours, P = 0.87 at 48 hours) (Table). A significant increase on the calculated means between pre- and postoperative times was observed between the 2 doses.
Pain
Patients in the 4 mg dexamethasone group used a total of 67 tablets of acetaminophen (750 mg) during the first 48 hours after surgery, while the 12 mg dexamethasone group consumed 75 acetaminophen (750 mg) tablets. According to the Wilcoxon test, there was no significant difference between the amount of acetaminophen tablets used for the 2 different doses at 24 hours or 48 hours postsurgery ($P = 0.59$ for both times). According to the Friedman test, there was no difference between the 2 doses of dexamethasone and the level of pain at postoperative 24 and 48 hours ($P = 0.636$).

Discussion
It was observed in both the 4 mg and the 12 mg groups that the sensitivity to pain decreased during the first week postsurgery, as shown in both the VAS and the quantity of acetaminophen ingested postoperatively.12-16 In a study presented by Laureano Filho et al, the authors obtained similar results when comparing 4 mg and 8 mg preoperative doses of dexamethasone.17 Dionne et al administered a 4 mg dose of dexamethasone to 33 patients both 12 hours before surgery and also shortly after, while 28 patients received a placebo.18

The present study analyzed the degree of inflammation via samples of prostaglandin E2 (PGE2) and thromboxane B2 (TxB2), which were collected during the surgery at the site of the operation. Dexamethasone was found to significantly decrease the levels of PGE2 and TxB2, but had a minimal effect in decreasing pain 24 hours postsurgery. When comparing the 2 different measures of pain used in this study (VAS and painkiller tablet consumption), it was observed that there was no difference between patients in the 4 and 12 mg dexamethasone dosage groups, suggesting a similar analgesic effect of dexamethasone for both doses.

A study by Esen et al evaluated 20 patients with bilateral displaced third molars and recorded the number of painkillers taken postsurgery after a corticosteroid (methylprednisolone 125 mg) was administered 1 hour before the first surgery vs the number of painkillers taken postsurgery after a placebo was administered 1 hour before the second surgery.16 The results showed that patients who received the methylprednisolone before the surgery used 42% fewer analgesics within the first 24 hours postsurgery than patients who received the placebo.16 These results indicate the efficacy of corticosteroids in controlling pain in the first hours postsurgery. However, in another study of displaced third molar surgery, Grossi et al found no significant difference in the amount of drugs taken postsurgery when they compared patients who received 4 mg dexamethasone versus patients who received 8 mg preoperatively.4

The postoperative analgesic used in this study was acetaminophen, as it is considered a safe drug that does not change coagulation time, platelet aggregation, or neutrophilic defense.19 No other drug was allowed until the closing of the postoperative phase of the study.
As reported in other studies, the authors of the present study observed that the preoperative administration of 4 mg of dexamethasone significantly decreased the swelling by postoperative Day 2. There was no difference in swelling when compared to the 12 mg dose. This would suggest that both doses presented the same effect in relation to swelling. In another lower third molar surgery study, Paiva compared the effects of preoperative doses of dexamethasone (4 and 8 mg). The results showed a reduction on the swelling of the buccal comissure jaw angles of patients who were treated with the 8 mg dosage. This is one of the primary regions to present swelling in lower third molar surgery. This may be due to the fact that the area requires extensive manipulation of the surrounding tissues and also because the surgery involves cutting through part of the masseter region that includes the buccinator muscle.

In a study by Lago-Mendez et al, the authors correlated postoperative pain to the degree of surgical difficulty in 139 patients. The pain was found to be—through a VAS evaluation—more intensive in postoperative Day 1, decreasing gradually until the sutures were removed on postoperative Day 7. The average time period of the surgical procedures was 36.8 ± 22.8 minutes. Patients who had longer surgical procedures reported greater pain intensity on postoperative Days 0 (day of surgery), 5, and 6.

A study by Al-Khateeb & Nussair also demonstrated that the length of the surgical procedure can be directly correlated to the degree of difficulty in such surgical extractions, and consequently, can also be related to the intensity of the swelling presented by the patient post-surgery. In order to mitigate any possible connection between longer surgical times and differing doses of dexamethasone, the present study recommended a selective inclusion of patients who had no more than 5 minutes difference between the 2 surgeries, thus averaging similar operative times between doses of 4 mg (24.22 min) and 12 mg (24.66 min), with no difference in the variable time.

According to Peterson et al, the mesiangular position of the mandibular third molar is the most prevalent, affecting approximately 45% of the teeth. In the present study, the authors found that the vertical position had the highest prevalence (51.9%) of the teeth removed. These data also agree with Aguiar et al who found a higher prevalence of vertical impacted teeth. Regarding the level of retention, slightly less than half of the sample in the present study was Class III (48.1%). This data corroborates those obtained by Aguiar et al.

In a similar study of 23 patients undergoing lower and upper third molar surgery, it was observed that 56.5% of the patients presented trismus on postoperative Day 2. The results confirmed the high incidence of this kind of sequelae in third molar surgeries. These results were further corroborated by Oliveira et al, who found that trismus and other complications—such as paresthesia and alveoli trauma—were directly correlated to the degree of difficulty of the surgery, whether or not the surgery involved an osteotomy, and whether the procedure required a prolonged surgical time.

In this study, the authors found that the positions of the lower third molars did not affect the analysis of the trismus variable between the 2 different doses of dexamethasone. This would suggest that the different doses presented similar effects, and have no impact regarding limited mouth opening postoperatively. Flores et al investigated the use of anti-inflammatory medication and/or antibiotics in third molar surgery. The authors reported that such medicines effectively reduced the incidence of trismus, but were not able to completely avoid it. In the same study, it was also reported that no significant relationship between the use of such medicines and the level of surgical trauma could be found.

Gботолорун et al reported that the main factor directly associated with the difficulty of removing mandibular third molars was radiological variables. The authors of that study also found that clinical variables (such as age and body mass index) exerted some influence on the degree of surgical difficulty. According to their results, patients of advanced age and high body mass index were submitted to longer, more complicated surgeries.

It is well known that cortisol found in the body changes its concentration over the course of a day, presenting a peak serum level in the early morning. If the daily production of cortisol by the human body averages 20 mg/day—with peaks of 300 mg reached during stressful situations such as trauma and infectious processes—this limit has to be taken into account if a patient is administered a maximum dose of glucocorticoid. There have been studies of patients taking methylprednisolone (125 mg, equivalent to 625 mg of cortisol) with no noted side effects. Other studies in which doses of 12 mg of dexamethasone (equivalent to 320 mg of cortisol) were administered reported no postsurgical complications and no pharmacological side effects.

The relationship between the use of glucocorticoids and the development of infections is controversial, as it depends on the dose and duration of treatment. Cornia & Anawalt reported that the dose and duration of supplemental steroids used traditionally may produce adverse reactions such as infections, and delay the healing process. The relationship between the use of glucocorticoids and possible side effects depends on the intensity and duration of the therapy.

It has been reported that corticosteroid therapy, whether in single large doses or short-term therapies, can cause side effects. In therapies in which a glucocorticoid was administered for >1 week, some signs of steroid toxicity have been reported, including hyperglycemia, myopathy, growth suppression, peptic ulcer disease, effects on the central nervous system, increased susceptibility to infection, and signs of suppression of the hypothalamic-pituitary-adrenal (HPA) axis. The effects of corticosteroids on the HPA axis were first investigated by Williamson et al. In their study, an 8 mg dose of dexamethasone was administered to patients undergoing third molar extraction. A significant difference was found between the patient’s preoperative values of 11-deoxycortisol (cortisol) and the values measured on postoperative Day 3. However, no significant difference was found when comparing the preoperative values with the values measured on postoperative Day 7. These results seem to indicate that the integrity of the HPA axis is completely restored 7 days postsurgery. Therefore, it can be assumed that the preoperative administration of a single dose of corticosteroids—to decrease the length of HPA axis suppression postsurgery—is a relatively safe and effective procedure.
Summary
In pharmacology, the terms clinical efficacy or clinical maximum are both defined as the plateau region in a concentration–response intensity graph. This plateau may be determined primarily by the receptor-effector effect of the drug and its properties. The results of the present study suggest that the therapeutic doses of 4 and 12 mg dexamethasone have shown similar effects regarding the evaluated variables—swelling, pain, and trismus. The results suggest that this is due to the fact that the investigated drug has a desired therapeutic effect at either dose.

The data also suggests that the 12 mg dose of dexamethasone and the 4 mg dose presented the same therapeutic effect on the evaluated variables at both 24 and 48 hours postsurgery. Thus, it can be concluded that both doses are effective and there is no need to use the larger dose to ensure successful postsurgical management of these variables.

Author information
Dr. Agostinho is a master’s candidate in the Postgraduate Program of Dentistry, Federal University of Maranhao-UFMA, Sao Luis, Brazil, where Drs. da Silva and Bastos are professors in the Oral Surgery Dentistry Department, and Dr. Cruz is a professor in the Pharmacy Department. Dr. Maia Filho is a professor in the Endodontics Department, University Center of Maranhao-UniCeuma, Sao Luis, Brazil.

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References

Manufacturers
DFL Industria e Comercio, Rio de Janeiro, Brazil 55.21.3528.6766, www.dfl.com.br
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Clinical evaluation of silorane-based and dimethacrylate-based resin composites: 1-year follow-up

M. Jacinta M.C. Santos, DDS, MSc, PhD • Abraham Kunnilathu, BDS, CRCA • Shawn Steele, DDS • Gildo C. Santos Jr., DDS, MSc, PhD

This study sought to evaluate the 1-year clinical performance of silorane-based and dimethacrylate-based Class II resin composite restorations using 2 bonding strategies. Eighty-two restorations were placed in 32 patients (median age 37 years) by a single operator. Only Class II restorations were included. Each patient received 1-2 pairs of resin composite restorations with both restoration materials. Between-group comparisons were made using an adjusted chi-square test and an adjusted McNemar’s chi-square test to analyze the intrasystem data (α = 0.05). Both systems demonstrated acceptable clinical performance after 1 year.

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Key words: clinical evaluation, composite resins, dentin-bonding agents, low shrinkage

The increased popularity of resin composites is due in part to their esthetics, low cost, and acceptable clinical performance.1–3 The longevity of resin composite restorations has been attributed to several factors. Clinical variables (such as restoration type, size, and location), the technique employed, operator experience, and behavioral aspects related to patients—such as caries risk, age, occlusion, and hygiene—are considered relevant to the long-term success of composite restorations.1–3 Studies have reported that fractures and recurrent caries are the most common reasons for failure.1,2,4,5 Dimethacrylate-based resin composites (DBCs) are known to experience polymerization shrinkage and shrinkage stress (generated during setting).6,7 These well-documented phenomena can compromise marginal adaptation, resulting in microleakage, postoperative sensitivity, marginal staining, recurrent caries, and inevitably restoration failure.7,9 To overcome these problems, research has focused on modifying the composition of the restorations (such as altering the amount and size of filler) and using high molecular weight monomers.10,11 The fundamental problem of polymerization shrinkage remains related to the radical polymerization of the methacrylate-based resin composites (MBCs). The predominant base monomers in dental resin composites have been dimethacrylates—such as bisphenol A-glycidyl methacrylate (Bis-GMA), tetraethylene glycol dimethacrylate (TEGDMA), and urethane dimethacrylate (UDMA).12 By converting dimethacrylate-based monomer molecules into a polymer network, van der Waals spaces are exchanged for shorter covalent bindings, resulting in a tighter arrangement of molecules, which leads to a reduction in material volume.6,9 Recently, a new type of resin composite that is silorane-based was introduced commercially. Siloranes contain a siloxane backbone with 4 attached oxirane rings that open to form a polymer chain.10 The oxirane ring opening results in volumetric expansion that offsets the shrinkage that results when converting monomers into polymers. In vitro studies have reported that silorane-based composites (SBCs) and standard DBC composites have similar mechanical properties.10,11,13 However, the SBC polymerization shrinkage is approximately 50% that of the current resin-based composites; a longer gelation time with a reduced shrinkage strain has been reported as well.11,14,15 These factors translate to a different polymerization rheology, allowing the material to better compensate for stresses during polymerization and improving marginal adaptation.15

Fig. 1. An example of 2 deficient mesiocclusal distal amalgam restorations.

Fig. 2. Cavity preparations on teeth No. 15 (left) and No. 14 (right).
SBCs require a dedicated adhesive system for bonding to dentin and other DBC materials. The silorane-dedicated adhesive system is available in a self-etch version which, according to the manufacturer, was created to fulfill the criterion of simplification; that is, using the reduced number of operative steps found in self-etch adhesive systems. Although 3-step etch-and-rinse adhesive systems are considered the gold standard, 2-step self-etch adhesives have reported satisfactory results. In that context, this study sought to evaluate the clinical performance of silorane-based and dimethacrylate-based resin composite systems in terms of clinical performance.

Materials and methods
This study selected 32 patients, ranging in age from 21 to 53 years (median age 37 years), who required at least 1 pair of Class II restorations (Fig. 1). Before the start of treatment, patients were informed of the research methodology, risks, and benefits, as well as their right to withdraw from the research at any time. Written informed consent was obtained.

The following were exclusion criteria: high caries risk (presence of incipient lesions, plaque, and/or xerostomia), generalized periodontal disease, a removable or fixed orthodontic appliance, signs of bruxism or clenching, more than 1 unit absent from the posterior region, poor oral hygiene, and pregnancy.

Preoperative bitewing radiographs were taken of the teeth that were to be restored. Vitality was tested with carbon dioxide snow (-26.2°C). A total of 82 Class II restorations were placed in pairs randomly, using 2 composite systems. Randomization was determined by selecting the restorative system (via a coin toss), then using the selected system on the tooth with the lowest number. The other system was then placed on the remaining tooth.

Clinical procedures
All cavities were prepared under local anesthesia and rubber dam isolation (Hygienic Dental Dam, Coltene/Whaledent, Inc.) using water-cooled high-speed carbide burs (No. 330 and No. 245, Brasseler USA). Carious tissues were removed using low-speed carbide round burs (No. 1-3, Brasseler USA). After caries removal, the undercuts were covered with a resin-modified glass ionomer (Ketac Nano, 3M ESPE). In cases with deeper areas, a calcium hydroxide lining (Kerr Life, Kerr Dental) was used. The enamel margins at the proximal box were finished using hand instruments to remove unsupported enamel and to bevel the cavosurface margins of the gingival and proximal walls (Fig. 2). All cavities were restored with 1 of the 2 resin composite/bonding agents: DBC (Filtek Supreme/Single Bond, 3M ESPE) and SBC (Filtek LS Low Shrink Posterior Restorative System/LS Adhesive Self-Etch Bond, 3M ESPE), according to the manufacturers’ instructions (Table 1) (Fig. 3). A sectional metal matrix, fixed with an elastic ring (Garrison Dental), was installed to restore the proximal contact and marginal ridge. The resin composites were placed incrementally and photocured for 20 seconds by a light-emitting diode lamp (Elipar FreeLight 2, 3M ESPE) with a power density of 660 mW/cm². Increments of resin composite (maximum thickness of 2 mm) were placed and photocured. Occlusal anatomy was developed using hand instruments before the composite was cured at the occlusal surface. After polymerization, the margins were inspected carefully for overhangs, which were removed with a No. 12 scalpel. Occlusal adjustments were performed with diamond finishing burs (No. H133F and H134F, Brasseler USA) under cooled water. The occlusal surfaces were then polished carefully with rubber tips (PoGo Points, DENTSPLY Caulk) and embrasures were refined with fine disks (Sof-Lex Finishing and Polishing System Kit, 3M ESPE).

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Adhesive</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBC: Filtek Supreme (Lot No. N142167)</td>
<td>Resin: Bisphenol A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA), tetraethylene glycol dimethacrylate (TEGDMA), ethoxylated bisphenol A glycol dimethacrylate (Bis-EMA), polyethylene glycol dimethacrylate (PEGDMA); filler: 72.5% weight, volume 55.6% zirconia/silica; etchant: 35% weight phosphoric acid; adhesive: Bis-GMA, hydroxyethyl methacrylate (HEMA), dimethacrylates, ethanol, water, silica nanofiller, copolymer of methacrylic acid (10%), photoinitiator, stabilizers</td>
<td>Adper Single Bond Plus (Lot: N162108)</td>
<td>Etch enamel/dentin with Scotchbond Etchant for 15 seconds, rinse with water for 10 seconds, gently air dry and immediately use applicator to apply 2 coats of adhesive, air dry for 5 seconds to evaporate solvents, photocure for 10 seconds, apply composite in 2 mm increments, and photocure for 20 seconds.</td>
</tr>
<tr>
<td>SBC: Filtek LS (Lot: N280238)</td>
<td>Resin: polysiloxane; filler: 53% volume; 73% weight quartz; adhesive: primer (Bis-GMA, HEMA, phosphorylated methacrylates, Vitrebond co-polymerer, water, ethanol, silica filler, initiators, stabilizers), bond (hydrophobic dimethacrylate, phosphorylated methacryltes, TEGDMA, silica filler, initiators, stabilizers)</td>
<td>Silorane system adhesive (Lot: N144629)</td>
<td>Apply self-etch primer for 15 seconds, air dry for 5 seconds to evaporate solvents, photocure for 10 seconds, apply bonding agent, air spread, and photocure for 10 seconds, apply composite in 2 mm increments and photocure for 40 seconds.</td>
</tr>
</tbody>
</table>

Table 1. Dimethacrylate-based (DBC) and silorane-based (SBC) resin composite systems with restoration specifications, according to the manufacturer’s instructions.
Evaluation procedures

One week following placement, the restorations were assessed using only mirrors and probes, in accordance with the modified USPHS criteria, by 2 independent investigators calibrated in the use of the system (Table 2). The investigators did not participate in the clinical procedures and neither the patients nor the evaluators knew which restorative system was used on the selected teeth. When disagreement occurred during the evaluation process, the evaluators had to reach a consensus before the patient could be dismissed. The same procedures performed at the baseline were performed again 1 year post-treatment (Fig. 4). Between-group comparisons were made using an adjusted chi-square test and an adjusted McNemar’s chi-square test to analyze the intrasystem data ($\alpha = 0.05$).

Results

Table 3 summarizes the results of the Alpha ratings for both resin composites at baseline and at 1-year recalls, according to the USPHS criteria. Concerning marginal adaptation, restorations from each system were assessed by the evaluators.

Marginal discoloration/marginal adaptation

Marginal discoloration was detected in some restorations from both groups. At the 1-year evaluation, the percentage of Alpha scores were 76.3% for the SBC samples, compared to 92.1% for the DBC samples. The marginal discoloration was considered clinically acceptable by USPHS Bravo criteria, and no Charlie scores were rated for any of the resin-based restorative materials. Concerning marginal adaptation,
both restorative systems recorded some enamel defects, with 78.9% of SBC and 92.1% of DBC samples receiving Alpha scores; however, no significant differences were found between both materials ($P = 0.09$).

**Surface texture**
In terms of surface texture, there was no significant difference between the 2 restorative systems ($P > 0.05$). All of the DBC restorations demonstrated ideal surface texture, compared to 97.4% of the SBC restorations.

**Postoperative sensitivity/Secondary caries**
Four (10.52%) of the DBC restorations demonstrated postoperative sensitivity at the baseline; however, no postoperative sensitivity was reported for either composite at the 1-year recall. None of the restorations had recurrent caries after 1 year of clinical service.

**Anatomic form**
All restorations at the 1-year recall were continuous with existing anatomic form.

**Color match**
In terms of the color match between the restoration and the tooth, 84.2% of the SBC restorations were rated Alpha, compared to 89.5% of the DBC restorations; this difference was not statistically significant ($P > 0.05$). The color match was assessed at baseline and did not change after 1 year.

### Clinical success rate
At the 1-year recall, all composite restorations showed acceptable clinical performance. The chi-square test revealed no significant difference between SBC and DBC for all aspects evaluated at baseline and at the 1-year recall ($P > 0.05$). The McNemar statistical test was used to draw a comparison between baseline and 1 year for each resin composite system and no significant differences were found.

### Discussion
The null hypothesis that there would be no difference in the clinical performance between the 2 resin composite systems was confirmed. At 1 year, no significant difference was found between the SBC and DBC for any of the aspects evaluated at different recall appointments ($P > 0.05$). The main reported disadvantage of DBC is its inherent degree of polymerization shrinkage during the setting reaction, when the monomers link to form polymer chains, inevitably leading to volume shrinkage. Although high filler content can reduce polymerization contraction, current resin composites shrink in volume by 2.6%-7.1%.

Conversely, the SBC system has been reported as a low shrinkage composite, with a volumetric shrinkage of approximately 1% (approximately 50% of the DBC system). However, the clinical relevance of this difference in polymerization shrinkage could not be upheld in this study at the 1-year evaluation. Both composite materials presented satisfactory results with no significant difference between them.

To increase the validity of this clinical trial and allow for future comparisons with similar studies, care was taken to reduce bias. A randomized allocation and fully blinded investigation was employed using 2 calibrated evaluators, with 1 experienced dentist placing all of the restorations. A paired allocation design was employed and a maximum of 2 pairs of restorations was allowed per patient to reduce the effects of clustering.

In the present study, 76 restorations were evaluated at the 1-year recall. The sample size was comparable to previous studies in which 1 operator performed all of the restorative treatments, rather than using a multicenter approach. Six restorations (7.3%) were not examined at the 1-year recall, as 3 patients could not participate.

The 1-year recall was used as an initial evaluation of the marginal adaptation, since polymerization shrinkage develops at an early stage during restoration placement. It is the authors’ intention to evaluate the restorations for a longer period to assess the medium-term durability of these restorations. Comparing the baseline data with those obtained at the 1-year evaluation revealed an increase in Bravo ratings for marginal discoloration, the most common problem reported in clinical trials involving resin composite restorations. This problem is possibly caused by several factors and may be due to excess composite material left behind after finishing and polishing, gaps as a result of polymerization shrinkage, a deficient adaptation around the margins, and/or the adhesive interface failing over time. In most cases, marginal discoloration of a restoration does not indicate a need for immediate replacement, but should be interpreted as a clinical sign of possible failure in the future.

In the present study, 2 restorative systems and their respective adhesives were employed. Filtek Silorane was designed for posterior restorations; it requires its own dedicated adhesive system, to which hydrophobic bifunctional monomers are added to match the hydrophobic silorane resin. The manufacturer elected to use a self-etch adhesive version with this restorative system for simplification. In contrast to the 2 resin composite systems and their respective adhesives were used in previous studies. Further studies should focus on the clinical longevity of resin composite restorations.

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**Table 3. Alpha scores (%) for resin composite systems used in this study.**

<table>
<thead>
<tr>
<th></th>
<th>Baseline (n = 82)</th>
<th>1-year follow-up (n = 76)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBC</td>
<td>DBC</td>
</tr>
<tr>
<td>Postoperative sensitivity</td>
<td>100.0</td>
<td>89.5</td>
</tr>
<tr>
<td>Secondary caries</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Marginal adaptation</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Color match</td>
<td>84.2</td>
<td>89.5</td>
</tr>
<tr>
<td>Anatomic form</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Surface roughness</td>
<td>97.4</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Abbreviations: DBC, dimethacrylate-based composite; SBC, silorane-based composite.
self-etch adhesive system is employed, due to its weak etching ability at the enamel margins. While the DBC system (used in conjunction with an etch-and-rinse adhesive) showed slightly better results, this difference was not statistically significant ($P > 0.05$). The SBC restoration showed slightly poorer marginal adaptation, although this difference was not significant at the 1-year evaluation.

The results obtained in the present study are in agreement with a 2011 study that evaluated SBC restorations for a 2-year period. However, 2 other clinical studies have reported a significantly worse marginal adaptation for the SBC compared to a DBC for the same timeframe. Color matching remained the same after 1 year. Although exceptional esthetic results are not considered essential for posterior restorations, both composites showed acceptable results. Previous studies have reported on the high color stability of SBC.

Although postoperative sensitivity has been considered as another clinical complication of posterior composite restorations, it was not an issue in the present study. After cavity preparation, all deep areas and undercuts were covered with a resin-modified glass ionomer to protect the deep dentin. In the present study, the SBC restorations demonstrated no postoperative sensitivity, while 4 DBC restorations exhibited postoperative sensitivity at the baseline; this problem was not present at the 1-year recall.

**Conclusion**

It can be concluded that both the SBC and DBC systems offered satisfactory results at the 1-year evaluation. The null hypothesis was accepted, since no significant differences were noticed between the 2 resin composite systems. As a result, the advantage of using a low shrinkage resin composite system could not be validated at the 1-year evaluation. Additional recall visits are planned to verify the clinical performance of these resin-based materials over time.

**Author information**

Dr. M. Santos is an assistant professor, Department of Restorative Dentistry, Schulich School of Medicine & Dentistry, Western University, London, Ontario, Canada, where Drs. Steele and Santos are adjunct professors, and Dr. Kunnilathu is a graduate student, Neuroscience, Western University.
Cytotoxicity of dentin bonding agents

Ebru Cal, DDS, PhD  Pelin Guneri, DDS, PhD  Ayse Atay, DDS, PhD  Vildan Bozok Cetintas, PhD

This study sought to evaluate the cytotoxicity of 5 dentin bonding agents (Admira Bond, Adper Single Bond Plus, Clearfil SE Bond, Clearfil S3 Bond, and Heliobond) by XTT assay using human gingival fibroblast cells. Samples of dentin bonding agents were prepared on a black 96-well microplate, and the cytotoxicity of each bonding material was measured every 24 hours for 7 days, then on Days 14, 21, and 28. One-way ANOVA and Bonferroni post hoc test were used for statistical analyses.

All 5 materials were evaluated as severely cytotoxic (P < 0.001) on the first day, with cell viabilities ranging from 6% to 24%. All the bonding agents showed severe cytotoxicity with viability results <10%. With the exception of Adper Single Bond Plus, toxicity continued to Day 28 for all the compounds. The utmost care must be considered during the clinical utilization of dentin bonding agents to keep them within the area of restoration and prevent their contact with adjacent tissues.

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Accepted: June 13, 2013

Materials and methods
Five dental adhesives were examined: Admira Bond (Voco America, Inc.), Adper Single Bond Plus (3M ESPE), Clearfil S3 Bond (Kuraray America, Inc.), Clearfil SE Bond (Kuraray America, Inc.), and Heliobond (Ivoclar Vivadent, Inc.) (Table 1). The adhesives were photocured with a halogen light curing unit (Optilux 501, Kerr Dental) per manufacturer recommendations. Each dental adhesive sample was prepared in a 96-well black microplate under laminar air flow. A total volume of 10 µl of adhesive material was pipetted into 10 wells. The ratio of sample surface area to solution volume was adjusted to approximately 4.32 cm²/ml, which is within the 0.5-6 cm²/ml range recommended by the International Organization for Standardization.13 The polymerization period for the adhesive materials was accomplished per manufacturers’ instructions.

Table 1. Adhesive materials used in the study.

<table>
<thead>
<tr>
<th>Name</th>
<th>Composition</th>
<th>Lot No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admira Bond</td>
<td>Ormocers, bisphenol A glycidyl methacrylate (Bis-GMA), hydroxyethyl methacrylate (HEMA), brain heart infusion (BHI) agar, acetone, organic acids</td>
<td>45309</td>
</tr>
<tr>
<td>Adper Single Bond Plus</td>
<td>Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator, polyacrylic, polyitaconic acid</td>
<td>51202</td>
</tr>
<tr>
<td>Clearfil S3 Bond</td>
<td>10-methacryloyloxydecyl dihydrogen phosphate (MDP), Bis-GMA, HEMA, hydrophobic dimethacrylate, ethyl alcohol, camphorquinone, silanated colloidal silica</td>
<td>41117</td>
</tr>
<tr>
<td>Clearfil SE Bond</td>
<td>MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate</td>
<td>41491</td>
</tr>
<tr>
<td>Heliobond</td>
<td>Bis-GMA, triethylene</td>
<td>K00250</td>
</tr>
</tbody>
</table>

Dentin bonding agents are designed to improve bonding strength between the resin and tooth structure, increase the retention of restorations, reduce microleakage across the dentin-resin interface, and scatter occlusal stress. Like many dental materials, dental adhesives may make direct contact with soft and/or hard tissues for a prolonged period of time; during this time, they may exert residues that can affect the health and structure of adjacent tissues, thus it is necessary to determine the cytotoxicity of these materials to identify and exclude any individual components that may adversely interact with adjacent cellular structures.

Before using a material in clinical conditions, it is necessary to evaluate the material’s biocompatibility. Among the in vitro tests that have been utilized to evaluate the biological effects of dental adhesives, cell culture tests generally have provided rapid, sensitive, inexpensive, convenient, and repeatable methods of material screening and ranking; in addition, these tests can be carefully controlled. Cell culture tests that investigate toxicity in a simplified manner that minimizes the effect of confounding variables usually are the first step toward evaluating biocompatibility. This method uses a range of cell types to quantitatively investigate the cytotoxicity of numerous dental materials and present biological endpoints.

XTT (tetrazolium salts reduction) cell proliferation assay has been used as a non-radioactive, colorimetric assay system for measuring the drug sensitivity of tumor cell lines. After its reduction by metabolic active cells, the color of tetrazolium salt changes from yellow to bright orange. Since the formazan produced by XTT reduction is soluble and can be quantified directly using an enzyme-linked immunosorbent assay (ELISA) reader, it can be used in real-time assays. Due to its many advantages—such as being more economical in time and cost and having lower detectable limits—an XTT assay is preferred over the cytotoxicity tests based on the release of ⁵¹Cr from the cells.

Previous cell culture studies have stated that the components of resin restoratives may elicit significant toxicity when they make direct contact with fibroblasts. This in vitro study sought to investigate the cytotoxicity of 5 commercially available dentin bonding agents using a cell culture technique on human gingival fibroblast (HGF) cells by XTT assay.

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Samples were topped with 200 µl of Dulbecco’s modified eagle medium (DMEM)—containing 10% fetal bovine serum, 100 U/ml of penicillin, and 100 µg/ml of streptomycin—to obtain medium extracts of adhesive materials. Plates were incubated in a highly humid atmosphere (5% CO2 at 37°C) for 24 hours. Next, the medium was removed and the samples were rinsed with 500 µl of phosphate-buffered balanced salt solution and topped again with 200 µL DMEM. Removed medium extracts (approximately 2000 µl) were filtered and set aside in sterile Eppendorf tubes at -20°C until cytotoxicity could be tested. This procedure was repeated every 24 hours for 7 days and again on Days 14, 21, and 28.

**Cell culture**

This study was approved by the ethics committee of Ege University, Turkey (No. 10-6/13), and the 3 patients who volunteered to donate signed informed consents. To obtain HGF cells, 3 biopsies were performed on healthy gingival tissues of 3 patients who were undergoing surgical treatment for impacted third molars. Each biopsy sample was placed into the DMEM culture medium during transportation to the laboratory. Biopsy samples were washed in DMEM and placed in tissue culture flasks using the explant culture method. HGF cells were grown in the humid atmosphere described previously using the supplemented medium. The medium was changed every 3 days, and cells were passaged when confluent with 0.05% trypsin in 0.02% ethylenediaminetetraacetic acid.

**Cytotoxicity tests**

Cytotoxicity was analyzed with an XTT cell proliferation reagent. HGF cells (1 x 105) were placed onto each well of a 96-well plate and incubated for 24 hours. At that time, culture medium was aspirated and 100 µl extracts of adhesive materials were pipetted onto the HGF cells. All procedures were performed in triplicate. At 24, 48, 72, and 96 hours, formazan formation was quantified spectrophotometrically at 450 nm with a microplate reader. Cell viability was calculated according to the following formula using optical density (OD):

\[
\text{% cell viability} = \left( \frac{\text{OD ratio of test group}}{\text{OD ratio of control group}} \right) \times 100.
\]

Cell viability was scored using a method described by Sjogren et al.\textsuperscript{16} Using this approach, material with cell viability >90% was deemed nontoxic, materials with 60%-90% cell viability were considered slightly cytotoxic, 30%-59% cell viability was regarded as moderately cytotoxic, and materials with <30% cell viability were considered severely cytotoxic.\textsuperscript{16}

### Table 2. Percentage and standard deviation (SD) survival rates of human gingival fibroblast cells during each measurement period.

<table>
<thead>
<tr>
<th>Day</th>
<th>Admira Bond</th>
<th>Adper Single Bond Plus</th>
<th>Clearfil S3 Bond</th>
<th>Clearfil SE Bond</th>
<th>Heliobond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>7.76 (0.86)</td>
<td>6.60 (0.81)</td>
<td>24.06 (3.01)</td>
<td>6.58 (0.72)</td>
<td>6.00 (0.52)</td>
</tr>
<tr>
<td>2</td>
<td>6.88 (0.51)</td>
<td>6.46 (0.44)</td>
<td>6.36 (0.81)</td>
<td>6.91 (0.40)</td>
<td>6.35 (0.47)</td>
</tr>
<tr>
<td>3</td>
<td>6.36 (0.55)</td>
<td>6.56 (0.20)</td>
<td>7.48 (1.05)</td>
<td>6.79 (0.41)</td>
<td>6.62 (0.60)</td>
</tr>
<tr>
<td>4</td>
<td>6.47 (0.52)</td>
<td>6.07 (0.41)</td>
<td>6.40 (0.28)</td>
<td>6.49 (0.50)</td>
<td>6.15 (0.31)</td>
</tr>
<tr>
<td>5</td>
<td>6.03 (0.28)</td>
<td>6.29 (0.59)</td>
<td>6.43 (1.16)</td>
<td>6.52 (0.40)</td>
<td>6.18 (0.55)</td>
</tr>
<tr>
<td>6</td>
<td>7.03 (1.39)</td>
<td>5.71 (0.27)</td>
<td>6.40 (0.40)</td>
<td>6.50 (0.55)</td>
<td>6.00 (0.29)</td>
</tr>
<tr>
<td>7</td>
<td>6.50 (0.72)</td>
<td>5.59 (0.45)</td>
<td>7.34 (2.08)</td>
<td>7.12 (1.37)</td>
<td>7.09 (1.35)</td>
</tr>
<tr>
<td>14</td>
<td>6.51 (0.84)</td>
<td>18.25 (1.43)</td>
<td>6.13 (0.77)</td>
<td>7.40 (1.45)</td>
<td>5.95 (0.59)</td>
</tr>
<tr>
<td>21</td>
<td>5.89 (0.17)</td>
<td>24.23 (6.72)</td>
<td>6.15 (0.95)</td>
<td>6.62 (0.91)</td>
<td>6.26 (1.00)</td>
</tr>
<tr>
<td>28</td>
<td>6.24 (0.41)</td>
<td>30.78 (0.40)</td>
<td>6.12 (0.72)</td>
<td>7.42 (1.07)</td>
<td>6.07 (0.44)</td>
</tr>
</tbody>
</table>

![Chart](chart.png)

Chart. XXT assay results showing percent cell viability for the 5 dentin bonding agents used in the study. Baseline began at 100% for all agents.
24% and 31%, respectively, which showed to decrease while viability increased to 20% (Fig. 3). Cytotoxicity of this compound started was detected during the first 7 days, the viability curve compared to the other adhesives. Although severe cytotoxicity was observed, the adhesives remained <30% (Table 2). Admira Bond, Clearfil SE Bond, Clearfil S3 Bond, and Heliobond had cytotoxic effects on human gingival fibroblasts (HGF), as the materials contain hydroxyethyl methacrylate, bisphenol A glycidyl methacrylate, and acetone showed severe cytotoxicity on primary HGF cells.

It is important to test the biocompatibility of materials that make contact with normal tissues to determine the host-to-graft acceptance. Assays that measure cytotoxicity are critical for testing materials to be used on human tissues. Increased public concern regarding the use of animals in evaluating dental materials has made in vitro testing more acceptable ethically. However, preparing test materials for experiments may alter the cytotoxicity of a material significantly.20 Every effort was made to simulate in vitro conditions in the laboratory due to the importance of the proper preparation of materials to test target cells.

The literature describes cell culture tests that use various cell types to establish the damage caused by dental materials; however, primary fibroblast cell cultures have not been used frequently in such experiments.21-23 The present study used HGF cells as the cell culture. The study model used followed previous studies that have recommended HGF cells for testing the cytotoxicity of dental materials.24-26 A 1994 study by Al-Nazhan & Spangberg used HGF and mouse fibroblast (L-929) cells and found that the Golgi apparatus of the L-929 cells were identified less frequently than those in the HGF cells.27 In addition, the organelles of the L-929 cells were destroyed almost completely after only 4 hours exposure to the test materials (polymers). The authors concluded that HGF cells were more resistant to environmental impact and appeared to be more suitable for testing various materials.27

According to the literature, continuous cell lines with homogeneous cells are recommended for long-term experiments.28 Tests involving primary gingival fibroblasts attempt to simulate clinical assays by establishing the impact of materials on cell cultures in long-term trials.28 Primary gingival fibroblast cultures are more closely related to the original tissue and therefore much easier to identify.29,30 In addition, cultures with primary cells generally are recommended for long-term experiments as they provide heterogeneous cells with physiological states of aging and offer

### Table 3. Statistical analysis of the test materials at different measurement periods.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Day</th>
<th>Difference</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admira Bond vs Adper Single Bond Plus</td>
<td>14</td>
<td>11.74</td>
<td>7.411 to 16.06</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>18.34</td>
<td>14.01 to 22.66</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>24.54</td>
<td>20.22 to 28.87</td>
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<tr>
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<td>11.97 to 20.63</td>
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<tr>
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<td>13.13 to 21.79</td>
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<td></td>
<td>14</td>
<td>-12.11</td>
<td>-16.44 to -7.787</td>
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<tr>
<td></td>
<td>21</td>
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<td>28</td>
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<td>21</td>
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<tr>
<td>Admira Bond vs Heliobond</td>
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*For those comparisons with significant differences, *P* < 0.001 according to Bonferroni post hoc test.*

**Statistical analysis**

Statistical analysis of the results was performed via 1-way ANOVA and Bonferroni post hoc test using analytic software (GraphPad Prism 5.01 for Windows, GraphPad Software, Inc.); *P* < 0.05 was accepted as statistically significant.

**Results**

The XTT results of cell viability are presented in the Chart. On the first day of the experiment, all adhesive materials showed severe cytotoxicity (*P* < 0.001) and cell viability of <30%. From Day 22 to Day 28, the cell viability of Admira Bond, Clearfil SE Bond, Clearfil S3 Bond, and Heliobond remained <30% (Table 2).

Adper Single Bond Plus had a different viability curve compared to the other adhesives. Although severe cytotoxicity was detected during the first 7 days, the cytotoxicity of this compound started to decrease at Day 14, while cell viability increased to 20% (*P* < 0.001). At Days 21 and 28, cytotoxicity continued to decrease while viability increased to 24% and 31%, respectively, which showed that aging had a positive effect on the material’s cytotoxicity.

There was a significant difference between the potential cytotoxicity of the materials tested. The effects of Clearfil S3 Bond were significantly different on the first day compared to the other materials. However there was no significant difference when Clearfil SE Bond was compared to Heliobond or Admira Bond, or when Admira Bond was compared to Heliobond (Table 3).

**Discussion**

Conservative dental intervention is intended to preserve pulp vitality and prevent possible adverse effects caused by restorative biomaterials used in dental clinical practice. Whenever deep cavities are treated with dentine adhesive systems, their components (such as monomers, acids, or solvents) may pass through the dentinal tubules before and after adhesive curing—particularly when the dentin permeability is high—which may lead to cytotoxic effects.27,28 A 2012 study by Kierklo et al reported that both Adper Single Bond 2 and Heliobond had cytotoxic effects on HGF cells.19 This finding was confirmed in the present study, as the materials containing hydroxyethyl methacrylate, bisphenol A glycidyl methacrylate, and acetone showed severe cytotoxicity on primary HGF cells.

According to the literature, continuous cell lines with homogeneous cells are suitable for establishing a concentration-dependent response curve in short-term experiments.24-26 Tests involving primary gingival fibroblasts attempt to simulate clinical assays by establishing the impact of materials on cell cultures in long-term trials.28 Primary gingival fibroblast cultures are more closely related to the original tissue and therefore much easier to identify.29,30 In addition, cultures with primary cells generally are recommended for long-term experiments as they provide heterogeneous cells with physiological states of aging and offer
a metabolic state relative to their original tissue that is nearly identical. Previous in vitro experiments that utilized primary gingival fibroblast cultures simulated in vivo conditions efficiently. For these reasons, primary gingival fibroblast cultures have been preferred to continuous cell lines. As dental adhesive technology develops, selecting bonding agents to provide the attachment between the surfaces of dental structures and restorative materials becomes more important. These bonding materials are considered to be technique-sensitive agents; in all cases, manufacturers’ recommendations should be followed meticulously. While these bonding materials may perform efficiently enough, they also may have destructive effects on oral soft tissues. Oral cells can be exposed to polymers either directly via contact with gingival tissue, or indirectly when materials released by the polymers migrate toward the pulpal tissue or surrounding tissues.

The results of this study supported the findings of previous in vitro investigations that used the MTT assay to evaluate the cytotoxicity of resins components. In addition, the extracts obtained from the Adper Single Bond Plus demonstrated cytotoxic effects, even though aging helped to improve cell viability. These results are in keeping with the 2009 study by Porto et al, who reported that Adper Single Bond Plus affected macrophages in vitro.

**Conclusion**

The findings of the present study showed that all of the bonding agents tested generated severe cytotoxicity on HGF cells at 1 or more points. Based on these results, dentists must take care to keep dentin bonding agents within the area where they are needed and prevent their contact with adjacent tissues, especially in cases with deep cavities.

**Author information**

Dr. Cal is a professor, Department of Prosthodontics, Ege University School of Dentistry, Izmir, Turkey, where Dr. Atay is an assistant professor, Dr. Guneri is a professor, Department of Maxillofacial Radiology, and Dr. Ceritnas is a research assistant, Department of Medical Biology.

**Disclaimer**

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Surgical crown lengthening helps to provide an adequate retention form for proper tooth preparation, thus enabling dentists to create esthetically pleasing and healthy restorations. Long-term stability requires accurate diagnosis and development of a comprehensive treatment plan in each case. This sequence of events stresses the importance of communication between the restorative dentist and the periodontist. This article presents 2 cases that involve surgical crown lengthening (including mucoperiosteal flap and osteotomy) for the restoration of teeth.

Key words: periodontist, restorative dentist, surgical crown lengthening

Surgical crown lengthening procedures are intended to provide an adequate retention form, while allowing dentists to properly prepare the tooth, make impressions, place restorative margins on sound tooth structure, and adjust gingival levels for esthetics. These lengthening procedures may include the removal of only soft tissue or both soft tissue and alveolar bone. When there is adequate attached gingiva and ≥3 mm of tissue coronal to the alveolar bone crest, soft tissue reduction alone is indicated. This reduction may be accomplished by either a gingivectomy or using the mucoperiosteal flap technique. When there is inadequate attached gingiva and <3 mm of soft tissue, a mucoperiosteal flap procedure and bone recontouring is required. In cases of caries or tooth fracture, surgery should provide at least 4 mm of clearance from the apical extent of the caries or fracture to the bone crest to ensure that restorative margins are placed on sound tooth structure with an adequate retention form.4

In cases involving anterior teeth, dentists should keep in mind that patient awareness and expectations have increased and that an outcome with less-than-optimal esthetics would not be acceptable.5 An essential goal of treatment is long-term stability; in such cases, the integrity of the dentogingival junction must be respected, and restorations and the periodontium must be in harmony. A predictable, successful outcome can only be expected if a complete and accurate diagnosis is obtained and used to generate an appropriate treatment plan.4

When assessing a patient, it is important to determine the patient’s chief complaint which could include pain, swelling, impaired function, unsatisfactory esthetics, or any combination thereof. Next, the medical status of the patient must be reviewed and vital signs recorded. This step will determine the patient's suitability for dental treatment and identify any special precautions that must be taken (for example, premedication for the prevention of bacterial endocarditis). Anticoagulant therapy, including low-dose aspirin, often must be modified to ensure adequate hemostasis during and after surgical procedures.12,13 While there is some controversy over the absolute necessity of discontinuing aspirin for 1 week prior to surgery, prudent clinical judgment and appropriate medical consultation (when needed) are in the best interests of the patient.14,15

Following a thorough review of the patient’s medical status, a clinical examination is conducted. This examination should begin with extraoral conditions, giving attention to facial symmetry and height, lip length and thickness, profile, and smile line. Generally, the interpupillary line is the reference point for assessing facial symmetry.16 Face height usually is analyzed by dividing the face into thirds. The upper third often varies, depending upon the patient’s hairstyle. The middle and lower thirds of the face are more involved in dental esthetic considerations. The midface is measured from the glabella (the most prominent point of the forehead between the eyebrows) to the subnasale, the point directly below the nose. The lower third of the face is measured from the subnasale to the soft tissue menton (the lower border of the chin). When measured in repose, the length of the middle third of the face should equal that of the lower third.17 Lip length is measured from the subnasale to the lower border of the upper lip and tends to increase with age. The average lip length is 20-22 mm for young (20-30 years) women and 22-24 mm for young men.17 In repose, young women display approximately 3-4 mm of the maxillary central incisors, while young men display approximately 2 mm less.17 With advancing age, as a consequence of dropping (reduction of muscular tonicity) of the upper and lower lips, there is a decrease in exposure of the maxillary incisors and an increase in exposure of the mandibular incisors.18 The smile line should be observed in a variety of situations, including rest, speech, smiling, and laughter. With a normal full smile, the upper lip should rest at the level of the midfacial gingival margins of the maxillary anterior teeth; the lower lip should rest at the incisal edges of the maxillary anterior teeth; the incisal edges of the maxillary anterior teeth should be parallel to the curvature of the lower lip.17 When any significant discrepancies exist in ≥1 extraoral parameters, it may be unrealistic to expect intraoral procedures alone to provide a satisfactory result. In these cases, it may be necessary to consider orthognathic and/or plastic surgical procedures, or to modify patient expectations.16,17

A thorough intraoral examination must be conducted, combining clinical and radiographic observations. The condition
and dimensions of the teeth should be determined, checking for caries, fractures, and pulpal pathoses. The height of the anatomic crown is measured from the cementoenamel junction (CEJ) to the incisal edge, while the height of the clinical crown is measured from the gingival margin to the incisal edge. Comparing these 2 measurements will determine whether short clinical crowns are a result of incisal wear or the coronal position of the gingival margin.

If excessive incisal wear has occurred, then parafunctional habits must be investigated and dealt with appropriately. Once the cause of the incisal wear has been identified and controlled, restorative procedures can be planned to replace lost tooth structure. Coronal position of the gingival margin in relation to the CEJ may be the result of delayed passive eruption or gingival enlargement. Delayed passive eruption occurs when the dentogingival junction fails to migrate apically to the vicinity of the CEJ after the tooth has erupted into occlusion. Width of keratinized gingiva may be excessive or within normal range, and the alveolar crest may be at the CEJ or 1-2 mm apical. Most often, gingival enlargement is due to inflammation caused by dental plaque, but it is also associated with such medications as phenytoin, cyclosporine, and calcium channel blockers, and with pathological conditions such as hereditary gingival fibromatosis. The width and thickness of keratinized gingiva must be measured, as should probing depths, clinical attachment levels, and the level of the alveolar crest with respect to the CEJ. Interproximal bone levels can be estimated using radiographs taken parallel to the long axes of the teeth. Facial and lingual bone levels can be determined through sounding with local anesthesia (often in conjunction with other procedures which require local anesthesia, such as scaling and root planing, or at the beginning of a surgical procedure). Alveolar bone thickness and any hard or soft tissue irregularities should be recorded as well. The condition of the teeth must be evaluated carefully and any necessary restorative treatment noted.

Excessive gingival display
For most patients, the lower edge of the upper lip assumes a gum wing profile which limits the amount of gingiva that is exposed when a person smiles. Patients with a high lip line expose a zone of gingival tissue and may often express concern about their “gummy smile.” The form and position of the lips during speech and smiling cannot be changed easily. However, if it is deemed necessary, the dentist can modify/control the form of the teeth and interdental papillae, as well as the position of the gingival margins and the incisal edges of the teeth. Thus, it is possible to improve dentofacial esthetics for these patients by using a combination of periodontal and restorative treatment measures. If excessive gingival exposure is due to insufficient length of the clinical crowns, a crown lengthening procedure is indicated to reduce the amount of gingiva exposed, which in turn will alter the shape and form of the anterior teeth favorably.

For young adults with an intact periodontium, the gingival margin normally resides approximately 1 mm coronal to
the CEJ. However, some patients may have a free gingiva height >1 mm, resulting in a disproportionate gingival crown. If a patient’s complaint concerns “small front teeth” and the periodontium is a thin biotype, a full exposure of anatomical crown can be accomplished by a gingivectomy or gingivoplasty. If the periodontium is a thick biotype with a bony ledge at the osseous crest, an apically positioned flap procedure is the optimal choice, as it allows for osseous recontouring. Subjects with normal occlusal relationships and incisal guidance are good candidates for this treatment. For patients in this category, the incisal line of the anterior teeth should remain unaltered, but the clinical crowns can be made longer by surgically exposing the root structure and locating the cervical margins of the restorations apical to the CEJ.

Exposure of sound tooth structure
Crown lengthening procedures may be required to solve such problems as inadequate amount of tooth structure for proper restorative therapy, subgingival location of fracture lines, and subgingival location of carious lesions. Techniques used to accomplish crown lengthening in such cases include an apically positioned flap procedure or a forced tooth eruption (with or without fiberotomy). This article presents 2 case reports in which crown lengthening was performed with a mucoperiosteal flap and ostectomy.

Case report No. 1
A 32-year-old man presented to the Dental College and Research Centre, Indore, India, with a chief complaint that the crown on a posterior tooth had become loose 3-4 days earlier. The crown was short, so the patient’s prosthodontist referred him to the hospital for crown lengthening surgery, as there was a strong possibility that the onlay may once again become loose at a future date. The patient was in excellent general health with no known allergies, was not on any medications, and denied using tobacco. Clinical examination revealed a short clinical crown on tooth No. 19 (Fig. 1). After a week of thorough full-mouth oral prophylaxis, surgical crown lengthening was performed on the tooth. Treatment consisted of a mucoperiosteal flap reflection, an ostectomy (to provide harmony with the adjacent teeth), and a 3 mm clearance between the final restoration margin and the alveolar crest (Fig. 2 and 3). Crown preparation for this tooth was performed at the same appointment. The restoration margins were kept supragingival as it was a posterior tooth (Fig. 4). Impressions were made for a provisional crown. The surgical wound area was irrigated and the flaps were replaced with interrupted sutures. Postoperative instructions were given. The next day, a provisional restoration was placed on tooth No. 19 (Fig. 5). With the patient’s consent, a bridge restoration (with support from teeth No. 21 and No. 19; tooth No. 20 was missing) was prepared. A noneugenol periodontal pack was placed. The pack and sutures were removed after 8 days. After allowing 1.5 months for the gingival margins to heal and stabilize, the final restoration (a white metal bridge) was placed, resulting in a remarkable improvement in the patient’s periodontal health (Fig. 6). Gingival health, comfort, and optimum esthetics were achieved and maintained. Weekly follow-up visits were scheduled for the first month and biweekly visits scheduled for the next 6 months, to ensure that meticulous plaque control was maintained and optimum healing had occurred. Subsequent recall visits at 3-month intervals over the next year revealed that the patient continued to practice highly effective plaque control and was very pleased with the results.

Case report No. 2
A 52-year-old man presented to the Restorative Department of the Dental College and Research Centre, Indore, India, with defective restoration margins in his 2 left anterior teeth, for which he had received endodontic treatment 8 years earlier. The patient stated that at that time his dentist had advised him that he should get the crowns of the endodontically treated teeth placed after the treatment. However, due to personal problems, the patient could not do so. Clinical and radiographic examinations (Fig. 7 and 8) revealed extensive mutilation on the distal aspect of tooth No. 10, and a carious tooth No. 11; both teeth had received endodontic treatment previously. Tooth
No. 10 also had a large periapical lesion. The prosthodontist determined that crown lengthening (via flap and ostectomy for new restorative margins) was necessary, as the apical extent of the old cement restorations were subgingival.

To establish sound margins for the new restorations, it was necessary to extend the preparation apically in close proximity to the alveolar crest. A diagnostic wax-up was performed to establish the desired end results. Using this wax-up, a surgical guide was fabricated to facilitate the crown lengthening procedure, allow the surgeon to identify accurately the future location of the restoration margins, and ensure at least 3 mm of clearance between the margins and the crest of alveolar bone. Scaling and root planing were performed to reduce inflammation and allow for healing, and oral hygiene instructions were given.

Surgical crown lengthening was performed in the region of teeth No. 9-12 under local anesthesia. The mucoperiosteal flap reflection from the buccal aspect revealed alveolar bone at the level of the CEJ. To ensure the maintenance of interdental papillae, neither palatal nor interdental soft tissue was reflected. Osseous recontouring was performed on the buccal aspects of teeth No. 10 and 11 so that the alveolar crest would be located 3 mm apical to the CEJ (Fig. 9 and 10). Using a tunneling technique, ostectomy and osteoplasty were performed in the interdental areas. After the surgical wound was irrigated, interrupted sutures were placed (Fig. 11). A noneugenol periodontal pack was placed and postoperative instructions were given. The pack and sutures were removed after 8 days, allowing the dentogingival junction to heal with the gingival margin at the level of the CEJ. Endodontic treatment was repeated for both teeth, as the temporary cement had dissolved partially and root canals were reinfected. A fiber post and core using glass ionomer cement (Miracle Mix, GC America, Inc.) was fabricated for tooth No. 10 (Fig. 12). A follow-up 2 months after the crown lengthening procedure revealed a stable, esthetic result.

**Discussion**

Contemporary dental treatment must result in true oral health while incorporating comfort, function, and esthetics. The key to a successful outcome with long-term stability is the establishment of an accurate diagnosis and subsequent development of a comprehensive treatment plan. The integrity of the dentogingival junction must be observed by ensuring adequate biological width. Harmony must exist between soft and hard tissues and between the periodontium of adjacent teeth.6

During preparation for full coverage restorations, margin placement should be guided by the position of the CEJ; as a result, interproximal margins (particularly on anterior teeth) should be more coronal than buccal and lingual margins. This approach will help ensure adequate biological width and the maintenance of healthy, intact interproximal papillae. When periodontal surgical procedures are performed in anterior areas, it is necessary to defer placement of final full coverage restorations for approximately 6 months to stabilize gingival margin levels. For patients with particularly thin buccal alveolar bone and gingiva, it may be reasonable to place final restorations within 6 months following periodontal surgery. Effective daily plaque control and periodic recall are essential to maintain long-term stability. By following these guidelines, the clinician can promote a stable, comfortable, and functional periodontium and provide the patient with an optimal esthetic result.6

The sequence of events in crown lengthening highlights the importance of communication between a restorative dentist and the periodontist. There should be a minimum of 3 mm distance between the restorative margin and alveolar crest.22 In a case of recurrent decay beyond the crown margins, the apical extent of caries (as well as maintenance of the biologic width) acts as a guide in establishing the position of the new crown margins. Planned crown margins should be placed on sound tooth structure at least 1 mm apical to the most apical extent of caries.22

Patients with defective restorative margins who have undergone prior endodontic therapy have been treated successfully.
by a combination of orthodontic extrusion for the involved tooth (approximately 1 mm/week for 4 weeks) and surgical crown lengthening involving a mucoperiosteal flap reflection with ostectomy. Orthodontic extrusion is particularly useful in cases where interdental papillae in the vicinity of the involved teeth have lost their height.

Both of the cases presented here were treated by surgical crown lengthening with mucoperiosteal flap and ostectomy in adjunct to endodontic and prosthodontic treatments. Postoperative follow-ups were uneventful.

**Conclusion**

Surgical crown lengthening with mucoperiosteal flap and ostectomy in collaboration with restorative treatment helps to provide harmony of a restoration with the adjacent teeth and periodontium by maintaining at least 3 mm of clearance between the margin of the restoration and the alveolar crest. The success of the 2 cases presented here emphasizes the importance of an interdisciplinary approach between a restorative dentist and periodontist in diagnosis, treatment, and postoperative maintenance of such cases.

**Author information**

Dr. S. Parwani is an associate professor, Department of Periodontics, Modern Dental College and Research Centre, Indore, India, where Dr. R. Parwani is a professor, Department of Oral and Maxillofacial Pathology.

**References**


**Manufacturer**

GC America, Inc., Alsip, IL
800.323.7063, www.gcamerica.com
Surface roughness of different composite resins subject to in-office bleaching

Andre Fabio Vasconcelos Moro, BDS, MSc ▪ Maira do Prado, BDS, MSc, PhD ▪ Renata Antoun Simao, MSc, PhD
Katia Regina Hostilio Cervantes Dias, BDS, MSc, PhD

This study used atomic force microscopy to evaluate the effects of an in-office dental bleaching protocol on the surface roughness of 3 resins: microfilled, microhybrid, and nanofilled. Two disks of each resin were prepared and evaluated. Twenty-four areas (5 x 5 μm) were scanned using an atomic force microscope. Then, each disk was treated with 35% hydrogen peroxide activated by a light emitting diode. After bleaching, the disks were scanned again. Data from the 24 areas before and after bleaching were evaluated qualitatively using topographical and 3-dimensional images, as well as profile lines. Quantitatively, roughness data (mean roughness and root mean square) were statistically evaluated using standard ANOVA and Student-Newman-Keuls tests (P < 0.05). The bleaching procedure increased roughness for each resin analyzed. Based on the results, it was concluded that in-office bleaching with 35% hydrogen peroxide-based gel significantly increased the surface roughness of microfilled, microhybrid, and nanofilled resins.

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Key words: dental bleaching, hydrogen peroxide, resin composites, roughness, atomic force microscopy

Restoration technology has advanced since dental resin composites were first introduced. One important advance in recent years is the application of nanotechnology to dental composites. Microfilled composites were introduced in the early 1980s. These composites offer a high polish (which can be maintained over time) and excellent enamel-like translucency. For these reasons, they are indicated for restoring anterior teeth and cervical abfraction lesions. However, they should not be used in heavy stress-bearing areas as their physical properties typically are inferior to those of hybrid composites. Microhybrid composites are stronger than most microfilled composites and therefore can be used in both anterior and posterior teeth. Microhybrid composites also provide optimal mechanical and physical properties combined with good polishing properties.

Nanocomposites have been developed to combine the advantages of hybrid and microfilled composites in a single restorative material. These nanocomposites offer low shrinkage, which is attributed to their high filler volume. These nanocomposites have favorable mechanical properties that are equal to and may surpass those of hybrid materials. They also demonstrate better surface quality, better polish and gloss, increased retention, and increased wear resistance.

Dental bleaching is a common esthetic clinical procedure. In-office bleaching involves applying a bleaching agent (typically a gel containing 35%-38% hydrogen peroxide) on the tooth surface and allowing it to remain on the teeth for 30-45 minutes. The bleaching agent is activated chemically (or by using a visible light curing lamp) to enhance the process. Anterior resin composite restorations are usually removed before the bleaching procedure. However, when the restorative material is placed in distal areas—such as the premolars and molars—where there is no esthetic compromise in terms of a change in resin color after bleaching, many dentists choose not to remove the restoration.

Composites with greater surface roughness can lead to increased pigment accumulation and alter the rate of water absorption, as well as cause changes in the optical properties, negatively impacting the appearance of the restoration. A rougher surface accumulates more bacteria than a smooth surface, which in turn reduces the free energy of the surface. Different techniques are used to evaluate surface roughness, including profilometry, scanning electron microscopy, and atomic force microscopy (AFM).

The present study used AFM to evaluate the effect of an in-office dental bleaching protocol (using 35% hydrogen peroxide) on the surface roughness of 3 resin types: microfilled, microhybrid, and nanofilled.

Materials and methods
Three different sample groups were prepared: a microfilled resin (Durafill VS, shade A2, Heraeus Kulzer), a microhybrid resin (Opallis, shade EA2, FGM Produtos

| Table. Roughness (Ra) and root mean square (RMS) surface values and standard deviations (SD) (in nm) for the different resins before and after bleaching. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Initial         | Final           | Initial         | Final           |
| Microfilled     | 26.2 (4.0)\(^a\) | 36.4 (4.2)\(^a\) | 19.2 (5.0)\(^a\) | 28.7 (4.8)\(^a\) |
| Microhybrid     | 14.9 (3.7)\(^a\) | 23.1 (4.2)\(^a\) | 35.4 (5.8)\(^a\) | 47.4 (5.6)\(^a\) |
| Nanofilled      | 23.7 (3.9)\(^a\) | 31.5 (6.0)\(^a\) | 29.6 (4.7)\(^a\) | 40.2 (7.8)\(^a\) |

Different letters indicate statistically significant values (P < 0.05).
Odontologicos), and a nanofilled resin (Filtek Z350, shade A2, 3M ESPE). Disc-shaped standardized specimens were prepared (9 mm diameter x 2 mm thick) with the use of a Mylar bipartite matrix and stainless steel bolts for fixing. The resins were mixed and placed in the matrix with a spatula until each specimen was completely filled. At that point, each resin sample was covered with 0.05 mm polyester tape and compressed with a glass microscope slide to obtain a flat surface. Photocuring was performed in a single step by touching a light emitting diode (LED) tip (output 600 mW/cm²) to the glass for 40 seconds. Two discs were evaluated in each group.

Samples were stored in neutral artificial saliva and placed in an oven at 37°C. After 24 hours, samples were washed with distilled water and polished with 1200 grit paper. The samples were washed again after polishing and stored in artificial saliva for 7 days.

Next, the samples were rinsed with distilled water, dried using a nitrogen flow, and analyzed by an AFM (JPK Instruments AG) in contact mode. The temperature was kept close to 26°C (relative humidity ranged from 45% to 55%). For all analyses, cantilevers (CSC17/Al BS, Micromash USA) with a curvature radius <10 nm were used. These cantilevers had a nominal resonant frequency of 12 KHz and an elastic modulus of 0.15 N/m. All images were acquired at a resolution of 512 x 512 points. In each sample, areas of 50 x 50 µm were evaluated for an overall surface analysis. Then, 24 different areas (5 x 5 µm) were recorded for an initial evaluation.

The samples were submitted to bleaching, using a solution containing 3 standard droplets of hydrogen peroxide and 1 droplet of thickening agent. The mixture was homogenized and applied immediately on the surfaces of the standardized specimens; 1 minute after application, the mixture was photocured for 20 seconds by an LED (Radii, SDI (North America), Inc.). The LED intensity was kept constant (650 to 700 mW/cm²) at a distance of 5-10 mm from the resin. After 3 minutes, the samples were photocured again using the same procedures. The bleaching solution was left on the resin for a total of 15 minutes. The procedure was repeated 6 times to simulate 2 sessions of 3 in-office procedures, the maximum protocol suggested by the manufacturer.

The 24 areas were scanned again postbleaching. The mean roughness value (Ra), the root mean squared (RMS) height of the surface topography roughness values, and the line profiles were obtained (IP software, JPK Instruments AG).

Data from the initial and final evaluations were evaluated qualitatively, using topographical and 3-dimensional (3D) images, as well as profile lines. Quantitatively, the roughness data was evaluated statistically using standard ANOVA and Student-Newman-Keuls tests ($P < 0.05$).

**Results**

The Ra and RMS values for the different resins are cited in the Table. An increase was observed in the roughness values for all 3 resins. Statistical analyses confirmed these findings. Figure 1 presents a representative 3D image and line profiles for an area on the microfilled resin disk. Comparing the initial and final line profiles, it was observed that the bleaching procedure resulted in nanometric changes on the surface. This behavior was observed also for the microhybrid and nanofilled resin disks (Fig. 2 and 3).

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**Table**

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**Fig. 1.** Top. Three-dimensional images and line profiles for an area of the microfilled resin before bleaching. Bottom. The same area after bleaching treatment.
Discussion

There may be times when it is necessary to replace a restorative resin composite for esthetic reasons. To the naked eye, resin composite restorations in posterior teeth may have an imperceptible postbleaching color, since there is less light in the region and consequently less visual acuity. Another situation to consider is the maintenance of bleaching, which is periodically indicated in patients who have previously been submitted to bleaching treatment, as tooth staining may reappear 1-4 years after the procedure. 14

The present study used AFM to evaluate how an in-office dental bleaching protocol (utilizing 35% hydrogen peroxide—the maximum dose recommended by the manufacturer) affected the surface roughness of 3 resins. Previous studies have evaluated the effect of bleaching with 35% hydrogen peroxide on resin surfaces; however, to the best of the authors’ knowledge, no study has used AFM scanning before and after a bleaching procedure using 35% hydrogen peroxide at the maximum dose on microfilled, microhybrid, and nanofilled resins. 6-8,15-18

Topographical analysis of each surface was measured using Ra and RMS values. Ra corresponds to the arithmetic mean of the absolute values of the profile. As it is a mean value, it does not always provide a direct indication of the state of the surface. The profile analysis has the advantage of being used most frequently in research related to roughness, and thus allows comparisons to be made among different scientific findings. 15-18 RMS describes the root mean squared height of the surface topography in relation to the mean plane. 19

In the present study, significant differences in the roughness were found before and after bleaching, regardless of the area analyzed. The overall topography did not change significantly; however, significant modifications were found in the nanometric scale. Profile lines of the same areas confirmed the nanometric modifications before and after dental bleaching, in keeping with previous studies. 15,17,18,20 Other studies did not discover such alterations, possibly because different methodologies were used; in addition, different products and formulations of bleaching substances may have had different effects on the surfaces. 7,8,16,21

Exposure time and peroxide concentration could affect resin surfaces as well. The present study evaluated the effect of in-office bleaching on the roughness of different composite resins. Using different experimental models on surface areas before and after bleaching demonstrated that the procedure increased surface roughness by introducing nanometric changes on the surface.

Conclusion

In-office dental bleaching performed in office with 35% hydrogen peroxide-based gel—used at the maximum dose recommended by the manufacturer—increased the surface roughness of microfilled, microhybrid, and nanofilled resins. Additionally, since the methodology used the same area before and after treatment, problems related to area selection were reduced. It is possible to conclude that the resultant topographical alterations were caused exclusively by the action of the bleaching agent.

Author information

Dr. Moro is a postgraduate student, Department of Restorative Dentistry, State University of Rio de Janeiro, Brazil, where Dr. Dias is a titular professor. Dr. Prado is a postdoctoral candidate,
Department of Metallurgical and Materials Engineering, Federal University of Rio de Janeiro, Brazil, where Dr. Simao is an associate professor.

References

Manufacturers
FGM Produtos Odontológicos, Joinville, SC, Brazil
35.47.344.1500, www.fgm.ind.br
Heraeus Kulzer, South Bend, IN
800.435.1785, www.heraeus-kulzer-us.com
JPK Instruments AG, Pittsford, NY
585.249.7629, usa.jpk.com
Micromash USA, Lady’s Island, SC
866.776.8477, www.splips.com
SDI (North America), Inc., Bensenville, IL
800.228.5166, www.sdi.com.au
3M ESPE, St. Paul, MN
888.364.3577, solutions.3m.com
An in vitro comparison of antimicrobial toothbrushes

Jeremy D. Hamal, DDS, MS • Donna M. Hensley, BS • Steven C. Maller, DDS, MS • Daniel J. Palazzolo, DDS, MS
Kraig S. Vandewalle, DDS, MS

The purpose of this study was to determine the efficacy of toothbrushes that advertise self-disinfecting, antimicrobial properties due to the inclusion of silver nanoparticles or chlorhexidine in the bristles. Three different types of toothbrushes—silver nanoparticle, chlorhexidine-coated, and a control—were submerged in suspensions of Streptococcus mutans and Candida albicans. At designated times postinoculation, organisms were removed from the toothbrush heads, then serially diluted, plated, and incubated. The colony-forming units (CFUs) were counted and a mean percent reduction was determined for each organism group. With the S. mutans groups, the chlorhexidine-coated toothbrushes had significantly greater percent reduction in CFUs at all 3 time points compared to the control or silver nanoparticle toothbrushes. With the C. albicans groups, neither the chlorhexidine-coated nor the silver nanoparticle toothbrushes had a significant reduction in CFUs compared to the control. Neither of the antimicrobial toothbrushes delivered the advertised claim of a 99.9% reduction in CFUs with either microorganism. However, the inclusion of chlorhexidine in toothbrush bristles appeared to be the most promising of the methods tested for toothbrush self-disinfection.

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Recent advertisements for antimicrobial toothbrushes claim to remove up to 99.9% of residual bacteria from toothbrush heads that can cause caries, halitosis, colds, and flu. The elimination of toothbrush microbial contaminants could be beneficial to patients, as these same pathogenic organisms have been associated with a wide variety of systemic diseases. Studies have linked significant bacteremias to routine toothbrushing, especially in patients with severe periodontitis. Moreover, bacteria from the environment, including enterobacteria found in bathrooms, can embed themselves on toothbrush bristles. Toothbrush decontamination could provide a means of preventing the inoculation or reintroduction of microorganisms from infected to noninfected tissues. A toothbrush that could help in controlling reinfection or cross-contamination following everyday toothbrushing would be a significant health benefit.

Many of the microorganisms that make up the oral flora have been linked to systemic ailments, which include circulatory, renal, pulmonary, and intestinal infections. Some authors have recommended disposable toothbrushes for patients who are taking immunosuppressants or who are undergoing transplant or other major surgeries, thereby avoiding any deleterious bacterial encounters. The introduction of an antimicrobial toothbrush could provide a means to promote health and wellness, as any potential bacteremia could jeopardize patients with serious ailments such as diabetes or immunosuppressive diseases. In addition, the elimination of cariogenic bacteria left on a toothbrush could help improve the caries status of a patient. Kozai et al found viable S. mutans on toothbrushes several hours following use. Even after only 1 use, a new toothbrush harbors a complex array of microorganisms, such as staphylococci, fungi, and pseudomonas. It is plausible that multiple strains of bacteria—which may include cariogenic and putative periodontal pathogens—could be introduced into the oral cavity with further use of the same brush, thus heightening the health risk in susceptible patients. A 2007 study found that air-drying of toothbrushes was an incomplete method for disposing of microorganisms. In fact, it has been shown that in a moist environment, approximately half the original amount of tested viral contaminants flourished on a toothbrush after 7 days. Herpes simplex viruses have also been shown to survive on toothbrushes at 1 week. Al-Ahmad et al reported that microorganisms can penetrate the mucous membrane during routine toothbrushing of inflamed gingiva, enter the circulatory system, and then undermine the healing of dental implants or proceed to life-threatening endocarditis or pneumonia infections. A 1994 study by Glass & Jensen showed ultraviolet sanitation devices to be useful in reducing the number of bacteria and viruses on toothbrushes. Other studies have sought to quantify the microbial reduction on toothbrushes by chlorhexidine treatments. Nelson-Filho et al found a chlorhexidine rinse to be a very effective means of inhibiting biofilm formation on toothbrush bristles, while Aysegul et al and Sato et al produced similar results using a chlorhexidine spray. Alternatively, Glass et al questioned whether antimicrobial rinses could successfully penetrate into the biofilm aggregates that cover toothbrushes in order to affect the entire microbial mass. Toothbrushes with inherent antimicrobial properties could prove valuable in preventing the establishment of these microbial colonies. Yokosuka et al studied the bacterial content on chlorhexidine-coated filaments of toothbrushes and determined that these brushes could reduce the bacterial load, with the antibacterial activity of the tip and base of the filament lasting for 8 and 20 days.
When toothbrush tufts were coated with silver particles, Efstratiou et al. found that toothbrush heads coated with silver nanoparticles yielded antimicrobial properties. Al-Ahmad et al. examined toothbrushes coated with chlorhexidine and found them to be effective.35 Similarly, Efratiou et al. found that triclosan-coated toothbrushes failed to limit the bacterial contamination of the brush heads.36

Another method of toothbrush sanitation involves incorporating metallic nanoparticles into the bristles, thereby imparting an intrinsic means of controlling the oral biofilm that resides on the toothbrush following routine use. Silver and other metallic nanoparticles are now commonplace in medicine, particularly in molecular imaging, drug delivery, diagnosis and treatment of cardiovascular diseases, wound healing, and the development of materials and medical devices with antimicrobial properties.37 Silver nanoparticles have been shown to act as an effective antimicrobial, though the exact mechanism remains unclear.15 Studies have suggested that silver nanoparticles contribute to structural changes in bacterial membranes, which result in cell death.15,16 According to Allaker, bacteria that makes contact with silver nanoparticles will absorb silver ions, which inhibit respiratory enzymes and help generate free radicals, subsequently damaging the cell membrane.15 Felloni et al. found that toothbrush heads coated with silver particles yielded antimicrobial effects, whereas Quirynen et al. failed to note any antibacterial properties when toothbrush tufts were coated with zeolitic crystals of silver and zinc.16,17 Al-Ahmad et al. examined toothbrushes with silver particle heads and found them to contain even more C. albicans than the control group, which led them to suggest that any reduction in bacteria on silver-coated brushes may be due to the dehydration of the brush head.1

Such findings seem to contradict the claims of manufacturers who claim their toothbrushes have self-disinfection properties. Advertisements for a silver nanoparticle toothbrush (Mouth Watchers Superior Manual Toothbrush, Mouth Watchers) and a chlorhexidine-coated toothbrush (GUM Travel Toothbrush, Sunstar Americas, Inc.) both advertise that their products are an effective, low-cost, and simple means of toothbrush decontamination, which warranted study. The bristles of the Mouth Watchers Superior Manual Toothbrush are embedded with silver nanoparticles, which the manufacturer claims will eliminate 99.99% of bacteria in 6 hours.18 The bristles of the GUM Travel Toothbrush are coated with chlorhexidine.19 These toothbrushes claim to eliminate residual toothbrush microorganisms. Dental providers should be aware of toothbrushes that could prove useful in preventing reinfection and cross-contamination of oral microorganisms.

The purpose of this study was to determine the antimicrobial characteristics of 3 toothbrush types—silver nanoparticle, chlorhexidine-coated, and a control with no antimicrobial claims. The research was geared toward measuring the extent of residual microorganism contaminants that remain on each type of toothbrush after testing at specified time points utilizing 2 common intraoral microbes, S. mutans and C. albicans. The null hypothesis to be tested was that there would be no significant difference in percent reduction in CFUs based on brush type or microorganism over time.

**Materials and methods**

A total of 240 toothbrushes—80 GUM Summit toothbrushes (Sunstar Americas, Inc.) as the control group, 80 Mouth Watchers Superior Manual silver nanoparticle toothbrushes, and 80 GUM Travel chlorhexidine-coated toothbrushes—were included in this study. All brushes were sterilized in a low temperature hydrogen peroxide plasma sterilization system (Sterrad NX, Advanced Sterilization Products) before testing. The organisms tested, S. mutans ATCC 35668 and C. albicans ATCC 10231, were grown on tryptcassoy agar with 5% sheep blood (BBL Trypticase Soy Agar (TSA II), Becton, Dickinson and Company). S. mutans plates were incubated at 35 ± 2°C for 24 hours in 5% CO2 and C. albicans plates were incubated for 72 hours in ambient air. After incubation, CFUs on the plates were counted and the CFU/mL calculated.

The mean CFU/mL recovered for each test group at each time point was calculated and converted to log10 format to discern the percent reduction of microorganisms from baseline (0 hours). The CFU/mL at subsequent time points was compared to the first time point to determine the decrease in CFU/mL recovered over time. The rate of reduction for the organism groups was then compared. A 3-log10 reduction was determined to be equal to a 99.9% killing of bacteria. If these brushes were to indeed provide clinically effective disinfection, then a 99.9% reduction in microbes from baseline would be needed.20 Groups were compared using a repeated measures ANOVA to examine the effects of brush type and bacteria on percent reduction in CFU over time (α = 0.05).
Results

The repeated measures ANOVA found a significant difference based on brush type ($P = 0.022$) but not based on microorganism ($P = 0.091$); however, there were significant interactions over time ($P < 0.05$). The data was further analyzed with multiple 1-way ANOVAs per type of microorganism. A Bonferroni correction was applied because multiple comparisons were done between groups per microorganism ($\alpha = 0.008$). Significant differences were found between groups based on brush type or time per microorganism ($\alpha < 0.008$) (Table).

With the *S. mutans* groups, at all 3 time points, the chlorhexidine-coated brush had significantly greater percent reduction in CFUs compared to both the control and silver nanoparticle brush groups. The percent reduction in CFUs for the control and silver nanoparticle brush groups were not significantly different from each other, except at 16 hours, when the percent reduction for the control brush was significantly greater ($P < 0.008$) than for the silver nanoparticle brush. The control brush also had a significantly greater percent reduction at times 16 and 24 hours than at 8 hours ($P < 0.008$). However, there were no significant differences between the time points of the chlorhexidine-coated and silver nanoparticle brushes.

With the *C. albicans* groups, no difference was found between the 3 brush types at 8 and 16 hours. At 24 hours, the silver nanoparticle brush had significantly greater reduction in CFUs compared to the chlorhexidine-coated brush, but neither were significantly different from the control group. All the brush groups had significantly greater reductions in CFUs at 16 and 24 hours than those recorded at 8 hours. Neither the chlorhexidine-coated nor the silver nanoparticle brush showed any individual statistical difference at any of the time points, as the 8-, 16-, and 24-hour samples showed similar reductions.

Discussion

This study sought to determine whether the purported claims of toothbrush self-disinfection were possible, and to see how time may play a role in this disinfection. This research did not quantify the actual benefit of any disinfection. However, other studies have shown at least a possible association between toothbrush disinfection and the maintenance of health in certain populations.2,4,5 While the level of disinfection provided by a brush could change over time, this study did not try to factor this variable, and should be the subject of future research.

In order for either the silver nanoparticle or chlorhexidine-coated brush manufacturers to make the claim of clinical disinfection, 99.9% of the microorganisms should have been eliminated by the 8-hour mark; this same level should have been maintained at 16- and 24-hours.20 Conversely, if the control brush surpassed this 99.9% threshold, then a reduction in microbes could be seen as a normal factor of time, which could possibly eliminate the need for further toothbrush disinfection. Finally, the authors assumed that 8 hours would be a reasonable interval between brushings. The subsequent measurements at 16 and 24 hours were used to verify the prior reading and discover any trends.

After a review of the results, the null hypothesis was rejected. There were significant differences based on brush type and time after contamination, but the differences were specific to the type of microorganism. In the *S. mutans* groups at 8 hours, the percent reduction in CFUs of the chlorhexidine-coated brush was significantly greater than the other 2 brushes. This trend continued for this brush type at 16 and 24 hours, with reductions of 99.8% and 99.3%, respectively. Furthermore, the 99.8% reduction indicated that the chlorhexidine-coated brush was nearly clinically disinfected at 16 hours. The control brush showed significant improvement from 8 to 16 hours, which suggests that *S. mutans* is subject to natural reduction under normal circumstances with the passage of time, although not enough to achieve clinical disinfection without added measures. Any differences in disinfection over time were not apparent with the chlorhexidine-coated brush, which suggests that disinfection was maintained over time. At all time points, the silver nanoparticle brush performed worse than the chlorhexidine-coated brush, and it was statistically worse than the control brush at 16 hours. This indicates that the silver nanoparticle brush did not perform any better than the standard control toothbrush and, furthermore, that it does not provide the level of effective disinfection that its manufacturer claims.

Looking at all time points, the chlorhexidine-coated brush came close to the 99.9% disinfection threshold for *S. mutans*, and it was the superior brush when compared to the silver nanoparticle brush and the control. A 2009 study by Turner et al could find no significant difference between control and chlorhexidine-coated brushes.13 However, the present study linked the chlorhexidine-coated brush to a notable improvement against *S. mutans* when compared to both the control and silver nanoparticle toothbrushes.

### Table. Percent reduction in colony-forming units (CFUs) per microorganism and brush type over time.

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Brush type</th>
<th>8 hours</th>
<th>16 hours</th>
<th>24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Streptococcus mutans</em></td>
<td>Control</td>
<td>88.6 (6.5)</td>
<td>96.3 (3.0)</td>
<td>95.4 (2.8)</td>
</tr>
<tr>
<td></td>
<td>Chlorhexidine</td>
<td>98.8 (1.0)</td>
<td>99.8 (0.1)</td>
<td>99.3 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Silver nanoparticle</td>
<td>90.6 (6.3)</td>
<td>93.0 (2.6)</td>
<td>96.3 (2.3)</td>
</tr>
<tr>
<td><em>Candida albicans</em></td>
<td>Control</td>
<td>75.6 (25.9)</td>
<td>96.2 (5.4)</td>
<td>98.7 (1.7)</td>
</tr>
<tr>
<td></td>
<td>Chlorhexidine</td>
<td>95.6 (3.9)</td>
<td>95.0 (7.7)</td>
<td>97.5 (1.2)</td>
</tr>
<tr>
<td></td>
<td>Silver nanoparticle</td>
<td>72.1 (48.9)</td>
<td>97.4 (2.4)</td>
<td>99.5 (0.3)</td>
</tr>
</tbody>
</table>

Groups with the same superscript uppercase letter per row or superscript lowercase letter per column were not significantly different ($P > 0.008$).
The authors do not have any financial interests in the companies whose materials are discussed in this article.

References

Conclusion
The chlorhexidine-coated toothbrush demonstrated significantly greater reduction in CFUs compared to both the control and silver nanoparticle toothbrushes when subjected to S. mutans. With the C. albicans groups, no clear differences were evident between the brush types. The silver nanoparticle brush did not meet the stated effectiveness of disinfection with the microorganisms used in this study.

Author information
Lt. Col. Hamal is a dental flight commander, Grand Forks Air Force Base, North Dakota. Ms. Hensley is a medical technologist at the Wilford Hall Ambulatory Surgical Center, Clinical Research Division, Joint Base San Antonio, Lackland, Texas. Dr. Maller is in private practice, specializing in periodontics and implants, in San Antonio, Texas. Maj. Palazzolo is director, Postgraduate Periodontics, Air Force Postgraduate Dental School, Uniformed Services University of the Health Sciences, Lackland, Texas. Col. Vandewalle is director, Dental Research, Advanced Education in General Dentistry Residency Program, Dunn Dental Clinic, Lackland, Texas.

Disclaimer
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 Department of Defense, or the United States government. The authors do not have any financial interest in the companies whose materials are discussed in this article.

The C. albicans groups did not present any identifiable trends between the brush types at 8 and 16 hours, with all 3 types being statistically similar in terms of percent reduction. When the 24-hour brushes were sampled, the silver nanoparticle brush was statistically better than the chlorhexidine-coated brush—but neither were significantly different that the control brush. Neither the chlorhexidine-coated nor the silver nanoparticle brush showed any individual statistical difference at any of the time points, as the 8-, 16-, and 24-hour samples showed similar reductions. The control brush did display a significant increase in reduction at 16 and 24 hours compared to 8 hours, so perhaps the disinfection properties of the chlorhexidine-coated and the silver nanoparticle brush were more evident at the earlier 8-hour point. It also could be that the nature of the testing circumstances did not allow C. albicans to flourish on a brush after 16 hours, regardless of the disinfection properties of the toothbrush.

Silver nanoparticles have proven to be effective in disinfection; however, in this study they did not produce the 99.9% reduction promoted by the manufacturer—nor were they as effective against S. mutans as the chlorhexidine group.16 These results are in keeping with previous studies in showing that silver nanoparticles were not effective in toothbrush disinfection, at least when S. mutans and C. albicans were sampled.1,17

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Manufacturers
Advanced Sterilization Products, Irvine, CA 800.595.0200, www.aspjj.com
Mouth Watchers, Swampscott, MA 866.941.8478, www.mouthwatchers.com
Sunstar Americas, Inc., Chicago, IL 888.777.3101, www.gumbrand.com
Evaluation of the association between periodontal disease and diabetic retinopathy

Ruchi Banthia, MDS • Sapna Raje • Priyank Banthia, MDS • Sudesh Kumar Saral, MBBS, DOMS • Pallavi Singh • Santosh Gupta

Periodontitis may act as a risk factor for diabetes and its various complications such as cardio-renal complications. The current literature is deficient regarding the association between periodontal disease and diabetic retinopathy (DR). This cross-sectional study of 100 type II diabetes patients sought to evaluate the association of periodontal disease with the occurrence and severity of DR. The results showed a definite association between periodontal disease status and the occurrence of DR, although a cause and effect relationship could not be established.

The association between periodontal disease and diabetes has been explored in several studies over the years, and it is generally accepted that periodontal disease is more prevalent and more severe in diabetic patients than those without the disease. Uncontrolled hyperglycemia in diabetic patients may predispose them to various complications. Most of these complications are vascular in nature. Macrovascular changes may lead to an increased risk of myocardial infarction and stroke as a result of atherosclerosis, while microvascular pathologies include retinopathy, end stage renal disease, neuropathies, poor wound healing, enhanced risk of infection, and periodontal disease. Diabetic retinopathy (DR) is a microvascular complication of diabetes and a leading cause of blindness. It occurs when diabetes damages the tiny blood vessels inside the retina, the light-sensitive tissue at the back of the eye. Hyperglycemia-induced intramural pericyte death and thickening of the basement membrane lead to incompetency of the vascular walls. These damages change the formation of the blood-retinal barrier and also make the retinal blood vessels more permeable. Prolonged inflammatory cytokines such as interleukin-6 (IL-6) have been shown to be involved in the pathogenesis of DR. Periodontal disease has been associated with poorer metabolic control of hyperglycemia. Advanced glycation end products (AGEs) formed as a result of hyerglycemia interact with various tissues. Blood vessel alterations secondary to AGE accumulation may contribute to the classic macrovascular and microvascular complications of diabetes mellitus (DM).

Severe periodontal disease is associated with elevated blood lipopolysaccharide levels as a result of periodontogenic bacteria, which induce higher levels of IL-6 and tumor necrosis factor-α. While there are various studies linking the occurrence and severity of various cardio-renal complications and periodontal disease in diabetic patients, the literature is deficient regarding the association of periodontal disease and DR. This study is aimed at evaluating the association of periodontal disease with the occurrence and severity of DR.

Materials and methods

This cross-sectional study was conducted among 100 known type II DM patients who reported to different ophthalmologic and endocrinial clinics of Indore, India. The patients were divided into a test group (patients with DR) and a control group (diabetics without DR). The test group was further divided into nonproliferative and proliferative retinopathies, which reflect the initial and advanced stages of retinopathy, respectively. The diagnosis of retinopathy was established by an ophthalmologist based on clinical findings (such as blurring of vision and watering of eyes) and a funduscopy examination showing the engorgement of blood vessels and hemorrhagic spots (Fig. 1 and 2).

The test group consisted of type II DM patients (35-65 years), who were recently diagnosed with DR (≤3 months duration) and had at least 20 teeth present. The control group met the same parameters, except they had no DR. Informed consent was taken from all the patients prior to conducting the study.

Patients with type I DM, those suffering from other systemic diseases and diabetic comorbidities, patients who have undergone surgery for retinopathy, those with a history of periodontal treatment and antimicrobial drug usage in the past 6 months, patients with other causative factors of retinopathy, smokers, and patients using tobacco in chewable form were excluded from the study.

Demographic variables (such as age and sex), the duration of DM and DR, and biochemical markers (random blood glucose and glycated hemoglobin) were noted in all patients.

Oral and periodontal examinations

Greene & Vermillion's Simplified Oral Hygiene Index (OHI-S) was used to evaluate the oral hygiene status of the patients. The OHI-S was calculated as a debris and calculus index on the buccal surfaces of teeth No. 11, 16, 26, and 31 and the lingual surfaces of teeth No. 36 and 46. The scores of debris and calculus were added to obtain the OHI-S of each patient. Bleeding on probing (BOP) was noted as present or absent at 4 sites (mesiobuccal, distobuccal, midbuccal, and midlingual) of each tooth. Probing pocket depth (PPD) and clinical attachment loss (CAL) were noted at the same 4 sites of the commonly known Ramfjord's teeth (teeth No. 11, 16, 24, 36, 41, and 44) with the help of a periodontal probe. The numbers of missing and carious teeth were also noted.

All data were expressed as means. The unpaired t-test was applied to calculate the significance of the difference of means of various periodontal parameters.
between the 2 groups. For all analyses, $P < 0.05$ was considered significant. A multiple logistic regression analysis was applied to evaluate the impact of individual factors, including age, numbers of missing and carious teeth, PPD, CAL, BOP and OHI-S scores. An adjusted odds ratio was calculated at a 95% confidence interval using the regression analysis.

Results
The study group consisted of 100 known type II DM patients, consisting of 73 men and 27 women with a mean age of 47.5. There were 50 patients in both the test and control groups. There were no statistically significant differences between the 2 groups in terms of variables such as age, duration of diabetes, random blood sugar, glycated hemoglobin levels, and mean number of missing and carious teeth. The comparison of the periodontal parameters of the test and control group revealed no statistically significant difference in mean number of bleeding sites. The differences in mean OHI-S scores, mean PPD, and mean CAL between the test and control groups were found to be highly significant ($P = 0.00$) (Table 1).

A multiple regression analysis failed to show any significant effect of any individual parameter except PPD and OHI-S at a 95% confidence interval, however, the odds ratio was found to be <1 (Table 2).

There were no statistically significant differences between patients with nonproliferative and patients with proliferative retinopathies in terms of other variables (Table 3).

Discussion
This cross-sectional study was conducted on 100 known type II DM patients. All patients were under medication (oral hypoglycemic agents) for the management of DM. They were under regular medical supervision and none of the patients had altered their diabetic treatment in the year previous to the initiation of this study.

The mean duration of DM in both the test and control groups was similar (approximately 5 years). This mean

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Table 1. Comparison of clinical and biochemical parameters in diabetic patients with and without retinopathy using unpaired t-test.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group*</th>
<th>Mean (SD)</th>
<th>t-test</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>1</td>
<td>48.55 (9.63)</td>
<td>1.014</td>
<td>0.313</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>46.57 (9.90)</td>
<td>1.014</td>
<td>0.313</td>
</tr>
<tr>
<td>Mean duration of diabetes mellitus (years)</td>
<td>1</td>
<td>4.96 (3.80)</td>
<td>-0.137</td>
<td>0.892</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.06 (3.54)</td>
<td>-0.137</td>
<td>0.891</td>
</tr>
<tr>
<td>Mean random blood sugar (mg%)</td>
<td>1</td>
<td>157.29 (14.56)</td>
<td>-1.229</td>
<td>0.222</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>160.94 (15.09)</td>
<td>-1.228</td>
<td>0.222</td>
</tr>
<tr>
<td>Mean glycated hemoglobin (g%)</td>
<td>1</td>
<td>7.03 (1.46)</td>
<td>0.154</td>
<td>0.878</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.15 (1.08)</td>
<td>0.155</td>
<td>0.878</td>
</tr>
<tr>
<td>Mean number of missing teeth</td>
<td>1</td>
<td>0.96 (1.14)</td>
<td>-0.153</td>
<td>0.878</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.00 (1.12)</td>
<td>-0.154</td>
<td>0.878</td>
</tr>
<tr>
<td>Mean number of carious teeth</td>
<td>1</td>
<td>1.57 (1.24)</td>
<td>0.716</td>
<td>0.475</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.39 (1.29)</td>
<td>0.716</td>
<td>0.476</td>
</tr>
<tr>
<td>Mean number of bleeding sites</td>
<td>1</td>
<td>107.78 (7.77)</td>
<td>1.665</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>105.27 (7.34)</td>
<td>1.667</td>
<td>0.099</td>
</tr>
<tr>
<td>Mean probing pocket depth (mm)</td>
<td>1</td>
<td>2.56 (0.31)</td>
<td>4.975</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.30 (0.20)</td>
<td>5.018</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean clinical attachment loss (mm)</td>
<td>1</td>
<td>2.57 (0.36)</td>
<td>3.185</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.38 (0.22)</td>
<td>3.213</td>
<td>0.002</td>
</tr>
<tr>
<td>Mean simplified oral hygiene index</td>
<td>1</td>
<td>2.78 (0.46)</td>
<td>4.067</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.46 (0.29)</td>
<td>4.101</td>
<td>0.000</td>
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</tbody>
</table>

*Group 1, patients with retinopathy; Group 2, patients without retinopathy. Abbreviation: SD, standard deviation.
duration of DM was shorter compared to another study that evaluated the relationship between periodontal disease and DR. In a study conducted by Noma et al, the mean duration of diabetes was 14.3 ± 7.1 years. Those authors found a significant relationship between the severity of DM and that of DR.

No statistically significant difference in the mean number of missing teeth and number of carious teeth was found between the test and control groups. Similarly, no difference in the mean number of sites showing BOP was found. BOP represents an early sign of periodontal disease, and diabetic patients tend to show an increased incidence in and severity of this disease. Statistically significant differences between the means of PPD, CAL, and OHI-S scores between the test and control groups indicated poorer oral hygiene and periodontal health in the test group. Similar findings were reported by Noma et al, who concluded that the severity of periodontal disease significantly correlated with the severity of DR. The authors' study also found a significant relationship between the duration of a patient's diabetes and the severity of the disease. In the current study, the mean duration of diabetes was similar in both groups. As all other factors were found to be similar in the test and control groups between this study and the study by Noma et al, it can be inferred that in the presence of periodontal disease, complications of diabetes may occur early, and periodontal disease can place diabetic patients at an increased risk of developing ocular complications.

In this study, diabetic subjects with retinopathy were found to have poorer oral hygiene and poorer periodontal status than diabetics without retinal changes, even though the mean glycated hemoglobin (Hb) values (an indicator of metabolic control) were found to be similar in both groups. Because the periodontal status reflects cumulative pathological change occurring over years, the HbA1c provides diabetic control information over 3-4 months, and the random blood sugar levels reflect a particular time assessment of diabetes control, it can be interpreted that a subject who presently has good metabolic control may have previously had poorer diabetic status. This makes it difficult to establish an unequivocal and precise association between the severity of risk and disease presentation.

The mean number of missing teeth in our study ranged from 0 to 7, with the number of sites showing BOP was found. Similarly, no difference in the mean number of missing teeth was found. No statistically significant difference was found between the test and control groups. The authors also found a significant relationship between the severity of periodontal disease and diabetic retinopathy. In a study conducted by Noma et al, it can be inferred that in the presence of periodontal disease, complications of diabetes may occur early, and periodontal disease can place diabetic patients at an increased risk of developing ocular complications.

Table 2. Comparison of clinical and biochemical parameters in diabetic patients with either proliferative or nonproliferative retinopathy using unpaired t-test.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groupa</th>
<th>Mean (SD)</th>
<th>t-test</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>1</td>
<td>50.54 (10.03)</td>
<td>1.189</td>
<td>0.240</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>47.41 (9.11)</td>
<td>1.178</td>
<td>0.245</td>
</tr>
<tr>
<td>Mean duration of diabetes mellitus (years)</td>
<td>1</td>
<td>5.62 (5.65)</td>
<td>0.497</td>
<td>0.622</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.03 (2.76)</td>
<td>0.468</td>
<td>0.643</td>
</tr>
<tr>
<td>Mean random blood sugar (mg%)</td>
<td>1</td>
<td>160.04 (22.71)</td>
<td>0.556</td>
<td>0.580</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>157.34 (11.77)</td>
<td>0.526</td>
<td>0.602</td>
</tr>
<tr>
<td>Mean glycated hemoglobin (g%)</td>
<td>1</td>
<td>7.03 (1.56)</td>
<td>0.303</td>
<td>0.763</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.15 (1.34)</td>
<td>0.299</td>
<td>0.766</td>
</tr>
<tr>
<td>Mean number of missing teeth</td>
<td>1</td>
<td>0.88 (0.85)</td>
<td>-0.322</td>
<td>0.748</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.00 (1.73)</td>
<td>-0.342</td>
<td>0.734</td>
</tr>
<tr>
<td>Mean number of carious teeth</td>
<td>1</td>
<td>1.42 (1.41)</td>
<td>-1.248</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.86 (1.19)</td>
<td>-1.228</td>
<td>0.226</td>
</tr>
<tr>
<td>Mean number of sites</td>
<td>1</td>
<td>109.00 (5.79)</td>
<td>1.090</td>
<td>0.281</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>106.69 (8.95)</td>
<td>1.134</td>
<td>0.263</td>
</tr>
<tr>
<td>Mean probing pocket depth (mm)</td>
<td>1</td>
<td>2.62 (0.36)</td>
<td>1.064</td>
<td>0.292</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.53 (0.25)</td>
<td>1.028</td>
<td>0.310</td>
</tr>
<tr>
<td>Clinical attachment loss (mm)</td>
<td>1</td>
<td>2.61 (0.39)</td>
<td>0.837</td>
<td>-0.407</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.53 (0.32)</td>
<td>0.821</td>
<td>0.416</td>
</tr>
<tr>
<td>Mean simplified oral hygiene index</td>
<td>1</td>
<td>2.85 (0.52)</td>
<td>0.851</td>
<td>0.399</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.74 (0.40)</td>
<td>0.831</td>
<td>0.411</td>
</tr>
</tbody>
</table>

*a Group 1, patients with proliferative retinopathy; Group 2, patients with non-proliferative retinopathy. Abbreviation: SD, standard deviation.

patients in any of the parameters studied. No association was found between the severity of retinopathy and periodontal status. This might be attributed to the small sample size (27 patients with proliferative retinopathy and 24 patients with nonproliferative retinopathy).

In this study, a multiple regression analysis failed to show a significant effect of any individual parameter except PPD and OHI-S at a 95% confidence interval. Though both PPD and OHI-S were found to have a significant effect ($P < 0.05$), the odds ratio was found to be very small ($<1$). This statistical distortion can be attributed to the fact that the arithmetic mean can be greatly affected by extreme values and may not reflect an accurate picture. Diabetic type II patients with retinopathy were almost 5 times as likely to have periodontal disease than type II diabetics without retinopathy.
As stated before, DR is a result of microvascular retinal changes. Hyperglycemia-induced, intramural pericyte death, and thickening of the basement membrane leads to incompetence of the vascular walls. Small blood vessels—such as those found in the eye—are especially vulnerable to poor blood glucose control. The over-accumulation of glucose and/or fructose in the blood tend to damage the tiny vessels in the retina.4

As the disease progresses, severe non-proliferative DR moves to the advanced proliferative stage. The lack of oxygen due to damaged blood vessels in the retina causes fragile new blood vessels to grow along the retina and in the clear, gel-like vitreous humor that fills the inside of the eye. Fibrovascular proliferation can also cause tractional retinal detachment. The new blood vessels may also grow into the angle of the anterior chamber of the eye, new blood vessels may also grow into the vitreous humor that fills the inside of the eye. Fibrovascular proliferation can also cause tractional retinal detachment. These can bleed and destroy the retina, cause retinal detachment, or neovascular glaucoma.25,26

The long-term complications of DM are mainly associated with prolonged hyperglycemia. There are various biochemical pathways that lead to vascular complications. These include increased polyol pathway flux (sorbitol/aldose reductase) and oxidative stress, increased formation of AGEs, accumulation of diacylglycerol, and activation of protein kinase C (PKC).

Moderate or poor glycemic control in DM patients raises PKC levels and activity, resulting in neutrophil priming. The increased inflammation and oxidative stress are consistent with an increased risk of DM complications, including periodontitis.27

**Study limitations**

The small sample size (100 patients) can be attributed to inclusion and exclusion criteria which were stringent in order to minimize confounding factors. Due to the limited sample size, it was not possible to obtain the statistical power needed to adequately evaluate the potential modulating role of periodontal disease on the severity of retinopathy. As this was a cross-sectional study, a larger sample size would have provided more authentic results.

Randomization was used in an attempt to eliminate bias, and controlled for various confounders, but in so doing, important variables may have been missed, such as the socioeconomic status of the patients, which might have acted as a confounding factor. Antidiabetic medications may have affected finding a clear association, but it would have been unethical to deprive the patients of their DM treatment. Any previous (>6 months) successfully maintained periodontal therapy may have altered the results.

**Conclusion**

The results from this study show that periodontal disease may act as a risk factor for the early development of DR. This is a preliminary study, so it would be premature to suggest any consensus regarding the true association of periodontal disease with diabetic complications. Long-term longitudinal trials with a larger sample size are recommended to evaluate the strength of the association of these 2 disease entities.

### Table 3. Multiple regression analysis.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Standard error</th>
<th>Wald test</th>
<th>Significance</th>
<th>Exp (B) Regression coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>0.028</td>
<td>0.427</td>
<td>0.513</td>
<td>0.982</td>
</tr>
<tr>
<td>Mean duration of diabetes mellitus (years)</td>
<td>0.070</td>
<td>1.217</td>
<td>0.270</td>
<td>1.081</td>
</tr>
<tr>
<td>Mean random blood sugar (mg%)</td>
<td>0.018</td>
<td>1.874</td>
<td>0.171</td>
<td>1.025</td>
</tr>
<tr>
<td>Mean glycated hemoglobin (g%)</td>
<td>0.220</td>
<td>0.143</td>
<td>0.706</td>
<td>1.087</td>
</tr>
<tr>
<td>Mean number of missing teeth</td>
<td>0.215</td>
<td>1.091</td>
<td>0.296</td>
<td>0.799</td>
</tr>
<tr>
<td>Mean number of carious teeth</td>
<td>0.217</td>
<td>1.296</td>
<td>0.255</td>
<td>1.280</td>
</tr>
<tr>
<td>Mean number of sites</td>
<td>0.039</td>
<td>2.548</td>
<td>0.110</td>
<td>0.940</td>
</tr>
<tr>
<td>Mean probing pocket depth (mm)</td>
<td>1.745</td>
<td>9.891</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>Clinical attachment loss (mm)</td>
<td>1.409</td>
<td>0.869</td>
<td>0.351</td>
<td>3.721</td>
</tr>
<tr>
<td>Mean simplified oral hygiene index</td>
<td>0.793</td>
<td>4.856</td>
<td>0.028</td>
<td>0.174</td>
</tr>
<tr>
<td>Constant</td>
<td>6.961</td>
<td>5.536</td>
<td>0.019</td>
<td>1.297</td>
</tr>
</tbody>
</table>

Antidiabetic medications may have affected finding a clear association, but it would have been unethical to deprive the patients of their DM treatment.

Any previous (>6 months) successfully maintained periodontal therapy may have altered the results.

**Conclusion**

The results from this study show that periodontal disease may act as a risk factor for the early development of DR. This is a preliminary study, so it would be premature to suggest any consensus regarding the true association of periodontal disease with diabetic complications. Long-term longitudinal trials with a larger sample size are recommended to evaluate the strength of the association of these 2 disease entities.
Author information
Dr. R. Banthia is a professor, Department of Periodontics, Modern Dental College & Research Centre, Indore, India, where Raje, Singh, and Gupta are postgraduate students. Dr. P. Banthia is a professor and head of Periodontics, Index Institution of Dental Science, Indore, India. Dr. Saral is a medical officer, Shashkiya Mahatma Gandhi Jila Chikitsalaya, Dewas, India.

References
An association between temporomandibular disorder and gum chewing

Diana Correia, DMD, MDent  •  Maria Carlos Real Dias, DMD, MDent  •  Antonio Moacho, DMD, MDent  •  Pedro Crispim, DMD, MDent  •  Henrique Luiz, DMD, PhD  •  Miguel Oliveira, DMD, MDent  •  Joao Carames, DMD, PhD

This single center, randomized, small study sought to investigate the prevalence and frequency of chewing gum consumption, and whether there is a relationship between these factors and the presence of symptoms associated with temporomandibular disorder (TMD).

Subjects were divided into 7 groups based on their parafunctional oral habits. Of these, subjects who chewed gum were divided into 5 subgroups (A-E) based on their gum chewing habits. Group A chewed gum <1 hour/day (n = 12), Group B chewed gum 1-2 hours/day (n = 11), Group C chewed gum 3 hours/day (n = 6), and Group D chewed gum >3 hours at a time (n = 8); the frequency of gum chewing in Groups A-D was once a week. Group E subjects chewed gum 1-3 times/week for at least 1 hour each occurrence (n = 2). Sixty-three percent of the subjects in Group D reported TMD symptoms of arthralgia and myofascial pain. Thirty-three percent of the subjects in Group C showed symptoms of arthralgia. Eighty-three percent of the subjects in Group A and 27% in Group B reported myofascial pain. All subjects in Group E reported masseter hypertrophy. The remaining 2 groups were Group F, subjects that didn’t chew gum but had other parafunctional oral habits (n = 2), and Group G, subjects who didn’t have parafunctional oral habits (n = 12).

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TM Disorders

Temporomandibular disorder (TMD) is a significant public health problem affecting approximately 5% to 12% of the population. TMD is the second most common musculoskeletal condition (after chronic lower back pain) resulting in pain and disability. Pain-related TMD can impact an individual’s daily activities and quality of life. Overall, the annual cost of TMD management, not including imaging, has doubled in the last decade to $4 billion.

For over 30 years, TMD has been classified as a group of disorders characterized by the presence of peri-auricular and masticatory muscle pain, the presence of arthralgia (joint pain) and noises during mandibular opening and closing movements, and deviations or restrictions in range of motion. There are a number of factors that contribute to TMD development, including parafunctional oral habits, malocclusions, stress, and trauma, although the presence of these factors does not necessarily lead to the development of TMD disorders.

When these factors occur with a certain frequency, duration, and intensity that exceeds the body’s physiological tolerance, the result may be tissue damage. This damage tends to begin in structures that are less tolerant to physiological change, such as teeth, muscles, and joints.

During normal oral function, there is a predominance of vertical masticatory cycles, with tooth contact occurring only in the final stages of mastication. The presence of parafunctional oral activity greatly increases the frequency and intensity of masticatory forces, which may cause tooth wear facets, especially in cases of bruxism (grinding/gnashing/clenching of teeth). The presence of tooth wear leads to a predominance of larger and more irregular horizontal and cyclic masticatory movements. The excess wear on the anterior teeth wear leads to a progressive loss of anterior guidance and increased friction forces, which further accelerate tooth wear. This loss of anterior guidance creates a vicious cycle, resulting in posterior overload that activates the action of the masseteric muscles, which further increases the friction between the tooth surfaces. Therefore, in excursive movements and in the absence of a guidance to disocclude, the centric cusps make contact on both the working (side toward which the mandible moves in a lateral movement) and the nonworking sides of the jaw, while the noncentric cusps make contact only on the working side. This causes the centric cusps to make contact twice as much as noncentric cusps, thus generating an inversion of the upward, U-shaped curvature of the maxillary and mandibular occlusal planes in the coronal plane (defined as the Wilson Curve). In this way, the interference on the nonworking side causes the temporomandibular joint (TMJ) to become a class I lever system, resulting in higher TMJ overload, causing ligament strain and increased intra-articular space, which may lead to an immediate Bennet movement (the lateral translation of the head of the mandible on the working side during a lateral excursion) before starting the progressive movement. This is not a dental problem, but a joint problem that involves the jaw. However, the consequences of this movement will lead to occlusal teeth surfaces with parafunctional facets.

Previous studies have established a positive relationship between TMD and parafunctional oral habits such as lip and tongue suction, bruxism, oral breathing without obstructive cause, nail and pencil biting, jaw “play,” and chewing gum.

Given how the major properties of food, including hardness, size, volume, and elasticity, affect mastication, the present study—in agreement with several other studies—defined a gum chewing habit as intense when it is maintained >3 hours at a time.

Intense gum chewing is strongly associated with the presence of joint noises and pain at the TMJ level, muscle soreness or pain at rest (especially in the masseter), and muscle hypertrophy. This is especially true in subjects with a prior history of TMD.

The existence of oral parafunctional habits in individuals without TMD suggests that these habitual movements do not always result in TMD, but can act as risk factors. The current study sought to determine a relationship between the prevalence and frequency of chewing gum and signs and symptoms associated with TMD.
Table 1. Temporomandibular disorder (TMD) diagnosis in study population (n = 38).

<table>
<thead>
<tr>
<th>TMD diagnosis</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myofascial pain</td>
<td>Yes 15</td>
<td>39.5</td>
</tr>
<tr>
<td></td>
<td>No 23</td>
<td>60.5</td>
</tr>
<tr>
<td>Arthralgia</td>
<td>Yes 25</td>
<td>65.8</td>
</tr>
<tr>
<td></td>
<td>No 13</td>
<td>34.2</td>
</tr>
<tr>
<td>Masseter hypertrophy</td>
<td>Yes 13</td>
<td>34.2</td>
</tr>
<tr>
<td></td>
<td>No 25</td>
<td>65.8</td>
</tr>
<tr>
<td>Headaches</td>
<td>Yes 6</td>
<td>15.8</td>
</tr>
<tr>
<td></td>
<td>No 32</td>
<td>84.2</td>
</tr>
</tbody>
</table>

Table 2. Correlations between TMD symptoms and chewing gum.

<table>
<thead>
<tr>
<th>TMD diagnosis</th>
<th>Groups (%)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthralgia</td>
<td></td>
<td>33</td>
<td></td>
<td>63</td>
<td>(P = 0.043)</td>
<td></td>
</tr>
<tr>
<td>Myofascial pain</td>
<td></td>
<td>83</td>
<td></td>
<td>27</td>
<td>(P = 0.025)</td>
<td></td>
</tr>
<tr>
<td>Masseter hypertrophy</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Materials and methods

This study was a single-center, randomized trial in students (n = 50) at the University of Lisbon, Portugal. The sample was composed of 43 females and 7 males with an age range of 19-27 years.

Exclusion criteria were orthodontic treatment, craniofacial anomalies, degenerative TMJ, and non-rehabilitation of edentulous spaces. Inclusion criteria included a signature of informed consent and permanent dentition only.

Subjects were divided into 7 groups who were then given a questionnaire concerning their parafunctional oral habits. Based on this questionnaire, 5 groups (A-E) were created based on the subjects' chewing gum habits as indicated on this questionnaire. Group A chewed gum <1 hour/day (n = 12), Group B chewed gum 1-2 hours/day (n = 11), Group C chewed gum 3 hours/day (n = 6), Group D chewed gum >3 hours/day (n = 8)—the frequency of gum chewing in Groups A-D was once a week. Group E subjects chewed gum 1-3 times/week for at least 1 hour each occurrence (n = 2). The remaining 2 groups were Group F, subjects that didn't chew gum but had other parafunctional oral habits (n = 2); and Group G, subjects that didn't have parafunctional oral habits (n = 12).

The questionnaire concerning parafunctional oral habits was based on the Oral Behavior Checklist found in the Diagnostic Criteria for Temporomandibular Disorders (2014). Primary outcomes before and after each observation period were recorded using the Numeric Rating Scale (NRS), in which patients determine their perception of pain on a scale of 1 to 10, 10 being the most severe. The subjects were told to maintain their habits for 6 months. For Groups A-E, a specific type of gum (Trident, Cadbury) was provided by the clinician. The data were collected by a calibrated operator.

Results

Clinical examination

The diagnoses of each subject were made according to the research diagnostic criteria for TMD. This included examination for muscle pain, joint pain, jaw limitation (vertical and side excursions), joint sounds, masseter hypertrophy (a benign increase in size), and headaches (Table 1).

Statistical analysis

Variables were analyzed by chi-square tests with a significance level of 5%. The presence of isotonic muscle contraction has proposed oral parafunctional habits as a possible cause of TMD, and symptoms of dysfunction have been published. Studies conducted in adults have shown a positive correlation between TMD and gum chewing, followed by tongue placement between teeth and jaw play, which are nonphysiologic, mandibular positioning habits. The results showed that the subjects that chewed gum for more hours—regardless of the frequency of the habit—had more signs/symptoms of TMD.

Discussion

The most important function of the stomatognathic system is chewing, defined as a voluntary and rhythmic activity of the masticatory muscles during the process of opening and closing of the jaw. The command for this activity is carried out by the cerebral cortex which receives the information sent by the motor nerves concerning the speed, time of action, and muscle contraction/relaxation, allowing for the adaptation of muscle and joint structures to the food type. Protective reflexes are constantly present, protecting against contacts that are damaging to the system. The presence of isotonic muscle contraction allows adequate blood flow to oxygenate the tissues and eliminate the metabolic products accumulated at the cellular level.

In the literature, a number of investigations have proposed oral parafunctional habits as a possible cause of TMD, and its prevalence and association with signs and symptoms of dysfunction have been published. Studies conducted in adults have shown a positive correlation between.
Parafuncional oral habits seem to present more in adolescents than adults, and in females more than males. Thus, there is speculation that parafuncional activities can contribute to a higher prevalence of TMD symptoms in females and adolescents. There was no statistical significance between gender and the presence of TMD in the present study, which could be due to the small number of male subjects (n = 7).

The literature also mentions that chewing gum interferes with the normal mastication pattern. It involves an increased mastication frequency due to a greater number of masticatory cycles and an increase in muscle intensity. Since chewing gum does not fragment during mastication, the masticatory muscle workload is greater and more sustainable than is the case with “fragmentable” foods. The masticatory cycles are also shorter, resulting in a lowered recognition from the muscle and joint structures of the existing force loads, which in turn creates a lower adaptation to these forces; this results in a lower tolerance of the masticatory system to the forces. There is also a predominance of unilateral mastication, which translates into an overload of the working side jaw muscles, resulting in muscle fatigue and hypertrophy. Unilateral mastication is also responsible for a lower proprioception (sense of place and strength of effort by the surrounding structures) and consequently a greater imbalance in muscle contraction.

This study was conducted on 50 university students between the ages of 19 and 27 in order to investigate the prevalence and inter-relationship of several parafuncional habits and their contribution to the presence of various signs and symptoms of TMD. Although this study was limited by a small study sample size and restricted age range, the results concur with those found by Wincour et al and Gavish et al. Further research is needed with larger subject populations exhibiting greater ranges of both the frequency and intensity of oral parafuncional habits in order to make more and better comparisons between groups. Specifically, a larger study is needed that includes subjects whose habit is chewing gum >3 hours at a time and more than once a week, to confirm whether the frequency of this habit exacerbates the symptoms of TMD found in intensive chewing.

The results from this study showed that it is the intensity of the habit—as reflected by hours of chewing per day—that was the most significant indicator of risk to the stomatognathic system. There was no consistent relationship between the frequency of chewing gum more than once and up to 3 times per week and the signs and symptoms of TMD pain.

There was a correlation between chewing gum more than once per week and masseter hypertrophy. This is in line with findings by Sari & Sonmez and Vanders & Manetas.

### Bruxism

The literature recommends that bruxism and TMD pain be managed as separate problems. It is important to understand the concept of a nonlinear relationship to avoid oversimplification of diagnosis and management. Svensson et al, Huang et al, and Kalamir et al have stated that while it seems evident that there are associations between TMJ pain and bruxism, care must be taken to not create a simplistic cause and effect relationship.

In a 2010 systematic review by Manfredini & Lobbezoo, this concept of cause and effect was corroborated, and the authors concluded that it was not possible to discuss the relationship between specific TMD signs and symptoms and different bruxism-related motor activities—namely clenching and grinding—due to the very low levels of specificity in the reviewed studies.

### Conclusion

Patients often consult general dentists concerning TMD symptoms, especially those associated with pain. The Diagnostic Criteria for Temporomandibular Disorders (2014) is presently one of the best techniques for diagnosis of TMD. This evidence-based criteria will assist clinicians when assessing patients, while facilitating communication in consultations, referrals, and prognoses.

In this study, chewing gum more than once per week was related to masseter hypertrophy. The presence of TMD symptoms, including arthralgia and myofascial pain, were related to chewing gum for >3 hours at a time (Group D). The intensity of the oral parafunction—as defined in this study as chewing gum >3 hours at a time—was determined to be the most important factor in the propensity toward symptoms of TMD pain.

Further standardized, randomized, and externally validated studies are needed to determine the specificity of the present parameters.

### Author information

Drs. Correia, Dias, Moacivo, and Crispin are lecturers, Occlusion and Temporomandibular Dysfunction Department, Faculty of Dental Medicine, University of Lisbon, Portugal, where Dr. Carame is an associate professor and chairman, as well as a full professor and chairman of the Implant Department; Dr. Luis is an auxiliary professor, Dental Hygiene Department; and Dr. Oliveira is a member of the Faculty of Dental Medicine.

### References