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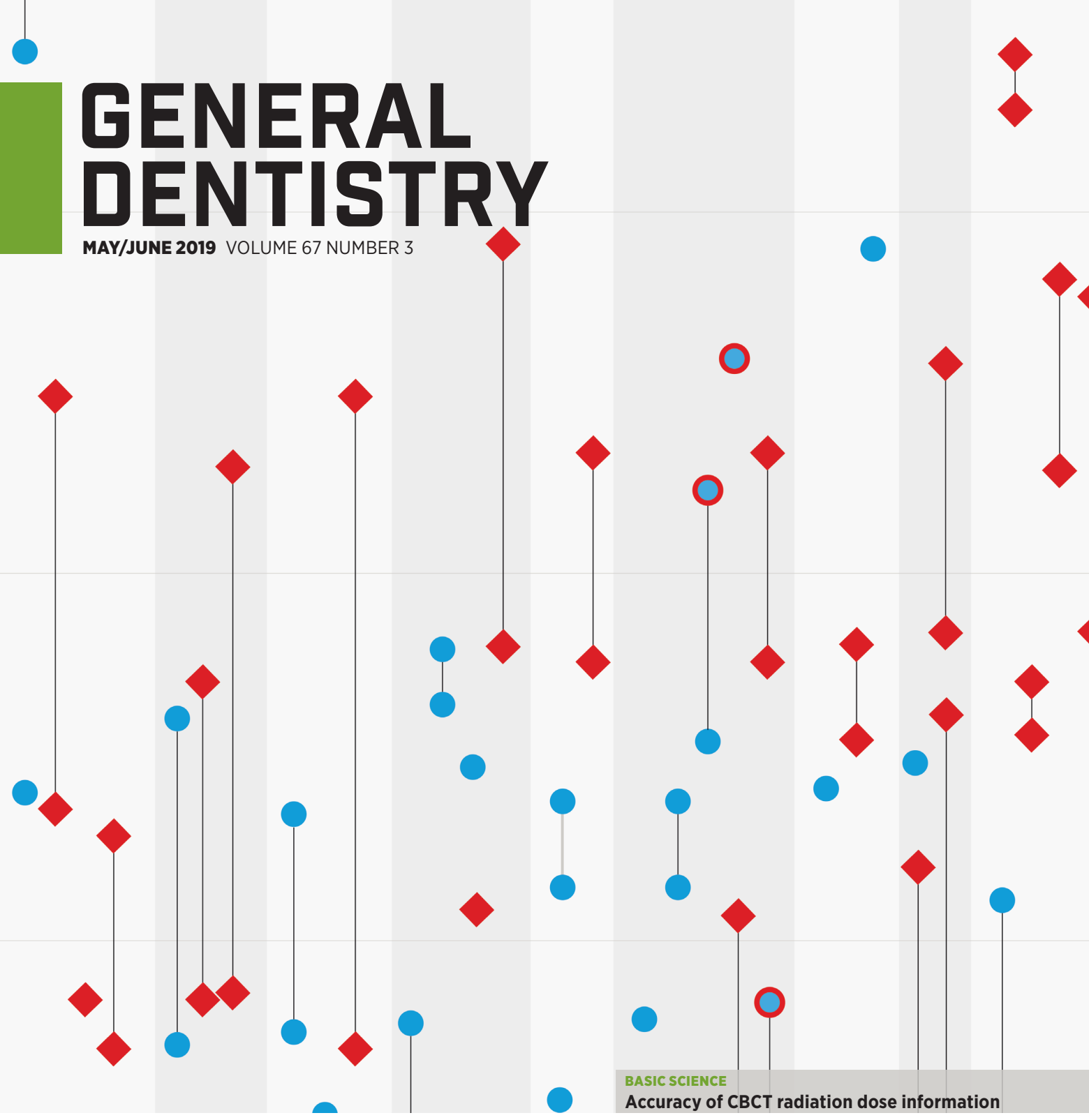

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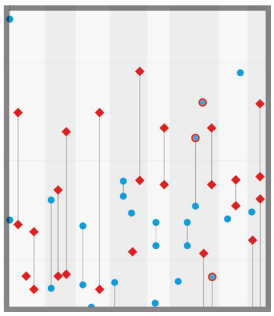

Cover image inspired by: *Comparison of the accuracy of CBCT effective radiation dose information in peer-reviewed journals and dental media,* on p. 38

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EDITORIAL

Effort

Achievement is the result of effort. Almost all of us succumb to the temptation to look for the easy way out at some point in our lives, but that approach rarely succeeds. No reliable substitute for hard work has ever been discovered. William Arthur Ward wrote, "Excellence without effort is as futile as progress without preparation."

Maintaining an ethic of continuous effort is challenging, but, as my father often reminded me, hard work never hurt anyone. While I've always taken his adage to heart, I rarely think about what defines "hard work" beyond the abstract. In truth, many tasks in our personal and professional lives could be considered hard work, even if we don't ever leave our chair. Every moral dilemma where we have to determine the "right" choice is hard work. Every second that we put into raising our children to be ethical and productive adults is demanding. Every treatment that we provide to improve the oral health of a patient represents our determined effort to succeed.

For many of us, the example of hard work that might be easiest to recall is getting through dental school. Right behind that is starting our careers. By withstanding the rigors of dental school and the demands of dental practice, we've proved that we know how to sustain effort for long periods. This is going beyond simply doing hard work—it's repeatedly working hard and producing successful outcomes. That is a skill that only comes with experience and is refined over time. It is why we should all be proud to call ourselves dentists.

We need to apply that same mindset to our participation in the dental profession as a whole. We need professionals who join organized dentistry and are willing to work hard and take initiative—to make bold moves to advance the science and practice of dentistry. And we need those same people to maintain that effort. There's plenty of room for dentists who want to contribute some sweat equity to better our profession. As Vince Lombardi stated, "Leaders are made, they are not born. They are made by hard effort, which is the price which all of us must pay to achieve any goal that is worthwhile."

We must work for what we want. We may have to give up something along the way, but, in the long run, our hard work and sacrifice will pay off. Marsha Evans, the former president and chief executive officer of the American Red Cross and a retired rear admiral of the US Navy, reminds us: "Working hard overcomes a whole lot of other obstacles. You can have unbelievable intelligence, you can have connections, you can have opportunities fall out of the sky. But in the end, hard work is the true, enduring characteristic of successful people."

Dentistry needs people who want to make a difference, not those who simply do the job. Work your hardest, and you will advance the entire profession.

Roger D. Winland, DDS, MS, MAGD
Editor

PROSTHODONTICS

Comparison of 2 methods for screw-retained implant prostheses

Samuel M. Strong, DDS

The screw-retained format for implant restorations has become our preferred method versus a cement-retained implant crown or bridge. Retrievability of the implant bridge is a highly attractive feature to allow repair of any damage to the prosthesis, among other considerations. However, traditional types of screw-retained restorations with a titanium or zirconia abutment could create difficulty for a laboratory-based repair. This is due to the nature of bonding a milled zirconia, titanium, metal casting, or other ceramic structure to an abutment (usually now made of titanium or zirconia). If any of the zirconia and/or porcelain layered material fractures, it is necessary to separate the abutment from the remainder of the restoration to complete the repair.

The following case examples illustrate implant bridge retrievability and compare the relative ease of repairability of prostheses made with 2 different approaches.

Case 1

The patient had an old, failing natural tooth-borne fixed prosthesis retained by teeth 4, 5, and 11. Recurrent caries was present on teeth 4 and 11, underneath the retainers. Tooth 4 was deemed nonrestorable, requiring extraction. Teeth 5 and 11 were evaluated and deemed acceptable for restoration with single crowns. Following a full review of options, the patient agreed to a treatment plan to place implants in the sites of teeth 4, 6, 8, and 10. A screw-retained, implant-borne fixed bridge was planned for tooth sites 6-10 (replacing the missing teeth 7 and 9), a single implant crown on tooth 4, and natural tooth crowns on teeth 5 and 11.

A large anterior bone graft was performed in the premaxilla to provide sufficient osseous width for later implant placements in that zone. The implant to replace tooth 4 was placed during the same appointment as the anterior bone graft procedure (Fig 1). A laboratory-fabricated provisional bridge was retrofitted to teeth 5 and 11 to serve during the graft maturation phase.

Six months after the graft procedure, the additional, final implants were placed in sites 6, 8, and 10. These implants were placed with 35 N/cm torque for initial stability and thus deemed acceptable for immediate loading. The provisional prosthesis was then retrofitted to implant abutments in the teeth 4, 6, 8, and 10 sites and cemented with a temporary cement. Following a 4-month period of osseointegration, the provisional bridge was removed, and all implants were successfully torque tested at 35 N/cm force.

The master impression for the final restorations was completed for all implants and natural teeth from sites 4-11. Impression copings were connected to all the implants, and teeth 5 and 11 received final preparations for the impression. The master cast was poured and mounted with a facebow on a semiadjustable articulator.

Custom titanium abutments (Nobel Biocare) were designed and milled for all of the implant sites. These titanium abutments were opaqued by the dental laboratory to enhance the esthetics of the final restorations (Fig 2). Milled zirconia final restorations for all the implant sites were fabricated with lingual access openings to accommodate screw access retention (Fig 3). All implant and natural tooth restorations were layered with porcelain to the milled zirconia on the facial surfaces (P2Z, Macstudio).

A try-in appointment resulted in the approval of the esthetics and occlusion of the combined restorations. The abutments and milled zirconia bridge were tried in as separate items; the implant crown and implant bridge were seated but not cemented to the abutments. In order to make the implant restorations screw retained, these abutments were cemented to the single implant crown in site 4 and the bridge retainers in sites 6, 8, and 10.

The case was completed by cementing natural tooth crowns on teeth 5 and 11 with a resin-modified glass ionomer cement. The implant restorations, consisting of abutments bonded to zirconia, were connected to the implants with screw retention. The screw heads were protected with polytetrafluoroethylene tape, and the screw access opening was sealed with light-cured temporary material (Fig 4).

Case 2

The patient presented with 2 failing fixed bridge restorations on natural teeth. One was a cast gold cantilever bridge cemented to tooth 6 with a pontic attached in the tooth 7 site. The other restoration was a gold casting/acrylic-facing fixed bridge with retainers on teeth 8 and 10 and a pontic in the tooth 9 site.

Both of these restorations had significant recurrent caries and had been in use

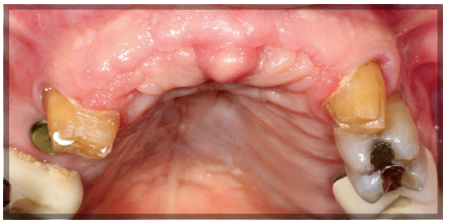

Fig 1. Case 1. Premaxilla after grafting and placement of implant in the tooth 4 site.

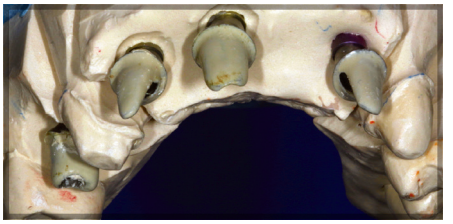

Fig 2. Case 1. Custom titanium abutments opaqued by the laboratory. The implant restorations will be bonded to these abutments prior to delivery.

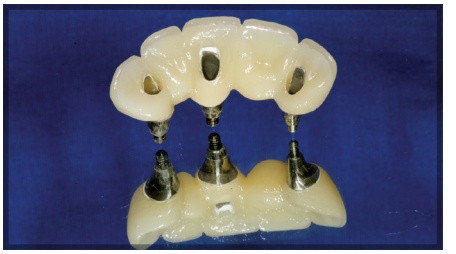

Fig 3. Case 1. Milled implant-retained fixed bridge with lingual access openings for screw retention.

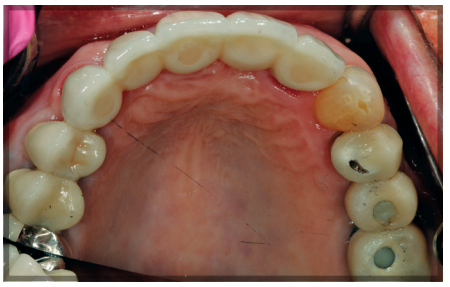

Fig 4. Case 1. Access openings sealed with composite over polytetrafluoroethylene tape.

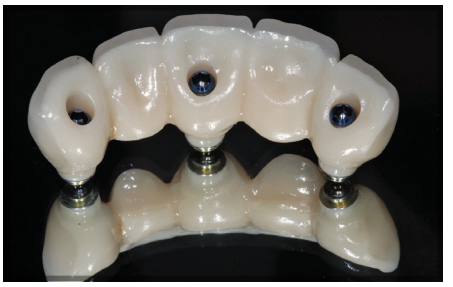

Fig 5. Case 2. Milled superstructure titanium bases with lingual access screw openings.

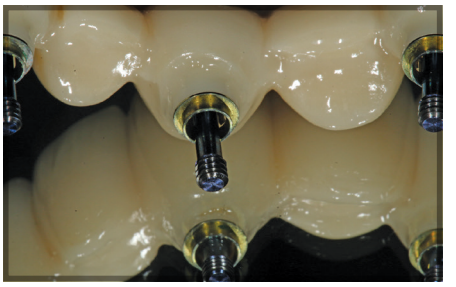

Fig 6. Case 2. The milled zirconia and titanium base are joined together with a screw and no cement.

for more than 30 years. The patient was aware of the underlying problems due to mobility of the restorations. The treatment plan was to place 3 implants in the sites of teeth 6, 8, and 10 for use with a new implant-retained fixed bridge.

Bone graft and implant placements were accomplished, and a provisional abutment with provisional bridge was placed. Four months after implant placement, prosthetic procedures were initiated to fabricate the final implant-retained fixed bridge.

As in case 1, the fixed prosthesis connected to implants 6, 8, and 10 was screw retained. In contrast, the connection between the milled zirconia and implant abutments required no cement or bonding material. The implant-retained bridge also incorporated a layered-porcelain facial/incisal segment for improved esthetics (Fig 5).

The zirconia/porcelain portion of the bridge was connected to titanium bases in the teeth 6, 8, and 10 sites with the angled screw channel (ASC) format (NobelProcera, Nobel Biocare). In this system, intraoral fixation of the implant bridge is accomplished by a single screw through the superstructure material that bolts the bridge to the implant and titanium base. No cement or bonding material is needed to stabilize the implant components (Fig 6).

Discussion

The primary advantage of the screw-retained format illustrated in case 1 is to ensure retrievability of the implant restorations if any fracture or damage occurs or if there is inflammation or infection of the implants. However, repairability of these screw-retained restorations can be problematic. For example, if some of the layered porcelain on the facial or incisal surfaces fractures, repair requires separation of the bonded titanium abutments from the remaining superstructure of the restoration. This separation requires heating up the restoration in an oven at sufficient temperature to break the cement bond between the titanium and zirconia. This can be accomplished but may result in damage to either or both components of the system. If the repair is successful, the abutments and zirconia portions then have to be rebonded.

With the ASC format shown in case 2, the implant-retained bridge is not only retrievable through the use of screw retention but also more easily repairable than the restoration in case 1. In the event of fracture or other damage, the prosthesis can be retrieved intact by accessing the retaining screw. Furthermore, the titanium base can be pulled away from the zirconia portion with an instrument

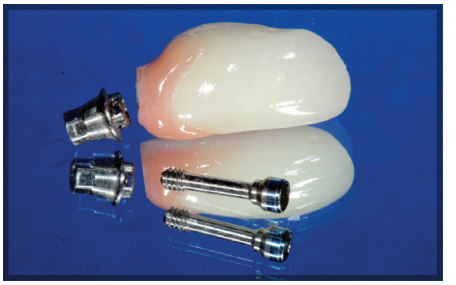

Fig 7. Example of separate titanium base, implant crown, and connecting angled screw.

(Fig 7). Fractured porcelain can then be replaced and fired in the laboratory oven. The completed repair can be rejoined to the original titanium base and replaced intraorally.

The ASC format's dual benefits of retrievability and repairability lend an advantage when the prosthetic dentist has to manage complications after delivery.

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Disclaimer

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PAIN MANAGEMENT

Appropriate imaging for diagnosis of orofacial pain conditions

John J. Frazier, DMD, MSPH, MS ■ Christopher J. Spencer, DDS

When a patient visits a dental office with complex orofacial pain concerns, the dentist's greatest challenge is the formation of an accurate diagnosis. This column addresses the question of which imaging modality best facilitates an accurate diagnosis.

In 1895, Friedrich Otto Walkhoff acquired the first dental radiograph just 2 weeks after Roentgen discovered X-rays.[1] New Orleans dentist C. E. Kells introduced radiographs into clinical practice in 1896.[2] Since its introduction, dental radiography has become an indispensable tool for dentists. Dental radiographs aid in diagnosis of oral conditions and diseases.[3] It is estimated that 100 million dental radiographs are obtained each year.[4] Since the introduction of cone beam computed tomography (CBCT) in the United States in 2001, dentists have rapidly embraced this tool for imaging the complex 2-dimensional and 3-dimensional anatomy of the maxillofacial region, but concerns regarding its proper use continue to be expressed.[5,6] The goal of this column is to help clinicians critically consider the use of appropriate imaging studies as part of the history and examination process. The Table serves as a summary of likely appropriate imaging for different signs, symptoms, and clinical impressions.

Odontogenic pain: pulpal and periapical

Odontogenic pain refers to any pain that originates from the teeth or structures that support them, such as the periodontal ligament, mucosa, or osseous structures of the jaws.[7] The most common source of oral pain is a toothache.[8] Only caries, apical periodontitis, postendodontic therapy pain, tooth fracture, and periodontal disease lend themselves readily to radiographic evaluation.

Pulpal pain usually is caused by inflammatory changes in the pulp tissue associated with dental caries. Because pulp tissue cannot be imaged directly, bitewing radiographs are the best available tool for assessment of carious lesions that suggest the presence of pulpal inflammation or necrosis. When a significant carious lesion is detected, periapical imaging also should be performed to evaluate possible apical pathology.

Apical periodontitis is characterized radiographically as a widening of the periodontal ligament space or a well-defined radiolucency surrounding the apex of a tooth root. The radiographic visibility of the apical lesion varies, depending on the extent of bone demineralization, the quality of the bone, and the position of the apex of the tooth root in relationship to cortical bone. A radiograph cannot differentiate between a granuloma, an abscess, and a radicular cyst.[9]

Lingering pain after endodontic treatment poses a diagnostic dilemma. The differential diagnosis must include postoperative incidence of neuropathic pain (3%-12%), potential untreated canal structure, and root fracture.[10] Neuropathic pain is a diagnosis of exclusion, made when no identifiable dental disease is responsible for symptoms. Absent or ambiguous radiographic findings should serve as a warning that further clinical intervention may be contraindicated.

The imaging reference standard for missed canals is CBCT, as it is superior to digital radiography, which has a sensitivity of 76%-84%, in contrast with CBCT, which identified 100% of canals in one study.[11] The sensitivity and specificity of CBCT for the detection of root fractures are higher than those of conventional radiography.[12,13] Direct radiographic visualization of root fractures is not always possible. An indirect radiographic indication of a root fracture is a J-shaped radiolucent lesion adjacent to the root.[14,15]

Temporomandibular disorders

Temporomandibular joint (TMJ) conditions are a subset of temporomandibular disorders (TMDs) for which imaging is of great importance. Common imaging modalities include panoramic radiography, CBCT, and magnetic resonance imaging (MRI).[16] Panoramic radiography can be used only as an initial screening tool for gross osseous pathology because it provides little further diagnostic information.[17]

Myofascial pain, which is the most common TMD, is a soft tissue condition that displays no clinical pathology.[18] A diagnosis of myofascial pain is based on a complete history and clinical examination findings. Therefore, imaging will not detect this condition. A panoramic image could be an appropriate screening tool to help exclude other conditions.

Table. Orofacial pain conditions and their suggested imaging modalities.

Clinical impression	Signs and symptoms	Imaging modality			
		Intraoral	Panoramic	CBCT	MRI
Pulpal origin: reversible or irreversible pulpitis	• Temperature sensitivity • Percussion sensitivity • Spontaneous pain	• Bitewing radiographs and periapical images from multiple angles	• Poor imaging modality	• Consider when signs or symptoms are inconsistent with pain of pulpal origin	• Contraindicated
Periapical and/or periodontal origin	• Periodontal attachment loss • Furcation or vertical bony defects • Percussion sensitivity	• Bitewing radiographs and periapical images from multiple angles	• Screening tool	• Consider when signs or symptoms are inconsistent with pain of periodontal origin	• Contraindicated
TMD: myofascial pain	• Dull, achy pain • Tired, tight muscles • Possible pain referral and/or limited ROM	• Use to rule out possible odontogenic sources of pain	• Screening tool	• Rarely indicated	• Consider if pain is unilateral and/or no resolution with management
Degenerative TMJ disease without pain or dysfunction	• Auscultation sounds, such as crepitus	• Contraindicated	• Screening tool	• Rarely indicated	• Not indicated
Degenerative TMJ disease with pain in the TMJ or significant dysfunction	• Pain and dysfunction in the TMJ associated with an intracapsular sound and/or with exacerbation by function and possible occlusal changes	• Contraindicated	• Poor diagnostic information	• Imaging modality of choice	• Indicated if initial management strategies fail and/or intracapsular pathology is suspected
TMJ articular disc displacement with no other signs or symptoms	No radiographic imaging necessary in most cases				
TMJ articular disc displacement with painful clicking or locking	• Pain and dysfunction in the TMJ associated with an intracapsular sound and/or exacerbation by function	• Not indicated	• Not indicated	• Most appropriate initial image to view bony degenerative changes	• Indicated if initial management strategies fail and intracapsular pathology is suspected
Trigeminal neuralgia	• Sharp, shooting, paroxysmal, electrical pain lasting for seconds to minutes	• To rule out possible odontogenic sources of pain	• Screening tool	• Rarely indicated	• Use determined by neurologist
Trigeminal neuropathy	• Burning, tingling pain that lingers; often constant • With or without history of trauma • Sources of trauma can be mechanical, biologically invasive, or chemical	• To rule out possible odontogenic sources of pain	• Screening tool	• To determine sites of dental mechanical/surgical treatment	• Rarely appropriate • Could be used for imaging of neural involvement
Maxillary sinusitis	• Midfacial pressure associated with recent upper respiratory tract infection	• To rule out possible odontogenic sources of pain	• Screening tool emphasizing maxillary sinus	• Appropriate to rule out odontogenic source	• Use determined by physician

Abbreviations: CBCT, cone beam computed tomography; MRI, magnetic resonance imaging; ROM, range of motion; TMD, temporomandibular disorder; TMJ, temporomandibular joint.

Articular disc displacement is a common phenomenon associated with repeated clicking in the affected TMJ. It is primarily a soft tissue condition associated with the derangement of the articular disc. If examination of the TMJ elicits no pain and demonstrates no dysfunction, then no imaging is indicated.

Articular disc displacement accompanied by pain and dysfunction in the TMJ requires radiographic imaging. Patients easily mistake preauricular pain of muscle origin for TMJ pain. A clinician can readily verify the source of pain through palpation of the area to find the structure that duplicates the patient's chief concern. Dysfunction may be displayed as a limited range of motion, locking, and/or catching in the joint; deviation and/or deflection on opening; and occasionally significant occlusal changes. The most appropriate imaging modality for this subset of problems is CBCT. Although this may seem counterintuitive, soft tissue can be evaluated predictably by clinical examination but bony degeneration cannot.[19]

Magnetic resonance imaging may be needed if initial management strategies fail and additional soft tissue pathology is suspected in the TMJ. However, an MRI evaluation for disc displacement is fraught with debatable diagnostic criteria; what findings are within the normal range and/or what findings are considered pathologic? Larheim et al reported that one-third of asymptomatic volunteers who underwent MRI had disc displacement that may not have represented pathology.[19]

Degenerative TMJ disease without pain may be suggested by crepitus during auscultation in the examination process. This condition often occurs with age and advances slowly, so there is little risk of future pain or dysfunction. Most often, a finding of joint sounds alone, without concomitant pain or dysfunction, requires no imaging. Sound clinical judgment is imperative because patients with dental restorative needs likely require imaging to ascertain the stability of occlusion.

Degenerative TMJ disease with pain and dysfunction occurs in a small subset of patients, who commonly exhibit degenerative TMJ changes. Pain associated with this condition likely will be reported during all types of function. Palpation of the TMJ during the physical examination can confirm that it is the source of the pain. Changes in occlusion; locking and/or catching; and deviation and/or deflection on opening can signify dysfunction. Cone beam computed tomography or MRI can be used to evaluate the osseous structure of the TMJ. However, CBCT is optimal because it allows the morphology of the condyles and their position within the fossa to be evaluated.[16,20]

Cross-sectional reformatting should be used for evaluation of the condyles because they are angled relative to the 3 standard reformatted planes of axial, coronal, and sagittal sections. Reformatting the planes of the image removes oblique slicing of the condyles by reorienting the coronal plane along the long axis of the mandibular condyles, which will in turn reformat the axial and sagittal planes so that all planes are orthogonal. Many CBCT software products have TMJ windows, which allow for reformatting, display of multiple sagittal or coronal slices, and simultaneous viewing of both TMJs.

Neuropathic pain

Neuropathic pain can occur as a result of traumatic injury or can be idiopathic. Appropriate imaging can contribute to the diagnosis of neuropathic pain by ruling out other sources of orofacial pain. Spontaneous neuropathic pain is primarily diagnosed by history (especially the use of pain descriptors such as *shooting* or *electrical*) and by sensory testing. Panoramic radiography is a good screening tool for confirming the diagnosis by eliminating other potential sources of oral pain.

Traumatic neuropathic pain occurs as a result of nerve damage such as deafferentation, demyelination, or inflammation to the damaged nerve.[21] Dental procedures are known to directly produce nerve damage.[22] Nerve injury during implant placement is a major concern, with a reported incidence of 0.6%-36% for neurosensory disturbances.[23] The inferior alveolar nerve and the lingual nerve are most commonly injured during implant procedures.[24] Direct intrusion of the inferior alveolar canal is not necessary for the initiation of neuropathic pain, as small branches of the inferior alveolar nerve exiting the inferior alveolar canal can be traumatized.[25] The American Academy of Oral and Maxillofacial Radiology recommends that cross-sectional CBCT be performed preoperatively for assessment of the implant site and postoperatively if necessary.[26]

Dentists need to be familiar with trigeminal neuralgia because approximately 80% of patients seeking medical attention for this disorder see their dentist first.[27] Trigeminal neuralgia is a diagnosis of exclusion because the pain originates from the trigeminal nerve without observable oral pathology. Panoramic radiography is a good screening tool because it can rule out other oral sources of pain. When an identifiable etiology exists, vascular compression of the trigeminal nerve is causative in 80%-90% of cases.[28] MRI, which is prescribed by a neurologist, has greatly increased the identification of offending cerebral vessels.[26]

Pain in the maxillary sinus region

Perceived pain in the maxillary teeth may originate in the maxillary sinus owing to the close proximity of the antral floor as well as the common trigeminal innervation.[29] Acute sinusitis pain is associated with an upper respiratory infection, but chronic sinusitis is rarely painful.[30] Sinus pain descriptors are *dull, aching,* and *tender*, and the patient will report mild-to-moderate severity.[31] Computed tomography is the imaging modality of choice, not only to confirm the diagnosis but also to eliminate other possible sources of pain that may mimic sinus-like pain.[30,32] Intraoral radiographs can help to identify odontogenic sources of pain.

Rationale and staging of diagnostic imaging

The principal concern regarding the use of dental radiography is exposing the patient to ionizing radiation. The clinician must weigh the information gained from the imaging study against the patient's X-ray exposure. The dentist should follow the principle of ALARA ("as low as reasonably achievable") and use the imaging modality that provides the requisite information with the least radiation exposure.[3,33] *Staging* is the term used to describe the prescription of minimal initial imaging followed by additional and more advanced imaging as clinical management necessitates. This practice is especially appropriate for TMJ imaging.

Conclusion

Imaging studies are crucial for assessing orofacial pain, but selecting the appropriate modality is not a simple task. The clinician must first ask, "Can the diagnostic information be acquired by any other modality?" Second, the clinician must understand the advantages and limitations of each imaging modality to obtain the most useful information. Third, the clinician's judgment has to be supported by current best evidence. Finally, the dentist needs to decide whether he or she will undertake the interpretation of complex imaging findings such as those of CBCT and MRI or refer the patient to a radiologist.

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PHARMACOLOGY

Phentolamine mesylate: pharmacology, efficacy, and safety

Elliot V. Hersh, DMD, MS, PhD ■ Paul A. Moore, DMD, PhD, MPH ■ Mana Saraghi, DMD

Phentolamine mesylate is a relatively old drug in the cardiovascular arena, approved in 1952 under the trade name Regitine (CIBA Ag) for the treatment of severe hypertension.[1] Its ability to rapidly reduce blood pressure is due to its α-adrenergic blocking effect on blood vessels, which opposes the vasoconstrictive effects of neuronally released norepinephrine and circulating epinephrine and norepinephrine from the adrenal medullas; the end result is vasodilation (Fig 1).[2]

Phentolamine mesylate is still used off-label for this purpose via the intravenous administration of a 5- to 15-mg bolus for the treatment of a hypertensive crisis.[3-5] Hypertensive emergencies can include those caused by drugs such as cocaine or amphetamine. In addition, intravenous phentolamine is still approved by the US Food and Drug Administration (FDA) for the prevention of severe hypertension during the surgical removal of a pheochromocytoma. During surgical manipulation and excision of this benign tumor, an outpouring of norepinephrine and epinephrine into the bloodstream can occur, leading to severe hypertension.[6]

Researchers at a start-up company (Novalar Pharmaceuticals) considered the possibility that the vasodilatory properties of phentolamine, employed at much lower doses than those employed to treat hypertensive states, could accelerate recovery of lip and tongue sensation from local anesthetics containing epinephrine. Residual lip and tongue numbness caused by local anesthetics following routine nonsurgical dental restorative procedures is considered a negative quality-of-life issue by many patients. A survey of 250 dental patients revealed that a therapeutic option to reverse this numbness more quickly would be of interest to as many as 88% of patients, even if it required an additional injection and added to the cost of the dental procedure.[7] A study of 22 patients, aged 13-75 years, reported that 86% voiced a moderate dislike and 14% a strong dislike for residual numbness.[8] Drooling and the inability to speak and smile properly are among patients' complaints arising from persistent lip and tongue numbness following discharge from the dental office.[9]

After mandibular block injections with 2% lidocaine plus 1:100,000 epinephrine, the duration of lip and tongue anesthesia can last 3-5 hours.[10] In children, prolonged soft tissue anesthesia can lead to inadvertent biting and mutilation of their lips and tongue (Fig 2).[11,12] The results of a prospective study of 320 children revealed that 18% of children younger than 4 years of age, 16% of 4- to 7-year-old children, and 13% of 8- to 11-year-old children displayed postprocedural soft tissue trauma after receiving mandibular block injections.[13]

The developers of the anesthesia-reversal agent hoped that phentolamine would reduce the incidence of lip and tongue mutilation in young pediatric dental patients or patients with special needs. The product that was eventually developed (OraVerse, now marketed by Septodont) is packaged in a standard 1.7-mL dental cartridge. At the completion of a restorative procedure, the phentolamine is injected submucosally at the initial local anesthetic injection site.

Approved indications

According to the manufacturer, "OraVerse, an alpha adrenergic blocker, is indicated for adult and pediatric patients ages 3 years and older for the reversal of soft-tissue anesthesia, ie, anesthesia of the lip and tongue, and the associated functional deficits resulting from an intraoral submucosal injection of a local anesthetic containing a vasoconstrictor."[1] Each 1.7-mL cartridge contains 0.4 mg of phentolamine. Like the local anesthetic preceding its administration, phentolamine is administered in a weight-based manner in a volume equal to the local anesthetic injected. For example, if a 20-kg (44-lb) child receives one-half cartridge of 4% articaine plus 1:100,000 epinephrine for 2 maxillary anterior infiltration injections, then at the completion of the restorative procedure, an equal volume of phentolamine (one-half cartridge, or a dose of 0.2 mg) is infiltrated into the same sites.

In pediatric patients weighing 15 kg (33 lb) to less than 30 kg (66 lb), the maximum recommended dose of OraVerse is one-half cartridge (0.2 mg). In those weighing at least 10 kg (22 lb) but less than 15 kg, the maximum dose recommended is one-quarter cartridge (0.1 mg). The maximum dose should not exceed 2 cartridges (0.8 mg).[1] OraVerse should not be used in children younger than 3 years of age.[1]

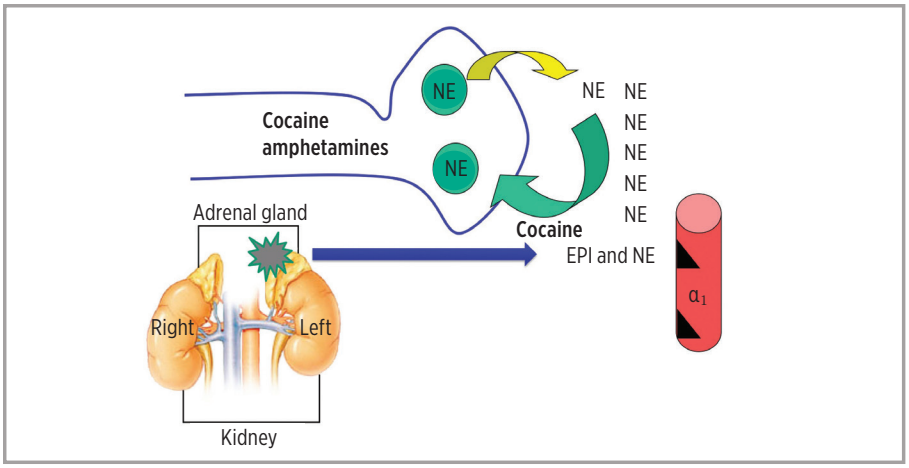


Fig 1. Drugs such as cocaine and amphetamines can cause excessive release of norepinephrine (NE) from nerve terminals (yellow arrow), causing overstimulation of vascular α_1-adrenergic (α_1) receptors (black triangles); the result is vasoconstriction and hypertension. Cocaine can also block norepinephrine reuptake (green arrow) into the nerve terminal, further increasing norepinephrine levels. A pheochromocytoma, represented by the star-like figure in the left adrenal medulla, leads to excessive epinephrine (EPI) and norepinephrine release (blue arrow), again leading to vasoconstriction and hypertension. Phentolamine blocks α_1-adrenergic receptors on blood vessels, reducing the vasoconstrictive effect of norepinephrine and epinephrine.

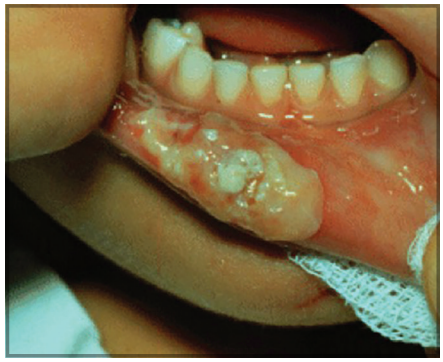


Fig 2. Lip mutilation in a young child following local anesthesia. (Courtesy of Dr Deborah Studen-Pavlovich, University of Pittsburgh, School of Dental Medicine, Pennsylvania.)

Non–epinephrine-containing solutions of 3% mepivacaine and 4% prilocaine can also induce prolonged lip and tongue numbness.[10,14] However, the efficacy and safety of phentolamine has not been studied when these local anesthetics are employed. Thus, phentolamine is not approved for use with these local anesthetics.

Drug misconceptions and pharmacokinetics

While the term *reversal agent* is also employed to discuss naloxone (Narcan, ADAPT Pharma), whose intranasal formulation has saved the lives of many people who have overdosed on heroin or prescription opioids, phentolamine should *never* be employed to treat a local anesthetic overdose.[15-17] Phentolamine is not reversing the direct effects of local anesthetics at the level of sodium channels; instead, it is "reversing" the vasoconstrictive effects of injected and possibly endogenous epinephrine.[2] Lidocaine is redistributed away from the injection site more quickly into the circulation, hastening the recovery of lip and tongue sensation and function.

Chart 1 illustrates blood levels of lidocaine when therapeutic doses of 2% lidocaine plus 1:100,000 epinephrine are administered. The subsequent administration of phentolamine slightly increases levels of lidocaine in the blood.[18] At therapeutic doses of lidocaine, these small and brief elevations in blood levels are clinically insignificant. Typically, blood levels of 5000 ng/mL of lidocaine are needed to produce symptoms of early local anesthetic toxicity (ie, confusion, tremors).[14] Even after the administration of 4 cartridges of lidocaine followed by 2 cartridges of phentolamine, peak blood levels of lidocaine are only 800 ng/mL.[18]

Nevertheless, if a clinician mistakenly employed phentolamine in an attempt to treat local anesthetic overdose symptoms—analogous to employing naloxone to reverse the unconsciousness and respiratory depression induced by an opioid overdose—the subsequent increases in blood levels of the local anesthetic agent would only worsen the situation. The authors are mentioning this issue because clinicians at continuing education venues have asked about the utility of employing phentolamine for treatment of local anesthetic overdose symptoms.

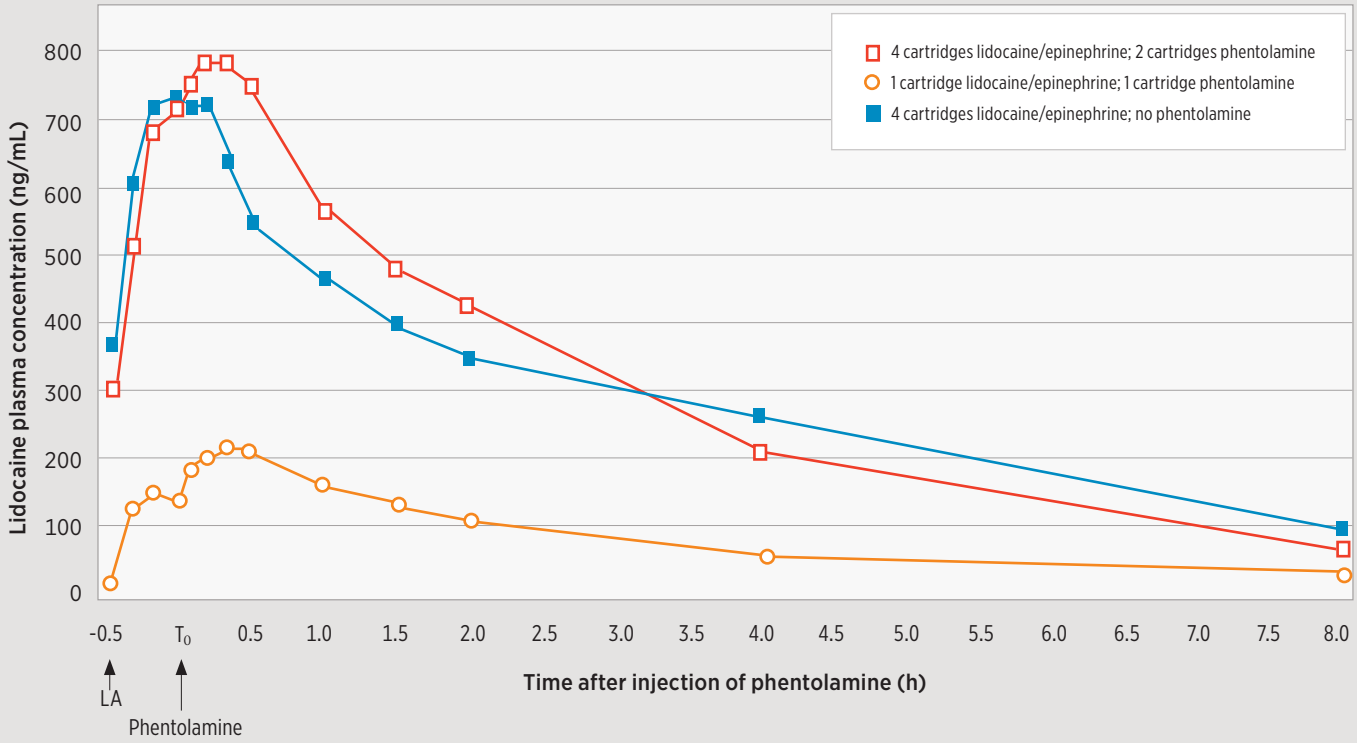
Clinical research

Phentolamine was initially approved for use in patients 6 years or older to accelerate soft tissue recovery from dental local anesthetics containing epinephrine. A series of multisite randomized controlled clinical trials demonstrated the efficacy and safety of the drug.[9,11,19]

The first study compared the action of phentolamine to a control vehicle in 122 patients aged 10-65 years who were receiving 1 or 2 cartridges of 2% lidocaine plus 1:100,000 epinephrine, 4% articaine plus 1:100,000 epinephrine, 4% prilocaine plus 1:200,000 epinephrine, or 2% mepivacaine plus 1:20,000 levonordefrin for restorative dentistry, single-crown, or periodontal maintenance procedures. An equal volume of phentolamine or the control vehicle was injected at the end of the procedure.[19] Patients who received phentolamine experienced a median acceleration in lip sensation recovery of 85 minutes (70 minutes for phentolamine and 155 minutes for control; $P < 0.0001$). Tongue sensation recovery also was accelerated by a median of 31.5 minutes in patients who had received mandibular block injections of local anesthetic followed by phentolamine ($P = 0.011$).[19] Both study treatments were well tolerated.

Subsequent studies employed a sham injection (in which the needle shield, still attached to the syringe, was pushed against the soft tissue injection site in research subjects who were wearing a

Chart 1. Lidocaine pharmacokinetics with or without phentolamine.[ab]



[a]Reprinted from Moore PA, Hersh EV, Papas AS, et al. Pharmacokinetics of lidocaine with epinephrine following local anesthesia reversal with phentolamine mesylate. *Anesth Prog.* 2008;55(2):40-48, with the permission of Allen Press.

[b]Plasma concentration–time curves for 2% lidocaine with 1:100,000 epinephrine (LA), which was administered in adults 30 minutes prior (–0.5 hours) to phentolamine administration (T_0).

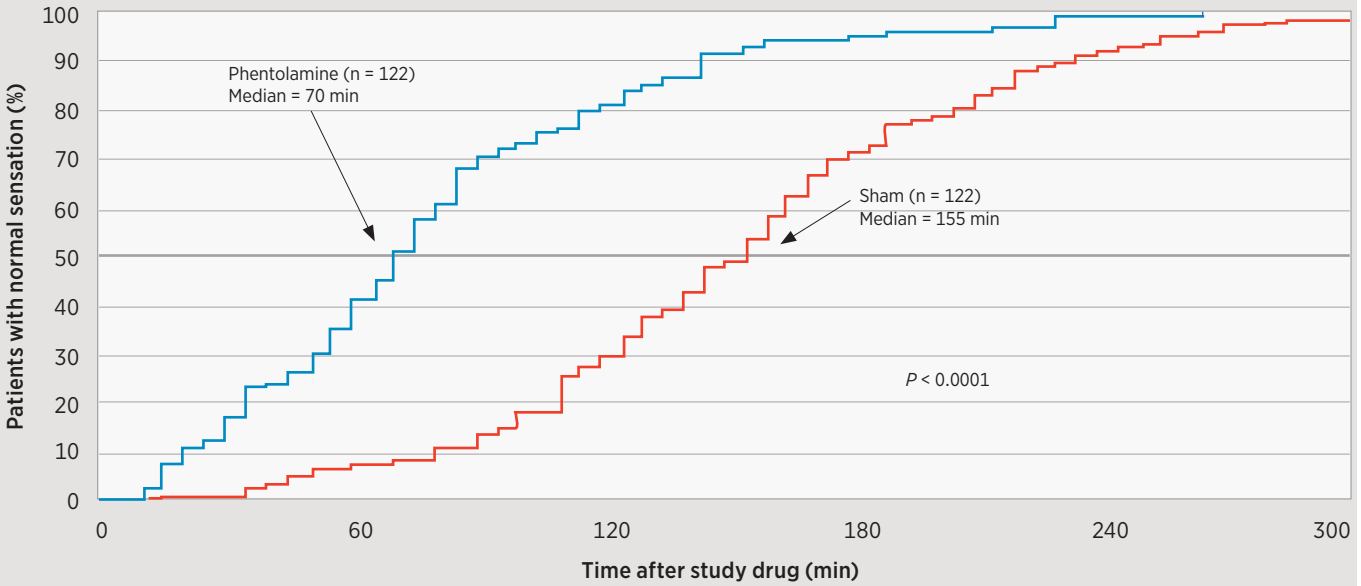
visual shield) as the control to phentolamine.[9,11] The personnel who were assessing lip and tongue sensation and safety endpoints remained unaware of the treatment allocation. One such study enrolled patients 12-92 years of age. The patients received 1 or 2 cartridges of the same 4 local anesthetics prior to the dental procedure and an equal volume of phentolamine at its completion.[9] Those who received phentolamine had a median acceleration to normal lower lip and tongue sensation of 85 minutes (54.8%) and 65 minutes (52.0%), respectively (Chart 2).[9] The median acceleration to normal sensation in the upper lip was 83 minutes (62.3%). All of these accelerations were statistically significant ($P < 0.0001$). This trial also demonstrated that oral function, the ability to smile and speak normally, and the ability to drink 3 oz of water without its dribbling out of the mouth returned significantly more rapidly in those patients who had received phentolamine ($P < 0.0001$ in both arches).[9]

From a safety perspective, the investigators and the FDA were interested in the effect of low submucosal doses of phentolamine on cardiovascular measures.[9] At much higher doses delivered intravenously, phentolamine induces a profound hypotensive effect and reflex tachycardia. The reflex tachycardia results when aortic and carotid baroreceptors (pressure sensors) detect hypotension subsequent to vasodilation and may also be triggered by the release of norepinephrine from neurons innervating the heart via phentolamine's blockade of neuronal α_2-adrenergic receptors.[2] The release of norepinephrine ultimately stimulates β_1-adrenergic receptors on the heart, leading to tachycardia.

In the dental study, at no point did systolic or diastolic blood pressure or heart rate in patients receiving phentolamine differ from those in patients receiving a sham injection.[9] Chart 3 illustrates the effects of both treatments on systolic blood pressure.[9] At 5 minutes and 10-20 minutes after phentolamine or sham, the research subjects were asked to stand in an attempt to elicit postural hypotension and reflex tachycardia, neither of which occurred.[9] Two postmarketing studies following the approval of phentolamine in Germany reported similar results with regard to efficacy and safety compared to sham injections.[20]

Because pediatric patients represent the patient population most likely to mutilate their lips and tongues after prolonged numbness to these structures, a study was carried out in 4- to 11-year-old children (n = 162) undergoing restorative procedures.[11] Only children 6 years of age and older were trained to evaluate efficacy. One-half to 1 cartridge of 2% lidocaine plus 1:100,000 epinephrine was employed for local anesthesia followed by an equal volume of phentolamine at the end of the

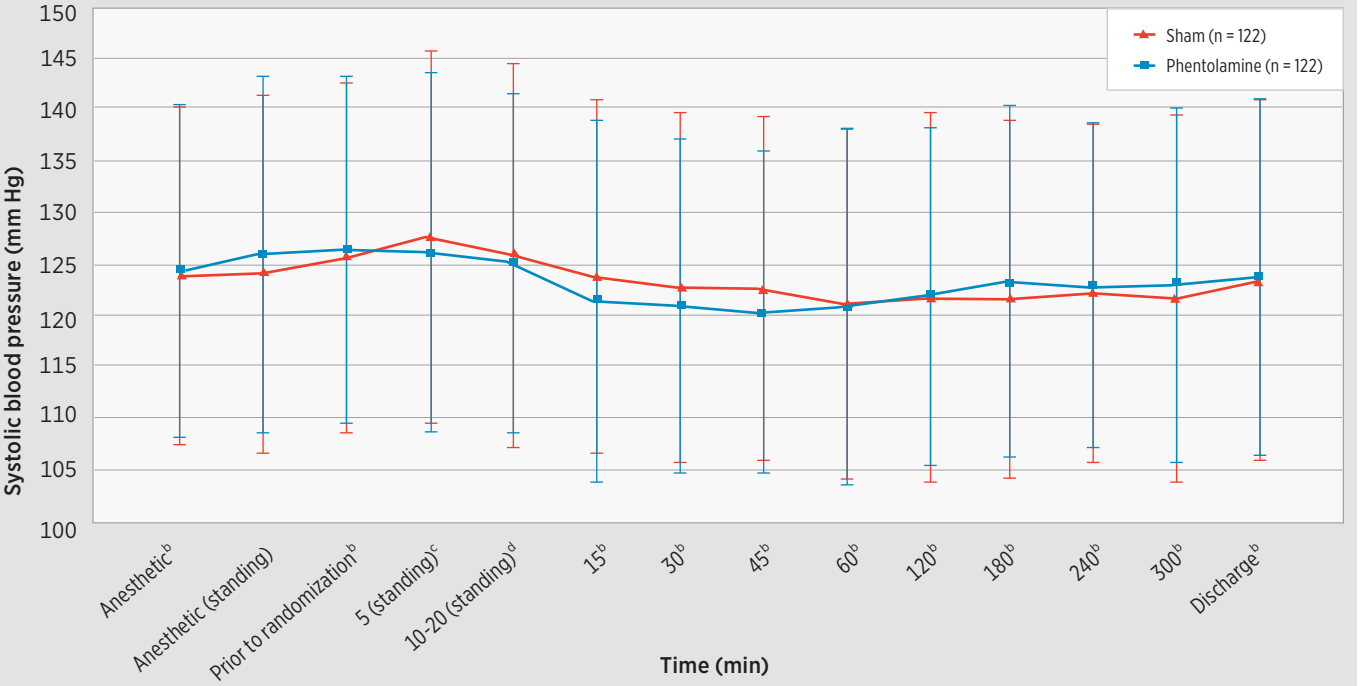
Chart 2. Median time to return of normal lip sensation in the mandibular arch.[ab]



[a]Reprinted from Hersh EV, Moore PA, Papas AS. Reversal of soft-tissue local anesthesia with phentolamine mesylate in adolescents and adults. *J Am Dent Assoc*. 2008;139(8):1080-1093. Copyright © 2008 American Dental Association. All rights reserved. Reprinted by permission.

[b]Return to normal as assessed by adult and adolescent subjects. Recovery curves for phentolamine mesylate and sham groups are shown in Kaplan-Meier time-to-event plots.

Chart 3. Systolic blood pressure in patients who received phentolamine or sham in the mandible.[a]



[a]Reprinted from Hersh EV, Moore PA, Papas AS. Reversal of soft-tissue local anesthesia with phentolamine mesylate in adolescents and adults. *J Am Dent Assoc*. 2008;139(8):1080-1093. Copyright © 2008 American Dental Association. All rights reserved. Reprinted by permission.

[b]Supine or sitting.

[c]Standing value within 5 minutes of study drug administration.

[d]Standing value between 10 and 20 minutes of study drug administration.

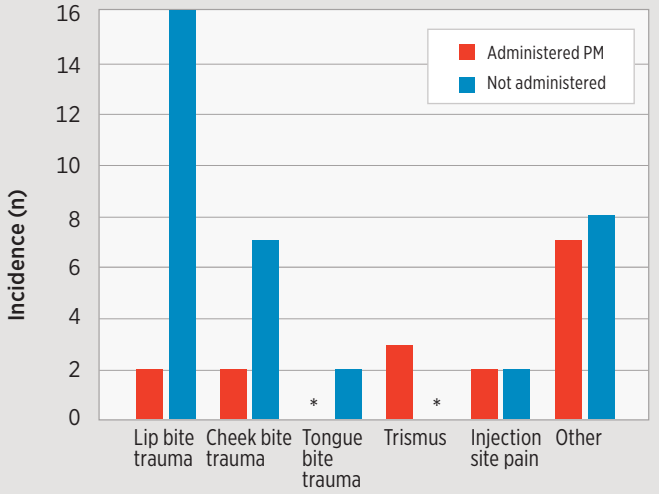
Table. Incidence of cardiovascular changes in 2- to 5-year-old patients receiving phentolamine or sham injection.[a]

	Phentolamine		Sham	
Changes	No.	%	No.	%
Total patients	99	100.0	51	100.0
SBP decreased > 20 mm Hg	12	12.1	3	5.9
DBP decreased > 20 mm Hg	7	7.1	1	2.0
HR increased > 20 bpm	10	10.1	3	5.9

Abbreviations: bpm, beats per minute; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

[a]Adapted from Hersh EV, Lindemeyer R, Berg JH, et al. Phase four, randomized, double-blinded, controlled trial of phentolamine mesylate in two- to five-year-old dental patients. *Pediatr Dent*. 2017;39(1):39-45. Copyright ©2017 American Academy of Pediatric Dentistry and reproduced with their permission.

Chart 4. Incidence of local anesthetic complications in children who did or did not receive PM.[a]



Abbreviation: PM, phentolamine mesylate.

[a]Reprinted from Boynes SG, Riley AE, Milbee S, Bastin MR, Price ME, Ladson A. Evaluating complications of local anesthesia administration and reversal with phentolamine mesylate in a portable pediatric dental clinic. *Gen Dent*. 2013;61(5):70-76, with permission from Academy of General Dentistry.

* = 0.

procedure. As in previously described studies, the pediatric subjects in the phentolamine group reported accelerated median times to recovery of normal lip sensation in both arches: 60 minutes for those who received phentolamine and 135 minutes for those who received the sham injection ($P < 0.0001$). This represented a 75-minute (55.6%) acceleration in recovery time for phentolamine over sham. In subjects who had received mandibular block injections, a 67.5-minute (60%) reduction in median time to recovery of normal tongue sensation occurred in the phentolamine-treated subjects compared to the time in the group treated with a sham injection ($P = 0.0003$). Vital signs remained similar in both the phentolamine and sham groups.[11]

Before FDA approval of OraVerse for patients as young as 6 years old, the manufacturer agreed to study the drug in an even younger patient population, as the FDA was concerned about clinicians employing the drug off-label in young patients despite limited safety data. In addition, children aged 2-5 years are the population most vulnerable to biting and traumatizing the lip and tongue due to residual soft tissue anesthesia.[13] In the resulting study, 150 subjects aged 2-5 years were enrolled, although only 4 subjects were 2 years old.[21] All received one-quarter to 1 cartridge of lidocaine plus 1:100,000 epinephrine for single restorative procedures, including stainless steel crowns, followed by an equal amount of phentolamine or a sham injection at the end of the procedure in a 2:1 randomization scheme. Patients who were 4 or 5 years old (n = 98) were trained to evaluate lip and tongue numbness, while 2- and 3-year-old participants were only evaluated for safety. The duration of lip anesthesia was reduced by a median of 48 minutes (44%) in the phentolamine group compared to the duration in the sham group ($P < 0.0001$). Tongue anesthesia was reduced by 31 minutes in the phentolamine group, but the difference from the result in the sham group was not statistically significant, possibly because of the small number of participants receiving mandibular block injections (n = 53).

The results of the same study revealed that cardiovascular changes after the phentolamine or sham injections did not significantly differ between groups, and there were no obvious instances of symptomatic hypotension or reflex tachycardia.[21] However, because these children were closely monitored with blood pressure cuffs and pulse oximeters, phentolamine demonstrated an ability to lower blood pressure and increase heart rate in some children (Table).[21] The safety and efficacy data generated in this study were instrumental in the FDA's decision to reduce the minimum age for approved use to 3 years in 2016.

A pediatric holy grail study

Two studies clearly show that phentolamine substantially accelerates recovery from residual lip and tongue numbness in pediatric patients.[11,21] Nevertheless, the ideal research would be a double-blind study of phentolamine versus sham in the pediatric population to see if lip and tongue mutilation were also reduced. A large study would be needed to achieve the required statistical power.

A large case series provides some evidence that phentolamine reduces these types of events.[22] Children with a mean age of 8 years were treated on a mobile dental van and either did or did

not receive phentolamine based on the dental procedures they were undergoing. Patients who did not receive phentolamine (n = 581) included patients undergoing invasive procedures such as extractions and pulpotomies, because the acceleration of local anesthetic dissipation would also increase the likelihood and/or accelerate the onset of postprocedural pain. In addition, patients younger than 6 years did not receive phentolamine, because the drug was not yet approved for younger patients. The patients who received phentolamine at the completion of the procedure (n = 342) included patients 6 years or older undergoing less invasive procedures, including restorative dentistry and placement of stainless steel crowns. A 24-hour follow-up was conducted to record any signs of tissue mutilation. The results revealed a trend for less lip bite trauma in the children who received phentolamine compared to those who did not (Chart 4).[22]

An unblinded study of 43 children aged 4-11 years who had received 2% lidocaine plus 1:80,000 epinephrine for local anesthesia reported that only 1 child who received phentolamine showed signs of lip trauma after the dental procedure, while 8 did not ($P = 0.039$).[23]

Both the larger case series and the unblinded study are subject to research bias, because evaluators knew which children received phentolamine and which did not.[22,23] Future research that employs randomized double-blind methodology is needed to substantiate the results of both these studies.

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ESTHETICS

Minimally invasive correction of a darkened anterior tooth

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The darkened anterior tooth is a common esthetic problem in general practice. Popular treatments include placement of crowns and opaque porcelain veneer, but they have some inherent disadvantages with regard to tooth conservation and the final esthetic appearance. Fortunately, new technology offers new methods for solving dental problems. The latest innovation in composite resin allows a minimally invasive approach to correct this anterior esthetic problem.

The problem of the darkened tooth

Discoloration of anterior teeth is an esthetic concern that arises for a variety of reasons.[1,2] It can result from extrinsic or intrinsic factors. Extrinsic stains create superficial discoloration along the clinical crown and may be due to ingestion of profoundly pigmented foods and beverages, poor oral hygiene, and/or dental plaque accumulation. Intrinsic staining of the dentition can be caused by a variety of factors, including congenital abnormalities (eg, ochronosis, phenylketonuria, dentinogenesis imperfecta, and amelogenesis imperfecta), pulpal trauma, and drug-induced staining (eg, tetracycline, minocycline, and sulfur drugs), that can cause irreversible pigmentation in the dentition.[1]

The proper approach to cosmetic dental treatment depends on the severity of the color problem. Porcelain-fused-to-gold crowns and lithium disilicate porcelain crowns are popular modes of treatment. However, the necessary 1.5-mm axial reduction of tooth structure is aggressive for cosmetic-related corrections. Porcelain veneers also have been effective in correcting this esthetic problem, because bonding procedures require less reduction of tooth structure than do crowns. Now, with recent technological advances in composite resins, clinicians are able to treat this problem with minimal tooth removal while achieving optimal esthetic results.

To attain natural-appearing esthetics via conservative approaches, it is important for the dentist to be aware of technological advances in material science. This column describes minimally invasive treatment of an intrinsically darkened anterior tooth using a composite resin veneer technique.

Case report

A 34-year-old man had a highly discolored maxillary right central incisor due to a traumatic episode (Fig 1). Despite having darkened by more than 4 shades, the tooth tested as vital.

The patient's central incisor appeared shorter than the adjacent tooth because of excess gingival tissue, which was determined to be an altered passive eruption issue. Therefore, a simple gingivectomy was performed with a diode laser before tooth preparation (Fig 2).[3,4]

Tooth preparation

In treating the darkened anterior tooth conservatively, the clinician first performed a uniform 0.7-mm preparation along the facial, proximal, and incisal areas. For a tooth with a 4-shade shift, a 0.7-mm thickness is the minimum depth needed.[5] After initially preparing the tooth for a composite resin veneer, the clinician must further assess the severity of the discoloration. If the internal tooth color is severely darkened, an additional 0.3-mm preparation is needed along the facial axial surface to create additional space for internal masking directly on the teeth.[5] This internal masking creates a natural lightening so that opaquers are not needed.

Placement of nanohybrid composite resin

During the bonding process, the tooth surface was cleaned with a microetcher (MicroEtcher II, Zest Dental Solutions) to remove all dental pellicle. The tooth was then isolated with a metal strip, and an all-in-one adhesive resin (G-Premio BOND, GC America) was placed for 10 seconds and then air thinned for 10 seconds. Finally, the adhesive was light cured for 10 seconds (Fig 3).

To consistently and predictably restore a tooth with a composite resin veneer, clinicians must develop and methodically apply a technical layering sequence.[6] Proper refraction, reflection, and absorption of light are important to achieving natural visual value. Opaquers do not allow natural light to penetrate the underlying tooth structure, and the result is a harsh, deadened, and unnatural appearance. Nanohybrid opaque dentin composite resins are more effective in

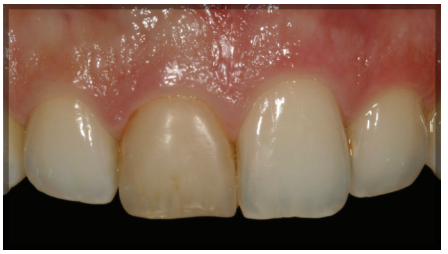

Fig 1. A 34-year-old man has a highly discolored right central incisor due to a traumatic episode. In addition, his central incisor appears shorter than the adjacent incisor owing to excess gingival tissue.

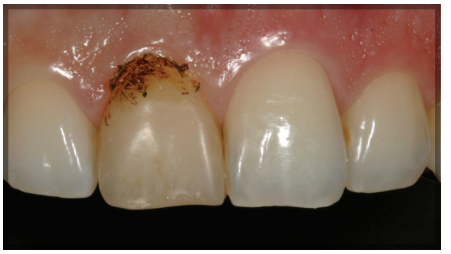

Fig 2. A simple gingivectomy has been performed with a diode laser before tooth preparation.

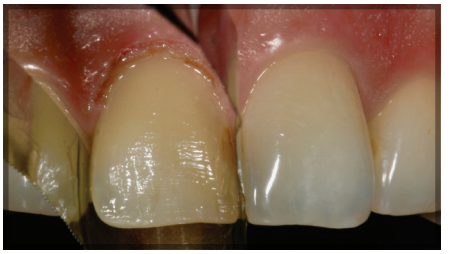

Fig 3. The tooth has been isolated, and an all-in-one adhesive has been placed and cured prior to placement of the composite resin veneer.

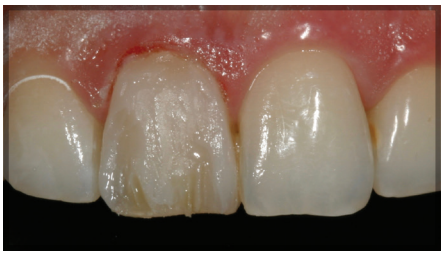

Fig 4. An opaque dentin shade has been sculpted along the facial axial surface to mask the dark internal shade of the anterior tooth.

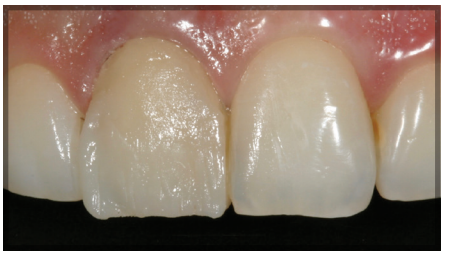

Fig 5. A B1 body shade has been sculpted and light cured to accent the brighter line angles and incisal halo to match the adjacent central incisor.

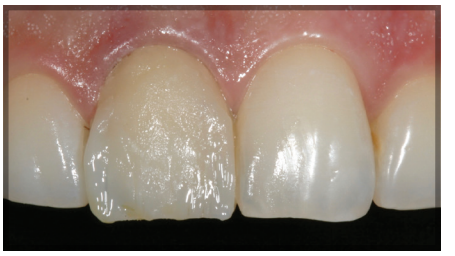

Fig 6. Subtle color tints have been placed to match the characterization of the adjacent central incisor.

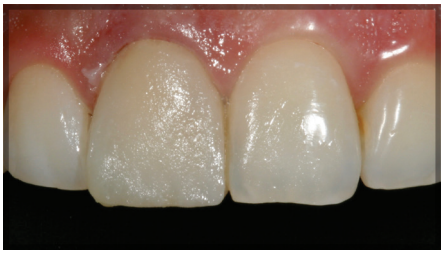

Fig 7. A freehand sculpting technique has been used to place a translucent shade of composite resin as the final layer.

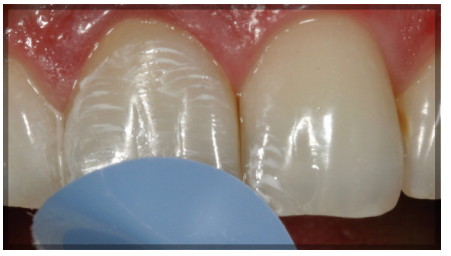

Fig 8. After the composite resin veneer has been finished and polished, a microdiamond polishing paste is used for a final polish.

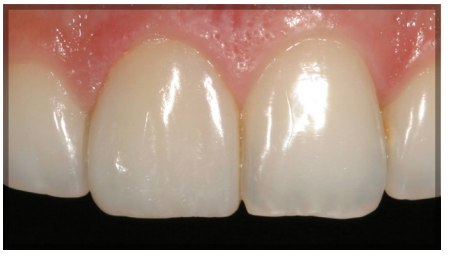

Fig 9. The darkened anterior tooth can be successfully treated using a creative approach with a minimally invasive composite resin veneer.

creating a natural appearance, yet they have a good depth of shade.

An opaque dentin shade (G-aenial Sculpt AO2, GC America) was used to sculpt along the facial axial surface to camouflage the dark internal shade of the anterior tooth (Fig 4). Using a thin layer of composite resin, the dentist was able to mask the darkened tooth.

Because nanohybrid composite resins create an excellent depth of shade, natural color blending is easy to achieve. The composite resin was placed in layers to blend with the existing tooth, creating a polychromatic effect. First, a B1 body shade was sculpted and light cured to accent the brighter line angles and incisal halo (Fig 5). Next, an A2 shade was placed along the gingival one-third. An A1 body shade was sculpted along the incisal two-thirds to mimic the shade of the adjacent central incisor. Creating internal effects is important in achieving a natural optical appearance.

Subtle characterizations were added with color tints (Kolor + Plus, Kerr Corporation) (Fig 6). Application of these tints can be important to mimic natural tooth characteristics.[7,8] Finally, with the use of a freehand technique, a translucent shade (G-aenial Sculpt WT) was sculpted over the facial surface and light cured (Sapphire Plus Curing Light, DenMat) (Fig 7).

Finishing and polishing

After curing, the final layer was sculpted with a medium-grit diamond chamfer bur (No. 850FG-016, Komet USA) to create the primary and secondary external anatomy. Esthetic refinement was then achieved with anatomical finishing burs (H50A-FG-010, Komet USA), Q-Finisher (H50AQ and H274QFG-018, Komet USA) composite resin finishing burs,

and finishing discs (Sof-Lex, 3M ESPE). Initial polishing was done with microdiamond-infused polishing wheels (Footsie 94028M.RA.130 and 94028F.RA.130, Komet USA). Interproximal contours were then refined with composite finishing strips (EPITEX, GC America). Finally, a microdiamond polishing paste (Diamond Polishing Paste, Ultradent Products) was used to create a mirror-like polished surface (Fig 8). The composite resin veneer successfully masked the darkened tooth and restored symmetry to the anterior dentition (Fig 9).

Conclusion

Discolored anterior teeth continue to cause esthetic problems for patients. Although many treatments are available, some involve moderate-to-aggressive tooth removal. Technological advances in materials and techniques provide enhanced solutions that allow minimally invasive treatment. Using a creative approach to dentistry, clinicians are able to provide patients with a new level of treatment excellence.

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Disclaimer

The author reports no conflicts of interest pertaining to any of the products or companies discussed in this column.

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Factor V Leiden thrombophilia: dental considerations

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Factor V Leiden thrombophilia, a relatively common inherited type of hypercoagulability resulting from a mutation in the gene for factor V, has received minimal attention in the dental literature. This review examines related demographic information, risk factors, comorbidities, the thrombotic mechanism, clinical features, diagnostic measures, and medical management strategies. In addition, oral and maxillofacial sequelae and management guidelines are provided. If a patient is known to have the mutation, the clinician should review the patient's potential risk factors for development of thrombosis and ascertain whether any coagulation agents are currently being administered. The practitioner should be prepared to manage instances of prolonged bleeding. The dentist also should be aware of an overall increased risk of systemic thromboembolic events, particularly following head and neck trauma. Rarely, the factor V Leiden mutation has been associated with osteonecrosis of the jaw, usually concurrent with intake of sex hormones.

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Factor V Leiden (FVL) thrombophilia is a relatively common autosomal dominant disorder of hypercoagulability.[1] A point mutation in the putative gene for the factor V peptide poses an increased risk for venous thromboembolism (VTE), notably among individuals with homozygous mutation, and manifests as deep vein thrombosis of the lower extremities, pulmonary embolism, ischemic stroke, and myocardial infarction.[2,3] Factor V is a participant in the extrinsic coagulation cascade, initiating the conversion of prothrombin to thrombin and ultimately culminating in the formation of a fibrin clot.

Affected patients may be managed with the administration of prophylactic thrombolytics, increased pregnancy surveillance, avoidance of certain medications, lifestyle modifications, and genetic counseling. FVL thrombophilia has been reported extensively in medical publications, yet only a few articles have appeared in the dental literature.[4-6] The objective of this review is to increase awareness of this potentially serious coagulopathy and provide clinical management guidelines for dental healthcare practitioners.

Demographics and risk factors

The overall prevalence of heterozygous FVL mutation has been reported as 3%-8% in subpopulations of the United States, with ethnic diversities ranging from 5.2% of whites to 2.2% of Hispanic Americans, 1.25% of Native Americans, 1.2% of African Americans, and 0.45% of Asian Americans; conversely, homozygosity is considerably rarer, affecting only 0.05% of whites.[1] There is a 1.3 female predilection in heterozygotes and a 1.2 female predilection in homozygotes.[7] When men and women are segregated by age, there is a 1.3 female predilection among patients younger than 40 years and a 1.7 male predilection among patients 40 years and older.[2]

Among patients with VTE, 20%-25% have been identified as having the FVL mutation.[1] Individuals with a heterozygous mutation have a 7-fold increased risk for VTE.[7] The mortality rate in heterozygous carriers has varied in studied subpopulations, ranging from no apparent increased risk to a 6.1% (5 of 82) increased risk among autopsied patients with pulmonary thromboemboli.[8-10] In contrast, homozygotes have demonstrated an 80-fold greater risk for thrombotic events, which tend to occur at a younger age.[7]

Various predisposing factors exacerbate the risk for VTE synchronous with FVL, especially pregnancy and recurrent early pregnancy loss, as well as surgical procedures (cardiac, orthopedic), active cancer, medication intake (estrogen contraceptives, selective estrogen receptor modulators, and hormone replacement therapy), diabetes, obesity, other concurrent VTE-related disorders, recent long-distance travel, and prolonged immobility.[1,11-22] Patients with the mutation who have had 1 or more unprovoked thrombotic episodes without any other defined risk factors are also at a higher risk than those with provoked VTEs.[23]

Thrombotic mechanism

Factor V is a participatory coagulation factor in the chain of events that leads to thrombin formation. In health, this thrombotic activity is otherwise downregulated by protein C and protein S. However, this pathway can be disrupted following a single point mutation in the factor V gene, typically arising from a guanine to adenine substitution at nucleotide 1691, followed by substitution of glutamine for arginine at the amino acid site 506.[1] This alternative amino acid is resistant to the proteolytic effects of activated protein C.[24] Thus, the loss of this autoregulatory mechanism increases the propensity for development of venous thrombi.

Clinical features of VTE

The clinical manifestations of VTE appear comparable in patients with the FVL mutation and patients with non-FVL etiologies. VTE may occur in various sites, preferentially in the deep veins of the lower extremities and pulmonary arteries and less commonly in the upper extremities and the cerebral, retinal, portal, mesenteric, ovarian, renal, splanchnic, or testicular veins.[25] Deep vein thrombosis may be associated with a painfully engorged leg, and pulmonary emboli may promote chest pain, palpitations, and dyspnea.[26]

Another important aspect of the FVL mutation is that it may confer an increased risk for recurrent VTEs. A meta-analysis determined a 1.45 relative risk for secondary thrombotic events in patients with heterozygous mutation.[27] Interestingly, another investigation found that the prevalence rates of recurrent VTEs are comparable in patients who are heterozygous for FVL and those who are homozygous for FVL.[28] Thrombophilia, including the FVL mutation, has been implicated as a promoter of osteonecrosis, with involvement of the femoral head, the knee, or multiple sites, and this risk may be compounded by the administration of sex hormones.[29-32]

Diagnosis of FVL

Because carriers of the FVL mutation do not display any definable clinical phenotype, a diagnosis is usually sought incident to the first VTE or on genetic screening of affected family members. The initial VTE in affected patients has been reported in all age brackets, including neonates.[33] In a cohort of patients with FVL, 73% (267 of 368) had experienced their first VTE by the age of 50 years.[2] Diagnosis of the mutation is rendered with a modified activated protein C resistance functional assay and the direct DNA-based polymerase chain reaction amplification method.[34]

Laboratory studies for the FVL mutation are recommended consequent to an initial or idiopathic VTE at any age but expressly in patients younger than 50 years; those with a history of recurrent VTEs; those with a VTE in an uncommon vascular site (cerebral, mesenteric, hepatic, or portal); those with pregnancy- and puerperium-related VTE or VTE concurrent with intake of an estrogen contraceptive or a hormone replacement; those who are a first-degree relative of an individual who had an initial VTE before the age of 50 years; and female smokers who had a myocardial infarction before the age of 50 years.[35]

Any unprovoked VTE warrants medical management and determination of underlying etiologies, as this event may serve as a harbinger of occult malignancy.[14] Specifically, a meta-analysis involving 2316 affected patients found a 5.2% prevalence rate of new cancers within 1 year of a diagnosis of a VTE.[36] However, routine screening for the FVL mutation in adults with a history of idiopathic VTE and their asymptomatic adult family members has not been advocated.[37]

Medical management of VTE

Patients with suspected VTE initially undergo a physical examination for determination of a Wells score (risk stratification of a thrombotic event). If indicated, they then undergo diagnostic imaging involving either compression Doppler ultrasonography for deep vein thrombosis or computed tomography pulmonary angiography for pulmonary embolism, as well as serum measurement for D-dimer fibrinolytic bioactivity.[38,39] Once a VTE has been diagnosed, low-weight heparin is usually administered for at least 5 days or until achievement of an international normalized ratio (INR) between 2.0 and 3.0 with a vitamin K antagonist.[40] Subsequently, use of warfarin or other newer-generation direct oral anticoagulants, such as dabigatran, rivaroxaban, apixaban, or edoxaban, is advocated for at least 3 months after thrombosis.[41]

In general, long-term prophylactic anticoagulation therapy for prevention of VTEs in asymptomatic individuals who are heterozygous for FVL has not been advocated, as the risk of excessive bleeding outweighs any perceived benefits.[1] A subset of patients who have had a VTE coincident with identified risk factors may continue to be treated with anticoagulants beyond 3 months.[41]

Oral and maxillofacial considerations

Sequelae associated with FVL

Adverse sequelae following dental procedures in patients with the FVL mutation are few. Sharma documented a case of a 45-year-old woman with the FVL mutation who developed an upper-extremity deep vein thrombosis that was attributed to excessive gripping of the dental chair while she underwent endodontic therapy.[42] Albeit rare, minimal injuries to the head and neck have led to VTE in individuals with the FVL mutation. Gumussoy et al noted the occurrence of internal jugular vein thrombosis following minor neck trauma of nondental origin in a 44-year-old with a history of FVL and methylene tetrahydrofolate reductase 1298C mutations.[43] Kieslich et al reported a series of 8 children who developed cerebral infarctions after minor head trauma.[44] One of the children had the mutation for FVL; at an 8-month follow-up, the patient continued to have moderate residual hemiparesis.

Various thrombophilic disorders, including the FVL mutation, have been associated with neuralgia-inducing cavitational osteonecrosis of the jaw.[4] There also have been several reports of biopsy-proven thrombotic osteonecrosis of the jaw coincident with FVL and intake of sex hormones. Glueck et al documented the case of a 32-year-old woman with FVL who developed severely painful osteonecrosis following extraction of a mandibular molar while receiving estrogen replacement therapy after a partial oophorectomy.[45] Pandit & Glueck reported maxillary and mandibular osteonecrosis, without any recent oral procedures, in a 55-year-old man who was heterozygous for the FVL mutation in conjunction with testosterone and anastrozole administration.[46] One other suspected case of osteonecrosis

involving both jaws occurred in a 32-year-old man who was heterozygous for the FVL mutation and receiving testosterone therapy; over an 8-month period, he had accelerated tooth loss that was confirmed on computed tomography as osseous loss with cavitation.[32]

Management guidelines

The first measure to be undertaken for a patient with FVL is to determine whether there is an ongoing risk of hypercoagulability or bleeding. Presurgical dental assessment of patients with the FVL mutation should include establishing the chronology and severity of VTEs (including the most recent episode) and reviewing coexistent risk factors for thrombosis (homozygosity, pregnancy, surgical outcomes, ongoing neoplasia therapy, current medications, diabetes, obesity, other thrombotic disorders, recent long-distance travel, and ongoing immobilization).

Additionally, the dentist should inquire whether any antithrombotic medications are being administered. For patients receiving warfarin treatment, an INR is warranted within 24 hours prior to surgical procedures; if the INR is greater than 3.5, surgical procedures should be deferred.[47] Preoperative interruption of warfarin or other anticoagulants for simple dental procedures is generally not advocated because of the increased risks of thrombophilia and a recurrence of the underlying disorder that prompted its use.[48,49]

Also relevant is ascertaining whether a patient has ever experienced a hemorrhagic event concomitant with an oral and maxillofacial surgical procedure as well as defining protocols that were followed to control bleeding. When oral procedures are performed in patients receiving antithrombotic treatment, hemostasis should be managed with hemostatic agents, pressure hemostasis, and efforts to achieve primary wound closure. Postoperatively, nonsteroidal anti-inflammatory agents and cyclooxygenase 2 inhibitors should not be prescribed for patients receiving anticoagulant treatment. Furthermore, patients should be given wound care instructions to minimize trauma to the healing mucosa (following a soft diet and resuming normal oral hygiene 24 hours after surgery) and provisions to manage any bleeding episodes (gentle biting on a gauze pad over the surgical site and changing the pad every 30 minutes until bleeding has stopped). Consultation with the attending physician (hematologist, vascular surgeon, or pulmonologist) is advised when perioperative anticoagulant withdrawal is contemplated.

Conclusion

To the best of the authors' knowledge, there are no published accounts of hypercoagulation events directly attributed to dental procedures or excessive bleeding in conjunction with oral and maxillofacial surgery in patients with the FVL mutation. Nevertheless, clinicians should ascertain if patients have risk factors and be prepared to manage hemodynamic consequences. Dentists should be aware of an increased likelihood of systemic thromboembolic events in patients with FVL thrombophilia and maintain particular vigilance subsequent to trauma to the head and neck. Additionally, isolated instances of osteonecrosis of the jaw have been reported in patients with the FVL mutation in association with sex hormone use; patients should be advised of the risk prior to oral and maxillofacial surgical procedures.

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Exercise No. 438

Special Patient Care

Subject Code: 750

The 15 questions for this exercise are based on the article "Factor V Leiden thrombophilia: dental considerations" on pages 21-24. This exercise was developed by Riki Gottlieb, DMD, MS, FAGD, in association with the *General Dentistry* Self-Instruction committee.

Reading the article and answering the questions will enable the participant to:

- increase awareness of factor V Leiden (FVL) disorder and its etiology;
- recognize risk factors for venous thromboembolism (VTE); and
- examine medical management strategies for patients with the FVL mutation undergoing oral surgery.

Answers can be submitted online at *agd.org/self-instruction.*

Answers for this exercise must be received by April 30, 2020.

1

FVL thrombophilia is a relatively common _____ disorder of hypercoagulability.

A. autosomal dominant
B. allosomal dominant
C. autosomal recessive
D. allosomal recessive

2

In FVL disorder, a mutation in the factor V protein may cause all of the following except one. Which is the exception?

A. pulmonary embolism
B. ischemic stroke
C. myocardial infarction
D. intracerebral hemorrhage

3

Factor V leads to the formation of _____.

A. methylcellulose
B. fibrin
C. platelets
D. vitamin K

4

The FVL mutation was identified in ___% to ___% of patients with VTE.

A. 10; 15
B. 20; 25
C. 30; 35
D. 40; 45

5

The FVL mutation involves the replacement of _____ with _____ at nucleotide 1691 in the factor V gene.

A. cytosine; guanine
B. thymine; cytosine
C. adenine; thymine
D. guanine; adenine

6

The FVL mutation involves the change from _____ to _____ at amino acid site 506.

A. alanine; tryptophan
B. leucine; serine
C. arginine; glutamine
D. proline; histidine

7

The alternative amino acid associated with FVL is resistant to the proteolytic effects of activated protein C. The loss of the autoregulatory mechanism associated with activated protein C decreases the propensity for the development of venous thrombi.

A. Both statements are true.
B. The first statement is true; the second is false.
C. The first statement is false; the second is true.
D. Both statements are false.

8

VTE is less likely to occur in all of the following veins except one. Which is the exception?

A. cerebral
B. portal
C. femoral
D. mesenteric

9

In a cohort of patients with FVL, ___% had experienced their first VTE by the age of 50 years.

A. 73
B. 76
C. 79
D. 82

10

A _____ score determines the risk of a thrombotic event in patients with suspected VTE.

A. Baux
B. Krenning
C. Mallampati
D. Wells

11

VTE is usually treated with direct oral anticoagulants for at least ___ months after thrombosis.

A. 3
B. 4
C. 5
D. 6

12

Rarely, minimal injuries to the head and neck have led to VTE in individuals with the FVL mutation. The FVL mutation has been associated with neuralgia-inducing cavitational osteonecrosis of the jaw.

A. Both statements are true.
B. The first statement is true; the second is false.
C. The first statement is false; the second is true.
D. Both statements are false.

13

In patients with the FVL mutation who receive warfarin treatment, the international normalized ratio (INR) should be obtained within ____ hours prior to dental surgical procedures.

A. 60
B. 48
C. 36
D. 24

14

In patients with the FVL mutation who receive warfarin treatment, dental surgical procedures should be deferred when the INR is greater than _____.

A. 2.0
B. 2.5
C. 3.0
D. 3.5

15

Patients younger than ___ years who had an initial or idiopathic VTE should undergo laboratory studies relevant to FVL.

A. 65
B. 60
C. 55
D. 50

Buccal injection of articaine to anesthetize the palatal mucosa

Mohamad Abu Sharkh, BMSc ■ Andrew Khalil, BMSc ■ Cathy Ong-Ly, BSc ■ Timothy Wilson, PhD
Khadry Galil, DDS, PhD

Buccal and palatal injections are required for administration of anesthetic agents before maxillary tooth extractions, but palatal injections are painful for patients. Studies suggest that the palatal injection can be eliminated when articaine is delivered as a local anesthetic agent via buccal injection, but the anatomical mechanism for this effectiveness remains unclear. The objective of this study was to explore the potential mechanism by which buccal infiltration results in palatal anesthesia. The study approach included examining cadaveric specimens and investigating the pharmacologic properties of articaine. Twenty-eight formalin-fixed cadaveric hemimaxillae were dissected and sectioned into anterior, premolar, and molar regions. The maxillary sections were measured in 3 planes: inferior, middle, and superior. Buccal cortical plate (BCP), palatal cortical plate (PCP), and total buccopalatal (TBP) thickness were independently evaluated by 2 measurers using standard digital calipers. Statistical analysis of regional maxillary thickness measurements was achieved via 2-way analysis of variance. Measurements of BCP and PCP thickness revealed no statistically significant differences along the maxillae ($P > 0.05$). Both the BCP and PCP mean values were significantly less than the TBP measurement ($P < 0.0001$). In all 3 regions, the mean TBP thickness in the superior plane was significantly greater than that of the inferior plane ($P < 0.05$). The mean TBP thickness was significantly greater in the molar and premolar regions than in the anterior region ($P < 0.05$). The mean BCP measurements were significantly lesser in the maxillary premolar and molar regions than in the corresponding mandibular regions ($P < 0.0001$). The pharmacologic properties of articaine, which is capable of diffusing greater distances than other local anesthetics, coupled with the uniformly thin, cancellous maxillary bone, provide a plausible explanation for the success of palatal anesthesia achieved through buccal infiltration of articaine, obviating the need for a palatal injection.

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Key words: anatomy, anesthesia, local anesthesia

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Exercise No. 439, p. 31
Subject code: Anesthesia and Pain Management (340)

Application of anesthetic agents to the roof of the mouth, or palatal injection, is a routine procedure for maxillary tooth extractions. This type of injection has proven to be a painful experience for many dental patients and is one of the reasons fearful patients avoid dental care.[1,2] Multiple clinical trials have demonstrated that this discomforting experience can be avoided by eliminating the palatal injection.[2-5] Most of these clinical trials were performed using articaine as a local anesthetic and found that maxillary buccal injections are sufficient to anesthetize the palate.[1,4,6]

Articaine is a relatively new anesthetic; introduced to the United States in 2000, articaine had become the second most popular anesthetic in the US market by 2011.[7] Articaine contains an amide and is structurally similar to lidocaine, the gold standard for local anesthetics. Unlike lidocaine, it contains a thiophene instead of a benzene ring. The difference in chemical structure renders articaine more lipid soluble and 1.5 times more potent, as a greater portion of an administered dose can enter the neurons. Articaine also diffuses through soft and hard tissues more reliably than other local anesthetics.[8]

For buccal infiltration to achieve successful palatal anesthesia, articaine must diffuse through the buccal cortical bone of the maxilla, into the cancellous structure of the bone, and past the palatal cortical bone. This seems to be a plausible route for the anesthetic to reach the target tissues, as Fan et al found that the cortical bone in the maxilla is more porous, which could provide a pathway for the anesthetic to migrate.[2] Additionally, the maxillary cortical bone has long been known to be thin and fragile, indicating that the body of the maxilla is largely cancellous bone.[9] This anatomy would enable easier diffusion of anesthetic to the palatal side.

The objective of this study was to explore a potential explanation of the mechanism by which the maxillary buccal injection of articaine is sufficient to provide palatal anesthesia.

Materials and methods

Twenty-eight human, formalin-fixed cadaveric hemimaxillae (14 left and 14 right) were examined. All cadaveric specimens were obtained with permission from the body bequeathal program at Western University, London, Ontario, Canada, in accordance with the Anatomy Act of Ontario and Western University's Committee for Cadaveric Use in Research. Of the 28 hemimaxillae, 12 were edentulous and 16 were dentate. Specimen donors varied from 61 to 92 years of age. Nine of the donors were female and 5 were male.

Prior to sectioning of the maxilla into separate regions and isolation from the cranium, soft tissue structures such as muscle and adipose tissue were removed with a scalpel. Soft tissue structures were detached from areas surrounding the maxilla, hard palate, and zygomatic arch to allow for easier

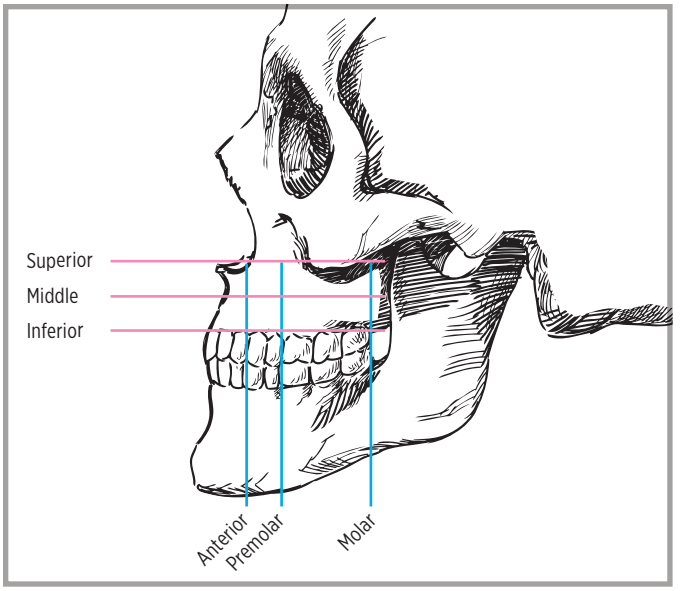


Fig 1. Division of regions. A bone saw was used to cut between teeth to create 3 regions—anterior, premolar, and molar—as shown by the vertical lines. In each region, 3 bone thickness measurements were taken in the planes designated by the horizontal lines: superior, middle, and inferior.

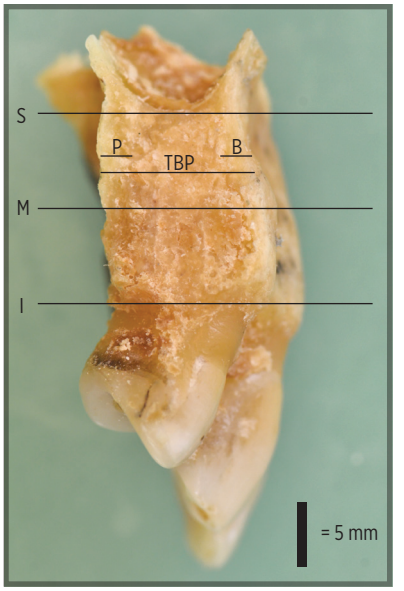


Fig 2. Sample section of the premolar region. The thickness of the cortical bone was measured in the premolar region on the palatal (P) and buccal (B) sides, and a total buccopalatal (TBP) measurement was taken in 3 planes: superior (S), middle (M), and inferior (I).

access to the maxillary alveolar bone. Division of the maxilla into anterior, premolar, and molar regions was performed using an autopsy saw. A cut was first made along the palatal plane that runs from the anterior nasal spine to the posterior nasal spine, and the soft palate was detached from the posterior nasal spine with use of a scalpel. Cuts were then made perpendicular to the palatal plane in the anterior, premolar, and molar regions of the maxilla (Fig 1).

Measurements were independently performed by 2 measurers using standard digital calipers in millimeters. Measurements were taken in each of the 3 sections: anterior, premolar, and molar. Each section was measured in 3 planes: inferior, middle, and superior. The inferior measurement was located at the cementoenamel junction. The middle measurement was made at a halfway point between the cementoenamel junction and the superior measurement, which was made roughly below the zygomatic arch. In the superior, middle, and inferior planes, 3 measurements were made: buccal cortical plate (BCP), palatal cortical plate (PCP), and total buccopalatal (TBP) thickness (Fig 2). The BCP and PCP measurements were limited to cortical bone thickness.

An interclass correlation coefficient was first calculated to determine interobserver reliability in the mean thickness measurements obtained by the digital calipers. Two-way analysis of variance (ANOVA) was performed for all measurements to determine whether significant differences existed between the mean buccal and palatal cortical plates and total buccopalatal thickness at the anterior, premolar, and molar regions along the superior, middle, and inferior planes on the maxilla.

Two-way ANOVA was also used to determine if there was any significant difference between samples in mean BCP thickness at the premolar and molar regions in the maxillary and mandibular profiles in the same specimens (n = 28 hemimaxillae; n = 18 hemimandibles). The mandibles were sectioned into premolar and molar regions, and measurements were obtained in 3 planes: top, middle, and bottom. The values of the 3 planes in each arch were averaged to obtain 1 mean premolar and 1 mean molar measurement for the maxilla and the mandible.

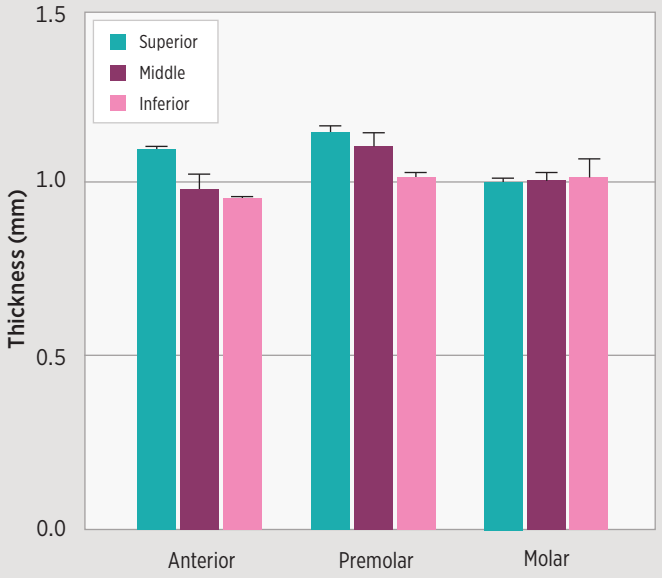
Differences between measurements were considered significant at $P < 0.05$. Statistical analyses were performed using SPSS statistical software (version 23.0, IBM Corporation).

Results

All measurements of BCP, PCP, and TBP thickness obtained with digital calipers displayed high interobserver agreement and consistency. The calculated intraclass correlation coefficient for all measurements between the observers was 0.99. This demonstrates that both observers could correctly and reliably locate and measure the BCP, PCP, and TBP thickness in the anterior, premolar, and molar regions along the superior, middle, and inferior planes of the maxilla. In addition, the measurements confirm the validity and reliability of the digital calipers used, allowing for reproducibility of the data. The measurements obtained from each observer were averaged and used in the study.

Measurements of the maxillary BCP in the anterior, premolar, and molar regions along the superior, middle, and inferior planes indicated no significant differences in thickness as the position changed ($P > 0.05$) (Chart 1). Similarly, PCP thickness showed no statistically significant difference in the anterior, premolar, or molar regions along the superior, middle, and inferior planes ($P > 0.05$) (Chart 2). However, both BCP and PCP were significantly thinner than the TBP measurement ($P < 0.0001$).

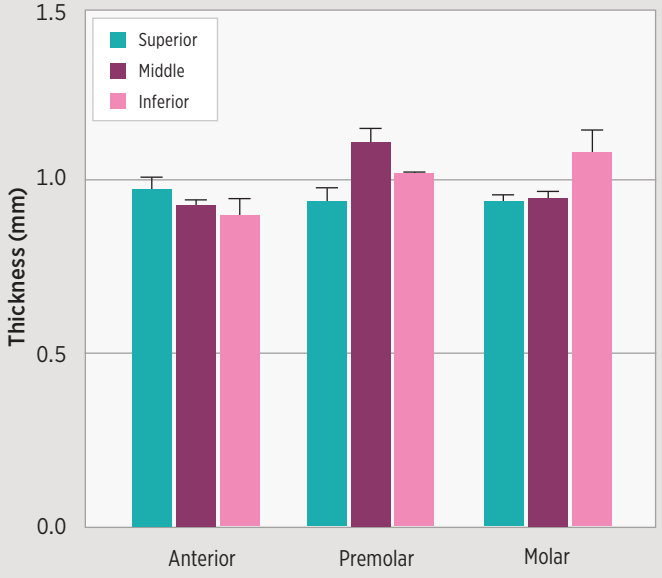
Chart 1. Mean maxillary buccal cortical plate thickness (n = 28).



Error bars represent the standard deviation.

There is no statistically significant difference in mean thickness ($P > 0.05$; 2-way analysis of variance [ANOVA]).

Chart 2. Mean maxillary palatal cortical plate thickness (n = 28).



Error bars represent the standard deviation.

There is no statistically significant difference in mean thickness ($P > 0.05$; 2-way ANOVA).

Maxillary TBP thicknesses were found to be statistically significantly different from the anterior to the molar regions and from the superior to inferior planes (Chart 3). The mean TBP thickness was significantly greater in the superior plane than in the inferior plane at each corresponding anterior, premolar, and molar region ($P < 0.05$). In the anterior region, the mean TBP thickness was significantly greater in the superior plane than in the inferior plane ($P < 0.05$). Similarly, in the premolar and molar regions, the mean TBP measurement in the superior plane indicated significantly thicker bone than that in the middle plane ($P < 0.05$) and inferior plane ($P < 0.05$). Moreover, the TBP thickness in the molar region (mean 11.23 [SD 2.07] mm) presented a significantly greater value ($P < 0.05$) than the TBP thickness in both the premolar region (8.48 [1.33] mm) and anterior region (7.38 [0.93] mm). Additionally, mean TBP thickness in the premolar region was observed to be significantly larger than the anterior region thickness ($P < 0.05$).

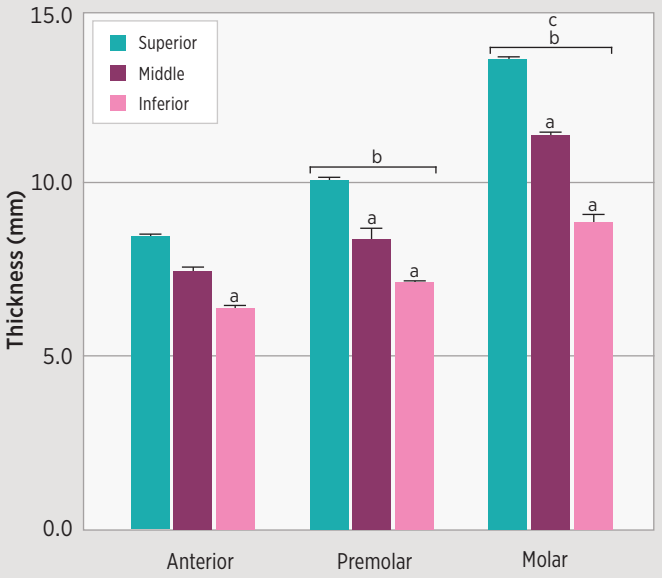
To demonstrate the anatomical advantage of the injection site in the maxilla, the mean thicknesses of the buccal cortical plate in the premolar and molar regions were examined with corresponding mandibular profiles of the same specimens and analyzed using 2-way ANOVA. The mean BCP thickness of the premolar and molar regions in the maxilla appeared significantly smaller than the corresponding mandibular measurements ($P < 0.0001$) (Chart 4). Specifically, the overall BCP thickness in the maxilla (1.05 [0.06] mm) was less than that in the mandible (3.98 [0.34] mm), indicating a significant anatomical difference in overall thickness between the maxilla and the mandible.

Discussion

Palatal injections remain a painful procedure for dental patients.[1-3,6] Firm attachment of the palatal mucosa to the underlying periosteum, dense innervation, and vascularization in the area contribute to this uncomfortable experience for the patient and to the difficulty of performing the procedure for dentists.[1,2,6,10,11] Eliminating the palatal injection and relying on buccal infiltration with the use of articaine has been shown to be successful in multiple clinical trials.[1-4] Somuri et al found that articaine hydrochloride administered as a buccal injection was able to provide palatal anesthesia for maxillary tooth extractions comparable to that achieved by the buccal and palatal injections of lidocaine.[1] This finding is consistent with the results of other studies in the literature, which have indicated that palatal anesthesia achieved by injecting articaine into the buccal vestibule is equivalent to the palatal anesthesia achieved from a palatal injection of lidocaine.[1,4] Similarly, Uckan et al found that articaine has been shown to be superior to other local anesthetics in its ability to diffuse through hard and soft tissues, thus rendering maxillary buccal infiltration sufficient to provide palatal anesthesia, without need for a palatal injection.[6]

In the current study, the thickness of the buccal and palatal bone plates did not vary significantly in the maxilla from the anterior to the molar region or from the inferior to the superior plane. However, the buccal bone in the maxilla (1.05 [0.06] mm) was found to be significantly thinner than that in the mandible (3.98 [0.34] mm). These results are in alignment with the proposed explanation by Fan et al, who argued that the success of the maxillary buccal infiltration may be due to the thinness of the maxillary cortical buccal bone.[2]

Chart 3. Mean total buccopalatal thickness in the anterior, premolar, and molar regions (n = 28).



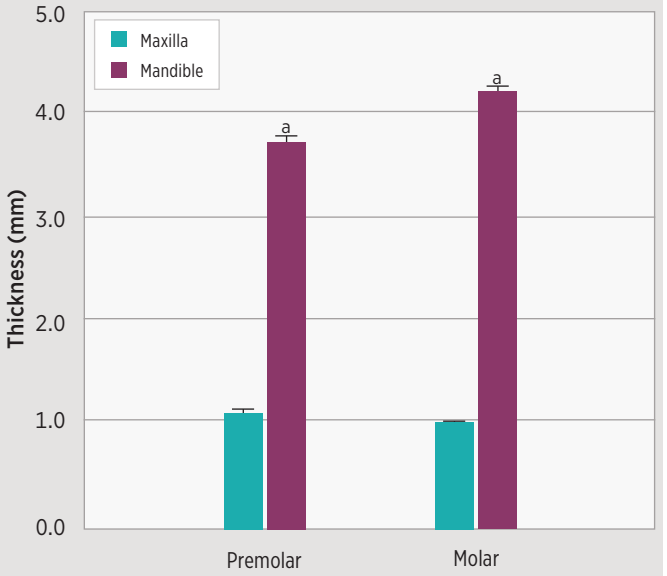
Error bars represent the standard deviation.

[a] The mean is significantly less than the mean in the superior plane in the same region ($P < 0.005$; 2-way ANOVA).

[b] The mean is significantly greater than the mean in the anterior region ($P < 0.005$; 2-way ANOVA).

[c] The mean is significantly greater than the mean in the premolar region ($P < 0.005$; 2-way ANOVA).

Chart 4. Mean maxillary and mandibular buccal cortical plate thickness in the premolar and molar regions (n = 28 hemimaxillae; n = 18 hemimandibles).



Error bars represent the standard deviation.

[a] The mean is significantly greater than the mean in the maxilla ($P < 0.05$; 2-way ANOVA).

The results of the present study also showed that the TBP measurement increased from the anterior area to the molar area and from the inferior area to the superior area, making the superior molar area the thickest and the anterior inferior area the thinnest. This is an important finding, as the success of local anesthetic diffusion depends on the TBP distance that the anesthetic needs to travel. As the TBP measurement increases, the ability of the local anesthetic to diffuse to the palatal side decreases.[3] Given that buccal and palatal cortical plates are thin, the findings indicate that the majority of the bone making up the maxilla is cancellous, which is more porous and allows anesthetic diffusion. This is consistent with previous reports that maxillary bone is more cancellous in structure than mandibular bone.[10]

Kumaresan et al found that buccal infiltration of lidocaine in the posterior area of the maxilla was not as successful at achieving palatal anesthesia as infiltration in the anterior area.[3] Palatal anesthesia was successful in 100% of buccal infiltration attempts in the anterior area and 92% of attempts in the premolar area, but only 52% of attempts in the posterior molar area. The authors concluded that extraction of anterior teeth and premolars can be done with lidocaine administered only via buccal infiltration but did not recommend this approach in the posterior area.[3]

Luqman et al, in contrast, found no statistically significant differences in the success of palatal anesthesia, regardless of whether buccal infiltration of articaine was used in the anterior, premolar, or molar area.[4] The success of articaine in the posterior regions can be explained by its excellent bone-penetrating capability and the thiophene ring in its structure, allowing for increased lipid solubility, greater potency, and a greater amount of the delivered dose to cross the epineurium of neurons.[4] Sharma et al, in agreement with Luqman et al, found that pain scores reported after probing of the palatal mucosa following buccal infiltration with lidocaine in the posterior region were higher than those following buccal infiltration of articaine.[4,11]

Results of the present study and evidence from the literature are in alignment with the study hypothesis. Maxillary bone contains more cancellous bone and has relatively thin cortical bone, which means that both articaine and lidocaine can be used to achieve palatal anesthesia through buccal infiltration. As the TBP width increases in the posterior region of the maxilla, lidocaine fails to achieve palatal anesthesia. This anatomical difference can be offset by the use of articaine, which is capable of diffusing greater distances than other local anesthetics, thereby achieving the necessary palatal anesthesia.

Conclusion

The chemical properties of articaine as a local anesthetic and the uniformly thin anatomy of the maxillary bone make it possible for buccal infiltration to result in successful palatal anesthesia. The results of the present study serve to provide a deeper

explanation and validation of studies in which articaine has shown its success.[1,4,6] Eliminating the need for a palatal injection would reap benefits to both the dentist giving the injection and the patient receiving it.

Author information

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Exercise No. 439

Anesthesia and Pain Management

Subject Code: 340

The 15 questions for this exercise are based on the article "Buccal injection of articaine to anesthetize the palatal mucosa" on pages 26-30. This exercise was developed by Brooke Elmore, 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 benefits of articaine buccal infiltration to anesthetize palatal mucosa;
- discover techniques and anatomical locations where articaine administration is beneficial; and
- recognize the differences in local anesthetic properties.

Answers can be submitted online at *agd.org/self-instruction.*

Answers for this exercise must be received by April 30, 2020.

1

By 2011, articaine was the _____ most popular anesthetic in the United States.

A. first
B. second
C. third
D. fourth

2

Lidocaine and articaine are similar because they are both _____.

A. amides
B. esters
C. naturally derived
D. compounded

3

Articaine contains a _____ ring.

A. pyrrole
B. furan
C. benzene
D. thiophene

4

Articaine is less lipid soluble and 1.5 times more potent than lidocaine. Articaine diffuses through tissue more reliably than other local anesthetics.

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.

5

A majority of the specimens examined in the study were _____.

A. human mandibles
B. canine mandibles
C. canine maxillae
D. human maxillae

6

The specimens were divided into __ sections for evaluation.

A. 1
B. 2
C. 3
D. 4

7

How many measurements were made in each region?

A. 6
B. 7
C. 8
D. 9

8

The buccal cortical plate thickness in the anterior, premolar, and molar regions along the superior, middle, and inferior planes showed a significant difference. The palatal cortical plate showed no significant difference.

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.

9

Total buccopalatal (TBP) thickness was found to be _____ from the anterior to molar regions, and mean TBP values in the superior plane were _____ than those in the inferior plane.

A. different; greater
B. different; lesser
C. the same; greater
D. the same; lesser

10

Which region had the greatest TBP measurement?

A. anterior superior
B. middle inferior
C. premolar inferior
D. molar superior

11

Mean _____ measurements demonstrated the anatomical advantage of the maxilla over the mandible.

A. total buccopalatal
B. buccal cortical plate
C. palatal cortical plate
D. cancellous bone

12

All of the following contribute to painful palatal injections except one. Which is the exception?

A. attachment of periosteum
B. dense innervation
C. anatomical location
D. vascularization

13

What do the authors believe makes articaine buccal infiltration successful at palatal anesthesia?

A. thickness of the palatal cortical plate
B. inability of anesthetic to diffuse tissue
C. total buccopalatal measurements
D. thickness of the buccal plate

14

Kumaresan et al found that buccal infiltration of lidocaine in which area most consistently achieved palatal anesthesia?

A. anterior
B. premolar
C. molar
D. none

15

Which local anesthetic has been proven to achieve palatal anesthesia by buccal infiltration in all areas?

A. articaine
B. lidocaine
C. bupivacaine
D. mepivacaine

Biometrics: digital technology as a clinical aid to dental examination and diagnosis

Patrick Girouard, BSc, DMD, MS

The new-patient visit includes examination, diagnosis, and establishment of a treatment plan. This process must include an evaluation of the dental occlusion and stomatognathic system, including the temporomandibular joints. This clinical case describes the use of biometric aids, including T-Scan, BioJVA, and JT-3D, in the digital evaluation of a patient with signs and symptoms of occlusal stress. These technologies provide clinicians with additional information that can help in the examination and diagnostic processes.

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Key words: biometrics, dental stress, digital occlusion, occlusal disease

GENERAL DENTISTRY SELF-INSTRUCTION CE CREDIT
Exercise No. 440, p. 37
Subject code: Occlusion (180)

The clinical examination is one of the most important aspects of dentistry. However, a dentist's ability to evaluate patients and establish accurate diagnoses depends in part on the availability of technology. For instance, plain radiographs enable visualization of a lesion, while cone beam computed tomographic scans allow better, 3-dimensional visualization. Thus, the capabilities and precision of the available technology may influence the dentist's ability to reach a diagnosis, establish a prognosis, and create an effective treatment plan.

The concept of occlusal disease is poorly understood by the dental profession; hence, it is rarely recognized, especially in its early stages. It has been defined as "the process resulting in the noticeable loss or destruction of the occluding surfaces of the teeth."[1] This definition should be extended to all structures associated with the stomatognathic system that are affected by occlusion. The subtlety of the early stages of disease renders its recognition difficult. Occlusal disease is often mistaken for functional wear in young adults and middle-aged patients.[1]

According to Peck, there are "dogmatic, passionate and often diverging views on the relationship between the dental occlusion and various diseases and disorders including temporomandibular disorders, non-carious cervical lesions and tooth movement."[2] The biomechanics of dental occlusion aid in understanding its precision, adaptation, bite force, jaw movement, structure, and function or malfunction. The stomatognathic system adapts—in structure or functionality—to changing biomechanical demands. The system is elaborate, involving 6 degrees of mandibular movement and 16 muscle groups exerting multiple force vectors on the teeth. Even with this complexity, the tooth contacts are reproducible, as are the rhythmic functional jaw movements generated from the regular motor command pattern in the brainstem.[2]

The ideal dental occlusion should include even, simultaneous, and bilateral tooth contacts during intercuspation, the assumption being that this state will result in a balanced distribution of occlusal forces.[3] However, the appearance of an even distribution of tooth contacts does not equate to an even distribution of occlusal forces. The stomatognathic system is not rigid; thus, disparate force loads can exist despite the appearance of "balanced" tooth contacts.[4] Further, despite the belief that articulating paper marks can indicate occlusal force load, this assumption has been shown to be false and misleading.[5-7] To date, no study has been published that demonstrates the reliability of marking paper to measure occlusal forces. Consequently, the clinician does not consider 2 of the most fundamental parameters of occlusion: force and time.

Advances in digital technology make it possible to accurately and reliably measure the relative force, sequence, and duration of occlusion.[8] The T-Scan (Tekscan) digital occlusal analysis

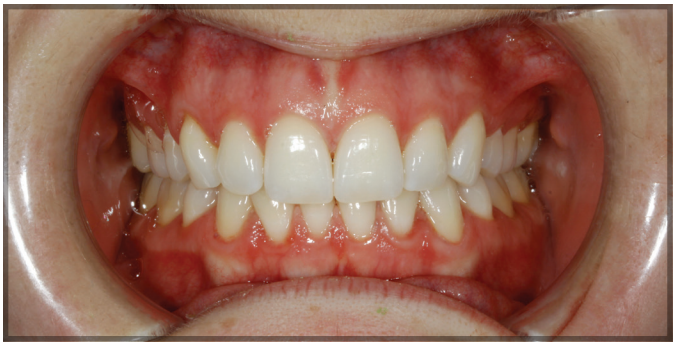

Fig 1. The anterior view of the articulated teeth reveals recession of the maxillary right premolars and a 1-mm left shift of the mandibular midline.

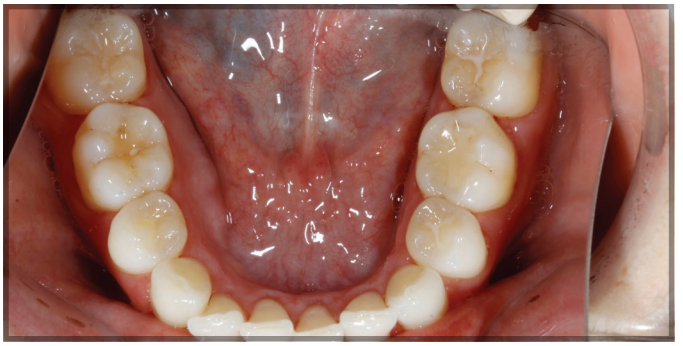

Fig 2. A lingual torus is present on the right side of the mandibular arch.

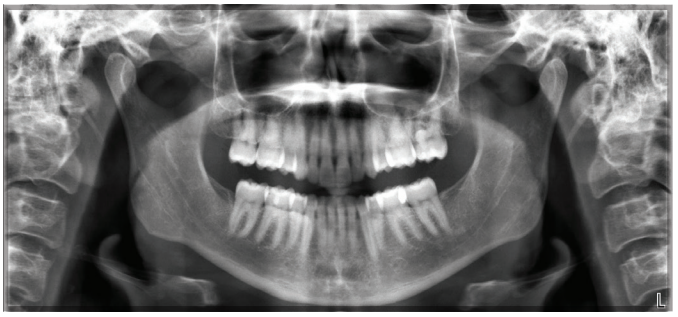

Fig 3. The panoramic radiograph demonstrates a type II elongation of the styloid process and gonial notching of the mandible.

system provides clinicians with a diagnostic assessment tool. The system was developed 30 years ago and continues to undergo technical improvements.[9] With this technology, clinicians' understanding of dental occlusion is enhanced.[10]

The following case report illustrates the use of digital technologies in the clinical examination of a patient with occlusal disease and stresses to her stomatognathic system.

Case report

A healthy 32-year-old woman was seen at a dental health center for a new-patient examination. She had no major complaints but had moderate occlusal wear. Her dental history included orthodontic treatment when she was a teenager, including extractions of premolars in all 4 quadrants (the maxillary first premolars and the mandibular second premolars). Her third molars also were extracted during her late teens, independently of the orthodontic treatment.

The anterior view of the articulated teeth revealed differences in gingival contour between the right and left sides; recession was present only on the right side (Fig 1). Also present was a 1-mm midline shift of the mandible to the left in maximum intercuspation. The intraoral examination revealed a unilateral lingual torus on the right side of the mandibular dental arch (Fig 2). The panoramic radiograph demonstrated a type II elongation of the styloid process and gonial notching of the mandible (Fig 3).[11,12]

The patient's dental occlusion was evaluated with the T-Scan, which can provide information such as relative forces, sequence, timing, and repetitive force patterns. Figure 4 shows the patient's maximum bite force; the distribution of forces favored the right side (64.6%) compared with the left side (35.4%). The digital occlusal perspective also allowed study of a new parameter: the digital occlusal force distribution patterns (Fig 5). These repetitive force cycles constantly impact the structures of the stomatognathic system during occlusion and disclusion of the teeth when engaging in articulation.[13] In this patient, these stresses were concentrated on the right side of the dental arches.

The patient's jaw movements were accompanied by sounds on opening and closing. To investigate, the dentist used a combination of jaw tracker (JT-3D, BioResearch Associates) and temporomandibular joint (TMJ) vibration analysis (BioJVA, BioResearch Associates). Briefly, a magnet is fixed on the labial surface of the mandibular incisors. As the patient moves the mandible, the displacement of the magnet is recorded bilaterally by sensors in a headset that the patient wears. The kinesiographic recording depicts the movement in 3 dimensions along with its velocity. For the vibration analysis, accelerometers are placed over both TMJs, allowing joint vibration to be recorded. Further details about these procedures are available elsewhere.[14]

In this patient, joint vibration during the opening cycle was 25.5 Hz at 27.8 mm from maximum intercuspation, which represents a medium-intensity vibration. This event coincided with a reduction of velocity during the opening cycle. During the closing cycle, a low-intensity vibration of 6.6 Hz was recorded. These events suggested disc displacement with reduction, which will be discussed in greater depth later.

The digital dynamic parameters of occlusion revealed that this patient had 2 lateral schemes of excursion. The right lateral excursion demonstrated group function (Fig 6). The left lateral excursion demonstrated canine guidance (Fig 7). Both lateral movements were subject to contralateral interferences during the excursive movement. The time of disclusion also is an important factor. In this patient, the disclusion times were 1.17 seconds for the right excursive movement, 0.49 second for the left excursive movement, and 0.33 second for the protrusive movement.

Despite the findings, the patient had no major complaints. Her adaptive capacity enabled her to tolerate some of the occlusal stresses, and she was aware of the gingival recession and attrition. The dentist discussed the clinical and digital examination findings with her. She opted to refrain from treatment and monitor the probable progression of her dental condition over time.

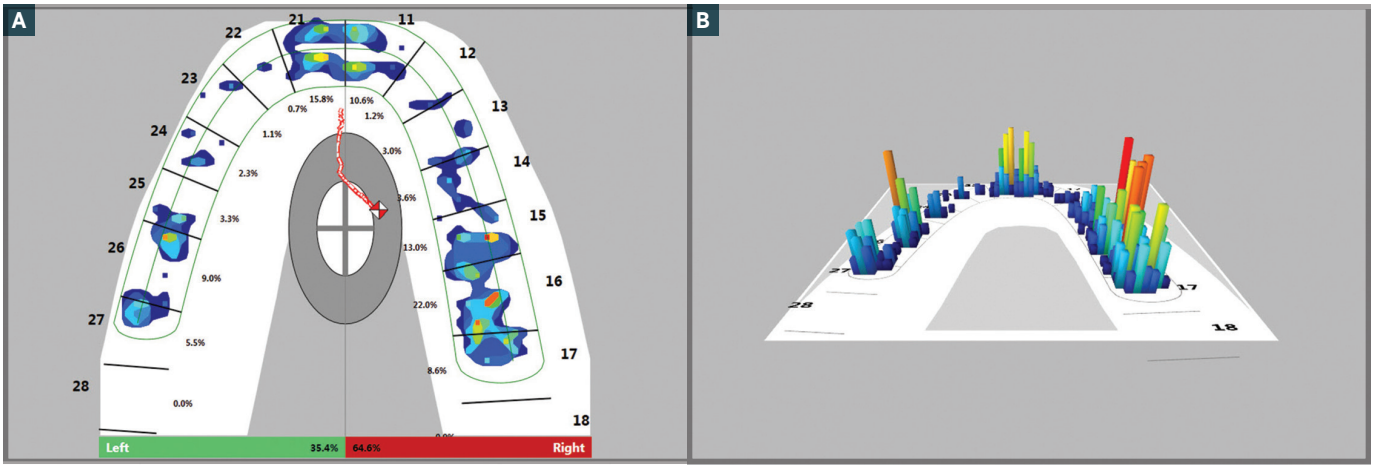

Fig 4. T-Scan recording of maximum bite force. A. The teeth are numbered, according to the international standard, on the outside of the dental arch. The dental arch is delimitated by the green arch outline. The relative forces of each contact are expressed in percentages on the inside of the dental arch. The center of force (COF), corresponding to the red and white square, and the COF trajectory, corresponding to the white and red line, display the displacement of the total resultant sum of total force during the occluding event. The bottom border shows that the left side of the arch, in green, receives 35.4% of the overall force while the right side, in red, is subject to 64.6% of the overall force. The different colors of the dental contacts represent the relative forces of individual contacts, blue being the weakest and red the strongest. B. The differences in contact forces are visualized by the relative heights of the vertical columns.

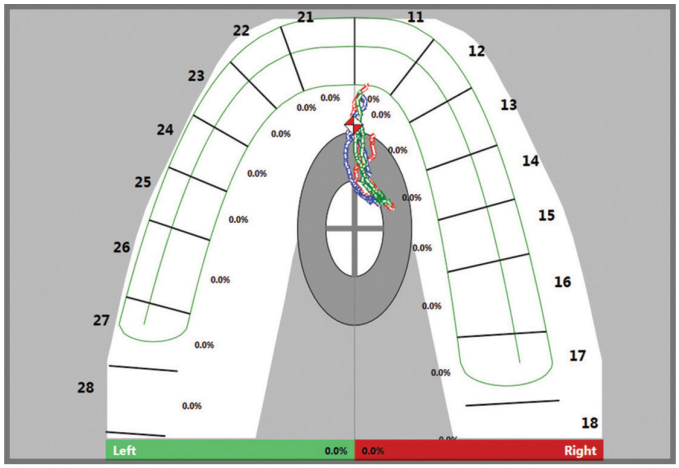

Fig 5. Digital occlusal force distribution patterns are repetitive force cycles recorded during the dynamic process of dental occlusion and disclusion. Three recordings of COF trajectory are represented by 3 different colors.

Discussion

The patient described in this case report had a history of tooth extraction during orthodontic treatment as a teenager. These extractions included premolars in all 4 quadrants (the maxillary first premolars and the mandibular second premolars). These extractions modified the dental arches and altered the structural integrity of the stomatognathic system. In a 2-year postorthodontic treatment follow-up study, Yoon et al found that occlusal function did not recover fully in patients who underwent extraction of 4 premolars; in contrast, patients who did not undergo extraction or underwent extraction of 2 premolars experienced full recovery of pretreatment occlusal function.[15] Dental arches that are reduced by orthodontic extractions bear more occlusal stress per tooth than complete arches; the biophysical constraints are modified, and the physics of occlusion differ.

The 100-µm sensor of the T-Scan system records each dental contact with respect to sequence, relative forces, and time.[16] In this patient, the maximum bite force favored the right side (64.6%) over the left side (35.4%). This asymmetry of forces represents a significant stress to the stomatognathic system. A normal dentition has a tendency for "bilateral equality of the tooth contacts about the sagittal axis and . . . the center of effort for tooth contacts anteroposteriorly is located in the region of the first molar and is symmetrical bilaterally."[17] In the patient in the present case, the unilateral presence of gingival recession on the right side corresponded to the increased occlusal forces on that side. Harrel et al noted that occlusal discrepancies are a risk factor for development and progression of periodontal disease.[18]

The digital biometric tools discussed in this report allowed evaluation of a new parameter—the digital occlusal force distribution patterns. These repetitive force cycles continually affect the structures of the stomatognathic system during occlusion and disclusion. Over time, the system may or may not adapt to these repetitive vectors; depending on the adaptive capability, these forces will be pathologic, causing damage, or physiologic, preserving the structures of the stomatognathic system.[13] Because of differences in biological structures and adaptive capacities, damage will vary from individual to individual.[19,20] Moreover, the damage is not instantaneous; over time, repetitive force cycles take their toll. In this clinical case, the digital occlusal force distribution patterns favored the patient's right side, ending near the second premolar, where the periodontal attachment loss was greatest. It is noteworthy that no recession developed on the contralateral side of the dental arch, where less force was present.

Thongudomporn et al demonstrated that alveolar bone thickness and shape are selectively and proportionally influenced by the maximum bite force; increased forces result in increased

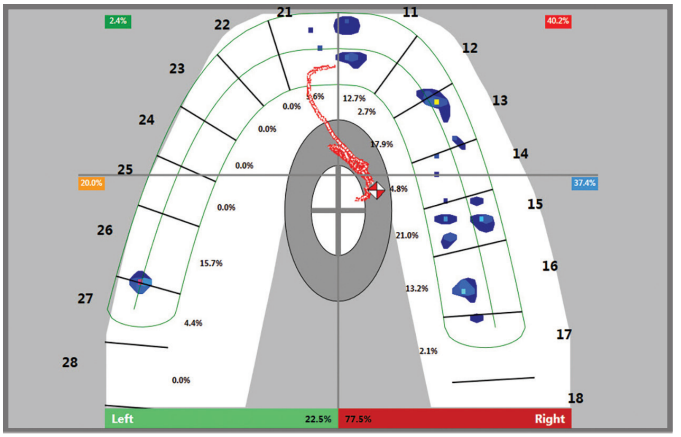

Fig 6. The digital dynamic occlusal analysis of the right lateral movement of the mandible depicts group function with contralateral interference. The COF trajectory is represented by the red line, while the COF corresponds to the red and white square. The blue markings within the dental arch, which is delimited in green, represent the dental contacts; the right (red) side shows group function, while the left (green) side shows the interference.

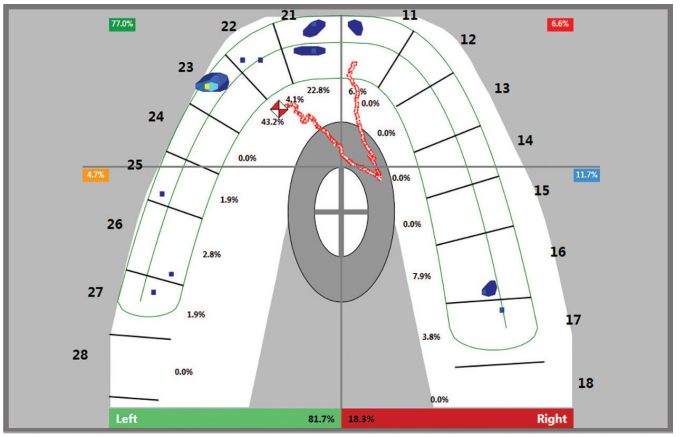

Fig 7. The digital dynamic occlusal analysis of the left lateral movement of the mandible depicts canine guidance with contralateral interferences. The COF trajectory is represented by the red line, while the COF corresponds to the red and white square. The blue markings within the dental arch, which is delimited in green, represent the dental contacts; the right (red) side shows the interferences, while the left (green) side shows the canine guidance (tooth 23).

bone apposition to withstand bending forces.[21] In addition, Yoshinaka et al found that the presence of mandibular tori is associated with mechanical stimulation from occlusal contact loads.[22] As mentioned earlier, the patient in this case exhibited a lingual torus on the right side of the mandibular arch, which corresponded to the high forces during maximum intercuspation and repetitive cycles.

The presence of tori has been found to be strongly associated with the clinical presentation of TMDs.[23] Temporomandibular joint noises such as reciprocal clicking or popping during opening and closing have been established as indicative of intracapsular TMD in the form of a disc displacement with reduction.[24] Ideally, magnetic resonance imaging would confirm the state and position of the disc complex, but it may not be practical or necessary for all routine dental examinations. Joint vibration analysis is a noninvasive and more cost-effective procedure that can detect the presence of a disc displacement with reduction.[25]

Joint vibration analysis is a digital technology that records the vibrations of the intracapsular tissue within the TMJs. Combined with a jaw tracker, it also records the mandibular jaw movement pattern during opening and closing cycles. Together, the waveform and kinetic aspects of the movement provide the clinician with data and diagnostic tools regarding the state of the stomatognathic system.[14] As discussed earlier, the patient in this case report had a medium-intensity repetitive opening cycle vibration of 25.5 Hz. This event coincided with a reduction in velocity during the opening cycle, indicating a physical obstruction in the path of the condyle during movement. In this case, it corresponded to the recapture of the disc over the condyle—the opening "click." As the opening-closing cycle continued, a deceleration occurred midway in the closing path, which corresponded to the disc's slippage from the condyle. The intracapsular events are present unilaterally, in the right temporomandibular joint, the side subjected to the most intense occlusal forces. The joint loading increases tissue stress and the risk of mechanical fatigue of the TMJ disc and ligaments.[26] The forces repeatedly imposed on the disc in the form of frictional and plowing forces produce deformation, stresses, and tissue fatigue.[27] Over time, these forces may exceed the individual's capacity to adapt and lead to degeneration of the injured tissue. In the present case, unilateral instability of the TMJ complex was observed on the right side, where forces were dominant.

The occlusal scheme—namely the lateral excursion—can impact the occlusal load on the stomatognathic system. Canine guidance has been shown to reduce interarch forces, tooth wear, and parafunctional loads.[28] This concept is not new; D'Amico published his well-known series on this topic in 1958.[29-34] These findings remain relevant today and have clinical applications for the T-Scan system.[35] The patient in the clinical case had 2 lateral excursion schemes: group function on the right and canine guidance on the left. Neither scheme was perfect; each exhibited balancing interferences of the second molar in the contralateral quadrant. Again, the right side was subject to more occlusal load than the left side during excursion. This additional load applied more stresses on the right side, requiring more adaptation from the system, which already was showing signs of maladaption and trauma.

Time remains an important factor in the traumatization of the stomatognathic system. Occlusal time represents the duration between the first dental contact and maximum bite force. In other words, it is the time required to attain maximum intercuspation, which should be the most stable bite position in function. Evidence shows that patients with TMDs have longer occlusal times than control participants.[36]

Ideally, all teeth contact immediately and equally with an even distribution of forces.[37] In a digital context, this translates into a very short and centered digital occlusal force distribution pattern, in contrast to the long and off-center pattern demonstrated by the patient in this clinical case. Patients with TMD have demonstrated an increased number of premature contacts and

occlusal interferences, longer occlusion and disclusion times, and increased anxiety and depression.[38]

Kerstein introduced the concept of disclusion time, which represents the "elapsed time required to exit complete intercuspation, and move right, left or forward to disclude all posterior teeth so that only canines and/or incisors [are] in tooth contact."[9,39] The immediate complete anterior guidance development, when posterior disclusion time of less than 0.4 second per excursion is achieved, cannot be determined without digital measurements.[40] The disclusion times for the patient in the present case report were 1.17 seconds for the right excursive movement, 0.49 second for the left excursive movement, and 0.33 second for the protrusive movement. The longer right lateral movement contributed to the application of forces over an extended period, which was reflected in the clinical presentation of changes to the stomatognathic system.

Conclusion

The digital analysis of occlusion reveals new parameters that had been inaccessible in the examination, evaluation, and diagnostic processes. Objective measurement of forces and time is now possible to redefine the parameters of occlusion and provide a new frame of reference for treatment planning. Joint vibration analysis also provides an alternative means to objectively assess and monitor the state of the TMJs. These biometric approaches are changing the perception and perspective of dental medicine. The digital era of occlusion has arrived in contemporary dentistry and will continue to progress toward a better understanding of the influence of occlusion on disease and health.

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Disclaimer

The author reports no conflicts of interest pertaining to any of the products or companies discussed in this article.

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Exercise No. 440

Occlusion

Subject Code: 180

The 15 questions for this exercise are based on the article "Biometrics: digital technology as a clinical aid to dental examination and diagnosis" on pages 32-36. This exercise was developed by Charles Martello, DDS, MAGD, in association with the *General Dentistry* Self-Instruction committee.

Reading the article and successfully completing this exercise will enable you to:

- understand the importance of a comprehensive evaluation of both the dental occlusion and stomatognathic system (SGS) to establishment of a harmonious treatment plan;
- appreciate the benefit of incorporating biometric aids in the dental evaluation of a patient with signs and symptoms of occlusal stresses; and
- realize that application of these technologies provides the clinician with a novel perspective that may assist in the examination and diagnostic process.

Answers can be submitted online at *agd.org/self-instruction.*

Answers for this exercise must be received by April 30, 2020.

1
The concept of _____ disease is poorly understood by the dental profession.
A. oral
B. periodontal
C. systemic
D. occlusal

2
The SGS is elaborate, involving ___ degrees of mandibular movement and ___ muscle groups.
A. 4; 8
B. 5; 12
C. 6; 16
D. 7; 18

3
The ideal dental occlusion should include even, simultaneous, and bilateral tooth contacts during intercuspation of teeth, the assumption being that this state will result in a balanced distribution of occlusal forces. An appearance of even distribution of tooth contacts equates to an even distribution of the occlusal force.
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.

4
Advances in occlusal digital technology make it possible to accurately and reliably measure all of the following except one. Which is the exception?
A. distress
B. force
C. duration
D. sequence

5
The healthy patient described in this case report collectively had __ teeth extracted.
A. 2
B. 4
C. 6
D. 8

6
The patient exhibited a __-mm shift of the mandible to the left in maximum intercuspation.
A. 0.5
B. 1.0
C. 1.5
D. 2.0

7
Digital evaluation of the patient's occlusion indicated that the distribution of forces favored the _____ side by ___ %.
A. right; 35.4
B. left; 64.6
C. left; 35.4
D. right; 64.6

8
The digital occlusal force distribution patterns recorded on the T-Scan illustrate _____.
A. a depletion process
B. acute left-side trauma
C. repetitive force cycles
D. stresses irregularly afflicting the SGS

9
The disclusion time for protrusive movement in the patient in the current clinical case was ____ seconds.
A. 1.17
B. 1.07
C. 0.49
D. 0.33

10
All of the following are present in an acceptable occlusal scheme except one. Which is the exception?
A. unilateral tooth contacts
B. balanced occlusal forces
C. canine disclusion
D. first molar occlusion

11
If the maximum bite force is _____ , bone apposition will _____ selectively and proportionally.
A. increased; decrease
B. decreased; decrease
C. increased; increase
D. decreased; increase

12
The clinical presentation of temporomandibular joint disorders has been found to be strongly associated with _____.
A. cervical caries
B. lingual tori
C. rapid disclusion
D. canine guidance

13
All of the following occurred during the patient's repetitive opening cycle except one. Which is the exception?
A. vibration originating prior to maximum intercuspation
B. a reduction in velocity, indicating path obstruction
C. medium-intensity vibration of 25.5 Hz
D. the "click" as the disc was displaced from the condyle

14
Which of the following increases the risk of mechanical fatigue of the temporomandibular joint?
A. joint loading
B. neuromuscular response
C. condylar resorption
D. disc deformation

15
Which of the following can impact the occlusal load on the SGS?
A. group function
B. lateral excursion
C. canine guidance
D. balanced first molar

Comparison of the accuracy of CBCT effective radiation dose information in peer-reviewed journals and dental media

Diana Hicks, MS, DPhil ■ Michael Melkers, DDS, MAGD ■ Julie Barna, DMD, MAGD
Kimberley R. Isett, MPA, PhD ■ Gregg H. Gilbert, DDS, MBA

Accessible sources of clinical information have proliferated over the past decade. Although these new sources that contextualize information for practice are user friendly, there are questions about their accuracy because much of the material is not peer reviewed. On the other hand, traditional peer-reviewed material can be somewhat removed from the needs of practicing dentists, and recently questions have been raised about the accuracy of journals. This study assessed the accuracy of cone beam computed tomography (CBCT) radiation safety information in both professional media and peer-reviewed journals. Articles introducing CBCT technology to dentists and published in peer-reviewed journals were compared to articles appearing in professional magazines, clinically oriented news sites, and blogs written by clinicians for clinicians. The reported radiation doses of CBCT and conventional dental radiographs were recorded, as were conclusions about the comparative doses of these 2 imaging modalities. The proportion of articles reporting CBCT dose to be greater than, equal to, or less than that of conventional dental radiographs was not different between the peer-reviewed and professional media articles during the period 2003-2016. There is weak evidence that the conclusions of peer-reviewed journal articles, but not professional media sources, became more conservative after the 2010 publication of an article in *The New York Times* that was critical of misinformation concerning the safety and efficacy of CBCT in dentistry. Professional media articles that were not peer reviewed were as accurate as peer-reviewed journals for this topic and during the time period assessed. However, the method used here necessitated a narrow focus, and more studies are needed to broaden understanding.

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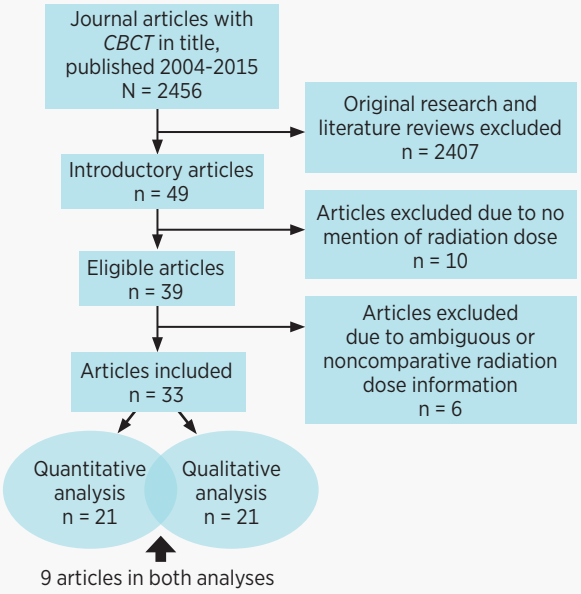
Increasingly frequent introduction of new technology into clinical practice presents dentists with the challenge of learning about these innovations and deciding whether to use them. As technology becomes more complex, overstretched dentists are challenged to the edge of their information processing and decision-making capacities. To cope with this increasing sophistication, clinicians turn to an array of resources to keep up-to-date, including colleagues, conferences, study clubs, continuing education, and peer-reviewed journals.[1-3] In addition to these traditional sources, an increasing number of clinical information media sources, such as magazines, news sites, and blogs, have emerged in recent years.[4] The question is how accurately these resources convey the complex, subtle, specialized information required to decide whether to use an innovative technology. To explore this question, the authors focused on literature produced for dentists to inform their clinical practice: peer-reviewed journals, magazines, news sites, and blogs. One innovation was selected: the introduction of cone beam computed tomography (CBCT) to dentistry. In the mid-2000s, CBCT was an innovation in dental imaging technology that had many advantages over other imaging modalities as well as 2 well-known issues—costs and radiation exposure.[5] Dental X-ray radiation risk concerns the public; therefore, CBCT use needs to be justified by balancing the risks inherent in radiation exposure against the clinical benefits expected from a better image.[6,7] Dentists need access to accurate information regarding CBCT radiation dose to decide whether to use the new technology for clinical care.

The radiation risk of dental radiography is difficult for dentists to assess for many reasons. The effects of low-dose imaging exposure cannot be determined via epidemiologic data; instead, risks are estimated based on a linear, no threshold model. The possible harm from low-dose radiation, cancer, occurs randomly and can happen many years after radiation exposure, making it difficult to attribute a cancer to a specific exposure.[8] For an individual, multiple images generate cumulative risk, but dentists have no way of knowing about other exposures.

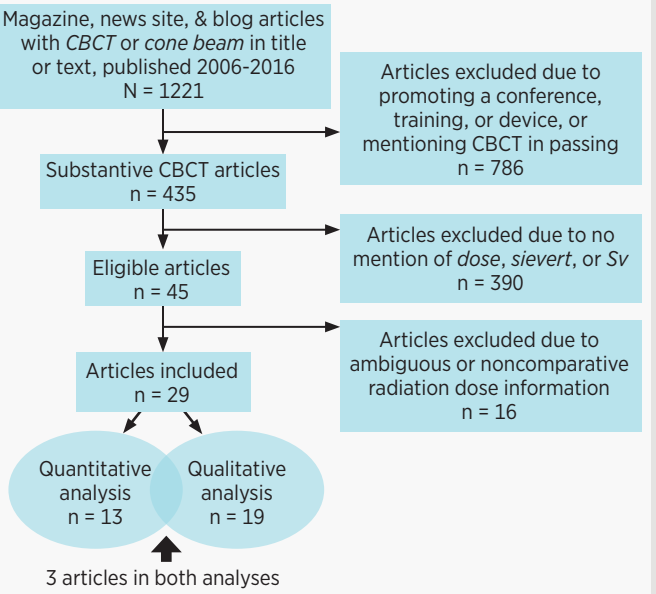
Standard methods of calculating a radiation dose changed through the 1980s and 1990s, which was confusing for clinicians trained before 2000. The International System of Radiological Protection changed the organs included in the calculation of effective dose in 2007, raising the effective dose values for dental imaging. Therefore, it would not be surprising if clinicians who are not radiologists are unclear about the proper radiation dose.[7] Research has demonstrated that nonradiologist physicians have moderate to poor knowledge of a computed tomography (CT) radiation dose.[9,10] Knowledge of the risk from CT scans is particularly

Chart 1. Identification of journal articles for analysis.



Abbreviation: CBCT, cone beam computed tomography.

Chart 2. Identification of professional media articles for analysis.



Abbreviation: CBCT, cone beam computed tomography.

variable; mainly, clinicians underestimate harm, but some overestimate it.[11] General dentists' knowledge is similarly poor.[12] A recent survey found limited and variable practices in CBCT radiation minimization, suggesting a void in knowledge of radiation safety.[13]

General dentists who want to understand the risks of CBCT radiation doses today would face great difficulty. Turning to promotional literature by manufacturers, general dentists would be unlikely to find any mention of radiation dose. Examining a machine would be similarly unenlightening, as early CBCT machines provided no readout of dose. New machines might provide a dose estimate, but nonspecialists are unlikely to know that this number is produced using nonoptimal methods of estimation.[14] In addition, nonspecialists probably are not aware of the many parameters that need to be managed to make dose information comparable.[15] For example, X-ray beams can be continuous or pulsed; exposures are lower for pulsed beams, which provide the same image quality. Research and methodologic debates surrounding CBCT radiation dose measurement occur in the radiology community, and a synthesis of this literature provided a confusing 382 dose values for adults and a further set of tables for children.[14]

Radiation dose is just one of many factors weighed by a dentist deciding whether to use or buy a CBCT machine. Therefore, general dentists curious about CBCT in the period after its introduction were unlikely to invest the time required to develop a sophisticated, specialty-level understanding of CBCT radiation dose. Instead, their knowledge of CBCT was provided by articles in peer-reviewed journals, professional magazines, news sources, and blogs introducing CBCT to the broader profession.

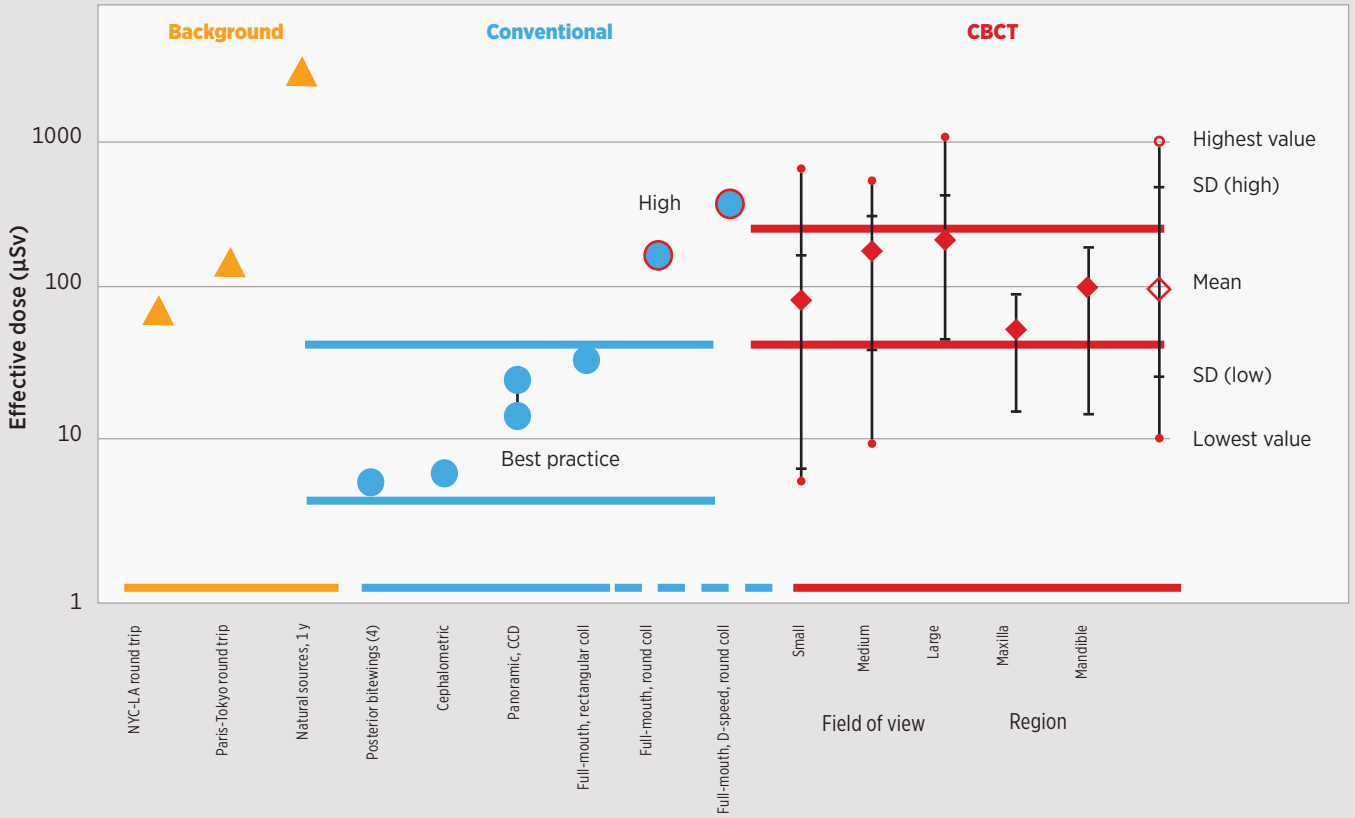
Both media and peer-reviewed journal articles addressed the complex issue of dosimetry by referencing articles by dental radiologists, contextualizing this information with comparisons to radiation doses received from medical CT, conventional dental radiography, and/or naturally occurring background radiation. This framing provided the nonspecialist with an explanation of dose relevant to deciding whether to use CBCT or not. For example, many articles noted that, as an alternative to medical CT, advantages of CBCT include exposing patients to much lower doses of radiation. However, although each article reached a seemingly straightforward conclusion comparing the radiation dose of CBCT and conventional dental radiography, those conclusions differed. This variation occurred because the radiation doses of CBCT scans reported in the literature vary greatly—machines differ, more than a dozen imaging parameters can be varied, and patients differ. The degrees of freedom are such that literature can be cited supporting any conclusion, that is, that CBCT radiation dose is greater than, equal to, or less than that of conventional radiography.

The risk of exposure to CBCT radiation was not just discussed in journal articles or professional media. In 2010, *The New York Times* (*NYT*) published an article criticizing the discussion of radiation risk in the professional literature, highlighting[16]:

...misinformation about dental CBCTs' safety and efficacy, some of it coming from dentists paid or sponsored by manufacturers to give speeches, seminars and continuing education classes, as well as by industry sponsored magazines and conferences...

This article was influential in the dental community, widely discussed in forums and blogs, and referenced by several journal articles.

Chart 3. Effective dose reference values.[14, 17-20]



Abbreviations: CBCT, cone beam computed tomography; CCD, charge-coupled device; coll, collimation; LA, Los Angeles; NYC, New York City.
The vertical axis is logarithmic, meaning the distance from 1 to 10 is the same as the distance from 10 to 100 and from 100 to 1000.

The present study was designed to assess the accuracy of information available to nonspecialist clinicians about dental CBCT when it was an innovative imaging technology. In particular, the research was intended to investigate whether magazines, news sites, and blogs were less accurate than the peer-reviewed literature. The conclusions drawn in introductory articles concerning the relationship between radiation doses of CBCTs and conventional dental radiographs were examined to determine whether there was any evidence that professional magazines, news sites, and blogs were less accurate than peer-reviewed journal articles. The study also examined whether discussion of CBCT dose in introductory articles became more conservative after publication of the *NYT* article.

Materials and methods

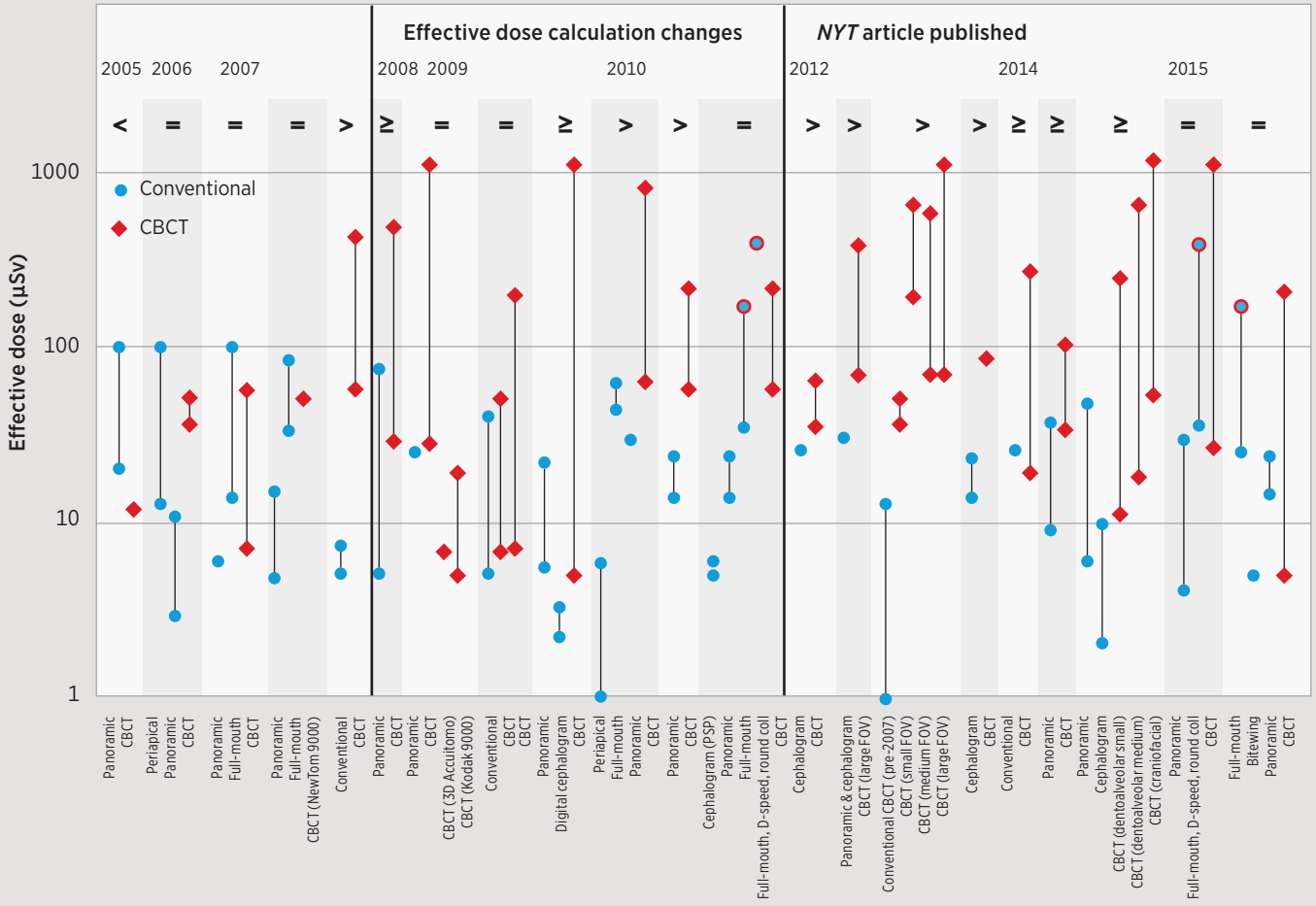
Article collection

Articles introducing CBCT were collected from peer-reviewed journals and professional magazines, news sites, and blogs. Because this analysis is part of a larger study of the US dental profession, the literature search included US-authored, English language, peer-reviewed journal articles published after 1999 and either indexed in Web of Science and published in journals classified as "dentistry oral surgery medicine" or published in US dentistry journals indexed in PubMed.

Aligned with the classification used by De Vos et al, introductory articles were defined as those that did not present the results of a study but rather provided the reader with an overview, introducing the new technology of CBCT.[15] Because CBCT is the focus of such papers, their titles should contain the words *cone beam* or *CBCT* or *imaging* (not *magnetic resonance*). Among articles that met these criteria, introductory articles were identified by the generality of the words in their titles: *endodontics, implants, orthodontics*. In comparison, nonintroductory articles had a narrow focus (such as *mandibular kinematics* or *mesiodistal angulation*) or reported the results of a study, identified by the presence of these words in the title: *accuracy, analysis, comparison, study, bone, root*, or *maxillary*. Articles reporting new guidelines, literature reviews, and articles that did not mention *radiation dose* were discarded. After exclusion of the articles that did not meet the inclusion criteria, 39 peer-reviewed journal articles were found to be eligible for analysis (Chart 1).

Articles from professional magazines, news sites, and blogs were collected during 2016 by scraping all available articles from the websites of the following US-based professional magazines

Chart 4. Effective radiation dose ranges reported in peer-reviewed journal articles.[a]



Abbreviations: CBCT, cone beam computed tomography; coll, collimation; FOV, field of view; *NYT*, *The New York Times*; PSP, photostimulable phosphor.

[a]Peer-reviewed journal sources are listed in Table A of the Appendix, available online at agd.org/general-dentistry.

The vertical rules indicate 2 relevant events: the 2007 change in calculation of effecive dose, which raised the values for dental imaging, and the 2010 publication of an article in *The New York Times* that was critical of the discussion of radiation risk in the professional literature.

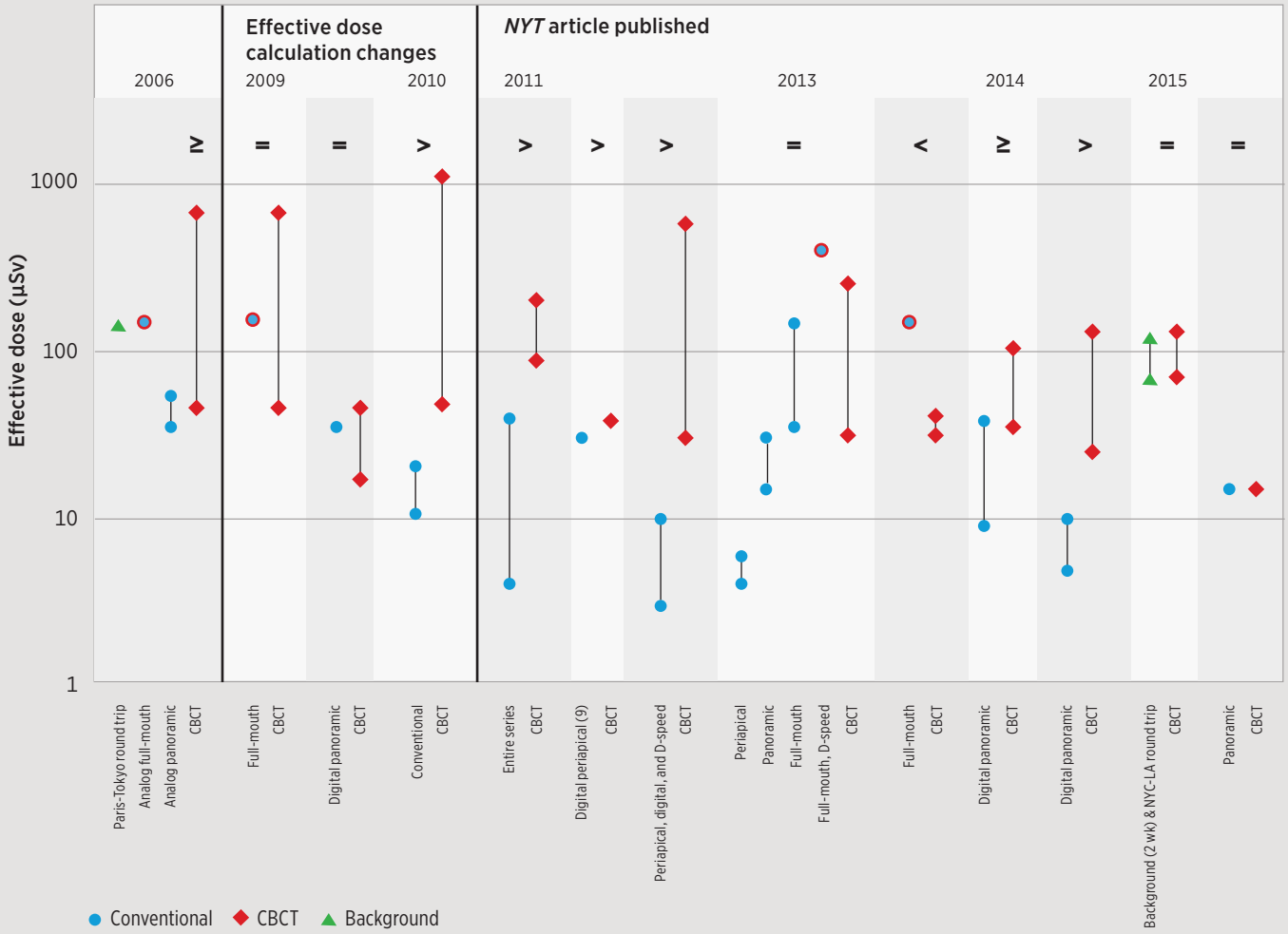
The vertical axis is logarithmic, meaning the distance from 1 to 10 is the same as the distance from 10 to 100 and from 100 to 1000.

and news sites: *Dentistry Today, Inside Dentistry, Dr. Bicuspid,* and *Modern Dental Network*. In total, 15,789 articles published from 2006 to 2016 were found. In addition, *Dentaltown* blogs were collected (4836 articles). Finally, blogs by US practicing dentists who discuss clinically relevant material were collected; 25 blogs containing 19,286 posts were found. Among these 39,911 articles, CBCT articles were identified by searching for titles or text containing these strings: *cone beam* or *CBCT*. These CBCT articles were examined and were discarded if they were about a conference, training, or promotion of a device or only mentioned CBCT in passing, leaving 435 posts. From these, articles and posts that included at least 1 of 3 terms—*dose, sievert,* or *Sv*—were extracted, and false positives were eliminated (eg, articles containing matching letter strings, such as *Louisville*). In total, 45 articles from the media outlets and 4 blogs (*Dentaltown* blogs, *The Dental Geek*, *The Endo Blog*, and *Ask Dr. Spindel*) contained these terms and were found to be eligible for analysis (Chart 2). Hereafter, the sources of these articles are referred to as *professional media* or *media*.

Quantitative and qualitative dose comparisons

Effective dose is the unit in which CBCT dosimetry is discussed. The international unit for effective dose is the sievert (Sv), which represents a 5.5% chance of developing cancer. The radiation dose of CBCTs is expressed in microsieverts (µSv): 1 µSv = 0.000001 Sv. Data collection for the study involved searching all 84 peer-reviewed and professional media articles for mentions of *dose, sievert*, and *Sv*. The highest and lowest reported effective dose values for CBCT and conventional dental radiography were recorded. Statements drawing conclusions about whether CBCT radiation dose was greater than, equal to, or less than that of conventional dental radiographs were also noted.

Chart 5. Effective radiation dose ranges reported in professional media articles.[a]



Abbreviations: CBCT, cone beam computed tomography; LA, Los Angeles; NYC, New York City; *NYT, The New York Times.*

[a]Professional media sources are listed in Table B of the Appendix, available online at agd.org/general-dentistry.

The vertical rules indicate 2 relevant events: the 2007 change in calculation of effecive dose, which raised the values for dental imaging, and the 2010 publication of an article in *The New York Times* that was critical of the discussion of radiation risk in the professional literature.

The vertical axis is logarithmic, meaning the distance from 1 to 10 is the same as the distance from 10 to 100 and from 100 to 1000.

The analysis had 2 parts: quantitative and qualitative. In the quantitative analysis, the ranges given for CBCT and conventional radiation dose were compared. The qualitative analysis tabulated statements that detailed whether the CBCT radiation dose was greater than, equal to, or less than that of conventional dental radiography. It is important to note that none of the statements were in error. Different conclusions about the relative radiation dose of CBCT versus conventional radiographs are the product of different ways of constructing the comparison.

Of the 84 eligible articles, 6 journal articles and 16 media articles were excluded from both analyses because their conclusions were ambiguous, acknowledged a wide dose variation, or provided only a few device dose numbers. Of the remaining 62 sources, 21 journal articles and 13 media articles reported maximum and minimum effective dose values for both CBCT and conventional radiography and were included in the quantitative analysis. In addition, 21 journal articles and 19 media articles drew unambiguous conclusions about the comparison between the radiation dose of CBCT and conventional dental radiography and were included in the qualitative analysis. Nine journal articles and 3 media articles were included in both analyses. Thus, 33 peer-reviewed articles from 21 journals and 29 media articles from 4 commercial channels and 4 blogs were analyzed.

Results

Canonical radiation dose values

Chart 3 displays canonical values for CBCT and conventional dental radiographs as well as values for 1 year of natural background radiation and the radiation exposure on round trip flights between New York and Los Angeles and between Paris

Table 1. Conclusions (No.) of articles comparing effective radiation doses of CBCT and conventional dental radiography.[a]

	Quantitative comparison		Qualitative comparison	
Conclusion[b]	Journal[c]	Media[d]	Journal[c]	Media[d]
< or ≤	1	1	5	3
=	8	5	9	3
> or ≥	12	7	7	13
Total	21	13	21	19

Abbreviation: CBCT, cone beam computed tomography.

[a]Journal and professional media sources are listed in the Appendix, available online at agd.org/general-dentistry.

[b]Conclusion about CBCT radiation dose compared to that of conventional dental radiography.

[c]Peer-reviewed journal articles. Overlapping ranges of CBCT and conventional doses were coded as "less than or equal to" or "greater than or equal to" values.

[d]Professional media, including professional magazines, clinically oriented news sites, and blogs written by clinicians for clinicians. Statements asserting that the CBCT effective dose is equal to that of a few conventional radiographs were coded as "greater than or equal to" conclusions.

and Tokyo.[14,17-20] Although the radiation dose from most conventional radiography is less than 50 μSv, it is possible to expose patients to much higher effective doses (between 150 and 400 μSv) if conventional equipment and less than state-of-the-art film (round collimation; D-speed film) are used. Of course, it is also possible to choose those high values as the comparison to the CBCT dose in discussions of relative doses.

Of the many parameters affecting CBCT effective dose that can be varied, Chart 3 shows 2: field of view (small, medium, or large) and the region imaged (maxilla or mandible). For each, the data recorded in the meta-analysis of Ludlow et al are plotted.[14] While the mean values of CBCT effective dose exceeded the effective doses of state-of-the-art conventional radiographs, the wide range of CBCT dose values published in the literature provides ample scope for any author to reference figures that support any conclusion.

Quantitative dose comparisons

Chart 4 presents the maximum and minimum values of effective dose for CBCT and conventional radiographs reported in introductory CBCT articles in peer-reviewed journals. Chart 5 provides the same information for articles in professional media. A list of the analyzed journal and professional media sources is provided in an Appendix, available online at agd.org/general-dentistry.

The canonical data presented in Chart 3 suggest that reasonable representative values for conventional imaging could range from less than 10 μSv to as high as 50 μSv. Reasonable representative values for CBCT would be means ranging from 80 to 200 μSv. However, values straying far outside these bounds were reported in both peer-reviewed journals and professional media. Some articles even compared full-mouth and D-speed film exposures to CBCT doses.

Comparisons of the dose ranges were tabulated, and overlapping ranges of CBCT and conventional doses were coded as "less than or equal to" or "greater than or equal to" values (Table 1). The majority of both peer-reviewed journal articles (57%) and professional media articles (54%) concluded that the effective radiation doses of CBCT are greater than those of conventional radiographs.

Qualitative dose comparisons

In the qualitative analysis, statements drawing conclusions about the comparative value of CBCT and conventional radiation doses were assessed (Table 1). Such statements were present in 21 journal articles and 19 professional media references. Statements asserting that the CBCT effective dose is equal to that of a few conventional radiographs were coded as "greater than or equal to" conclusions. Among the journal articles, 24% concluded that CBCT doses are less than those of conventional radiographs, 43% reported equal doses, and 33% concluded that radiation doses associated with CBCT are greater than those of conventional radiographs. The majority of professional media articles (68%) concluded that CBCT radiation doses are greater than those of conventional radiographs.

Combined results

In 3 of the 4 analyses (qualitative and quantitative for both peer-reviewed and media articles), more than half the articles concluded that the radiation doses of CBCT exceed those of conventional dental radiography; the exception was the qualitative analysis of peer-reviewed journal articles. A 2-tailed t test assuming equal variances suggested that the probability that the articles were drawn from the same distribution was greater than 10%, meaning that there was no difference between journal and professional media articles in how conservatively they reported CBCT radiation doses in relation to conventional radiography doses (quantitative analysis: $t = 0.10$, $P = 0.92$; qualitative analysis: $t = -1.43$, $P = 0.16$).

When the 2 analyses were combined, the number of articles became large enough to examine the question of whether the publication in 2010 of a *NYT* article critical of misinformation about CBCT safety influenced authors of introductory articles to be more conservative in their conclusions. Table 2 reports

Table 2. Conclusions (No.) of articles comparing effective radiation doses of CBCT and conventional dental radiography before and after publication of a 2010 *NYT* article.[16,ab]

	Journal[d]			Media[e]		
Conclusion[c]	Before	After	Total	Before	After	Total
< or ≤	3	1	4	1	3	4
=	11	1	12	3	5	8
> or ≥	7	7	14	5	12	17
Total	21	9	30	9	20	29

Abbreviation: CBCT, cone beam computed tomography.

[a]Journal and professional media sources are listed in the Appendix, available online at agd.org/general-dentistry.

[b]The 2010 article in *The New York Times* was critical of the discussion of radiation risk in the professional literature.

[c]Conclusion about CBCT radiation dose compared to that of conventional dental radiography.

[d]Peer-reviewed journal articles. Overlapping ranges of CBCT and conventional doses were coded as "less than or equal to" or "greater than or equal to" values.

[e]Clinical media, including professional magazines, clinically oriented news sites, and blogs written by clinicians for clinicians. Statements asserting that the CBCT effective dose is equal to that of a few conventional radiographs were coded as "greater than or equal to" conclusions.

the conclusions of articles published before and after the *NYT* article. Three journal articles (1 before and 2 after the *NYT* article) that included both qualitative and quantitative analyses were deemed to have drawn contradictory conclusions from their qualitative statements and quantitative data. These studies were excluded from this combined analysis.

Before publication of the *NYT* article, fewer than half of journal articles (33%) concluded that CBCT radiation doses are greater than those of conventional radiography. After the *NYT* article, the majority of journal articles (78%) concluded that CBCT radiation doses exceed doses of conventional radiography, suggesting that authors of peer-reviewed journal articles were more conservative in assessing the risks associated with CBCT radiation doses after publication of the *NYT* article. Authors of media articles were less influenced, with a majority concluding that CBCT radiation doses are higher than those of conventional radiography both before (56%) and after (60%) publication of the *NYT* article. A 1-tailed *t* test suggests that reporting of doses changed for journal articles ($t = -1.82$, $P = 0.04$) but not for professional media articles ($t = -0.23$, $P = 0.41$) after the *NYT* article.

Discussion

This study used reported comparisons between CBCT and conventional radiography effective radiation doses as markers for the accuracy of information in peer-reviewed and professional media sources. Nonscholarly sources for such articles have proliferated over the past decade, providing more accessible and practice-relevant resources for dentists seeking clinical information. In 2001, the US Food and Drug Administration approved the first CBCT scanner for the US market. Its use in dentistry began to grow in the years 2006-2007 with the first educational sessions on CBCT at the 2006 Annual Session of the American Dental Association.[21] Contemporaneously, electronic media emerged, with the first dental blogs and *Dentaltown* appearing in 2000, *Inside Dentistry* in 2005, *Dr.Bicuspid.com* in 2007, and *Modern Dental Network* in 2012.[4,22]

The rise of electronic media brought increased awareness of the importance of credibility in medical information sources. As such, the validity of claims made in dental advertisements has been evaluated and found to be lacking, paralleling a similar circumstance in medicine.[23-27] Many studies have evaluated the credibility of information about various conditions that patients might find in an internet search and found that the quality was variable.[28-39] Six studies investigated the accuracy of clinical information on websites for patients.[40-45] In these studies, clinicians devised lists of items that should appear in any discussion of a condition and then scored websites based on how many of these items appeared. Five studies concluded that most websites presented low-quality information, and 1 study concluded that 20%-30% of sites offered good-quality information. Electronic media are also seen as beneficial, however, in that information access is broadened and disparities in knowledge between clinicians and patients are reduced, although information that a patient may glean from a website may be poor.[46] The present study extended this line of inquiry by examining information for clinicians.

In addition to concerns about the quality of information on electronic media, serious questions have been raised about the reproducibility of previously unimpeachable, peer-reviewed literature.[47-49] This recent questioning adds to long-standing credibility concerns connected with industry sponsorship. The 2010 *NYT* article singled out the flagship peer-reviewed *Journal of the American Dental Association* as well as the Association's annual meeting for, respectively, publishing a special section underwritten by a manufacturer and, in a conference saturated with demonstrations by CBCT manufacturers, presenting a panel on CBCT in which 3 of 4 panelists had received payments from manufacturers.[16]

It is possible that the proliferation of new information sources makes dentists vulnerable to misinformation, but the

present analysis is reassuring. There was no evidence that professional media differed in their presentations of the relative risks of CBCT and conventional radiography. The reliability of peer-reviewed articles is increasingly questioned, and indeed both peer-reviewed and professional media articles were found to espouse the minority position that CBCT radiation risk is lower than that of conventional radiography. There is evidence that a high-profile discussion of CBCT radiation dose in the *NYT* may have prompted more conservative conclusions about CBCT radiation doses to be drawn in peer-reviewed journal articles.

This study is unique in examining clinically relevant information written for clinicians. Other studies of the accuracy of medical information examine websites aimed at patients. The focus on dentistry and these information sources is also unique to the best of the authors' knowledge. This study also differs in that it examined the conclusions drawn in articles rather than scoring articles on a checklist of topics covered. However, this method required a narrow focus. There are many other dimensions that could be examined, even in articles introducing CBCT to dentists.

Conclusion

Easily accessible electronic professional media now provide a wide range of clinically relevant information for dentists in addition to the more traditional commercial information about product costs and buyer guidelines for product use. The present study found no evidence that professional electronic media are less accurate than peer-reviewed journal articles in discussion of CBCT relative radiation doses. Based on the current analysis, professional electronic media should not be ignored or dismissed as possible sources of accurate information in clinical dentistry. Newer information providers serve the dental profession in a responsible fashion and draw on the peer-reviewed literature, often very quickly. The greater variety of information sources provides opportunities for a greater volume of relevant information to be better contextualized for practicing dentists than may be done in peer-reviewed journals. Future research should investigate whether this conclusion holds in other clinical areas and examine how information gleaned from these sources combines with peer-reviewed material to shape decision-making by clinicians.

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Appendix

Additional supporting material, including a list of the analyzed journal and professional media sources and summaries of their conclusions, is available online at agd.org/general-dentistry.

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Disclaimer

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Immediate restoration after mineral trioxide aggregate pulpotomy with amalgam condensation: an in vitro study

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Mineral trioxide aggregate (MTA) pulpotomy may be an alternative to root canal therapy, with reported success rates as high as 85%. However, little technique-specific information has been reported regarding MTA placement in 1 visit. The purpose of this study was to evaluate different placement methods for MTA and resin-modified glass ionomer (RMGI) cement before immediate restoration with amalgam. Forty pulpotomized extracted third molars were randomly divided into 4 groups, and moist cotton was used to simulate pulp tissue in all teeth. In group 1, cotton was placed over the entire pulp chamber floor and in each canal orifice, and MTA was placed over the cotton. The procedure for group 2 was the same as that for group 1 except that a layer of RMGI was placed over the MTA. In group 3, cotton was placed in the canal orifices only, a layer of MTA was placed only over the cotton in the orifices, and RMGI was layered over the MTA and pulp chamber floor. The procedure for group 4 was the same as that for group 3 except that RMGI was placed over the MTA but not on the pulpal floor. Each of these procedures was followed by amalgam condensation. After a 7-day setting period, restored teeth were sectioned mesiodistally, photographed, measured, and evaluated for disturbance of the MTA-restoration junction. The study findings showed that the MTA layer was disturbed in 40% of the specimens in group 1, whereas 10%-20% of specimens in groups 2 through 4 demonstrated disturbed MTA. Analysis with a Pearson chi-square test indicated that the difference between group 1 and groups 2 through 4 was statistically significant ($P < 0.05$), but there was no significant difference ($P > 0.05$) between groups 2, 3, and 4. Group 3, in which MTA was placed over each canal orifice and RMGI was placed over the entire pulpal floor, performed best—only 10% of specimens exhibited deformed MTA. The findings suggest that RMGI may protect initially placed MTA during amalgam condensation.

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With the introduction of mineral trioxide aggregate (MTA) and the advances in regenerative endodontics, there has been a renewed interest in vital pulp therapy, as the procedure has been shown to be more predictable with the use of MTA.[1-3] Numerous studies have investigated the significant benefits of MTA, including its antibacterial, antifungal, and positive healing properties as well as its sealing capability and minimal irritation to the pulp.[4-7] MTA also has the ability to induce odontoblastic differentiation when in contact with dental pulp cells.[8,9]

In symptomatic carious vital teeth, MTA pulpotomy may be a useful alternative to root canal therapy or tooth extraction.[10-13] Conventional root canal therapy may not be ideal in the following situations: the tooth has an immature apex, the patient is uncooperative, or the cost of treatment is prohibitive. An immature apex is frequently encountered in children. By preserving the pulp tissue in the canal and, hence, its vitality, pulpotomy allows the root to mature, thereby increasing the chance of long-term function.[14]

In mature teeth, root canal therapy may involve lengthy appointments and multiple visits, which may be challenging for certain patients, particularly younger individuals who may experience heightened stress. As a result, these patients may not return for required follow-up visits, which may compromise treatment or, worse, introduce the potential for development of a serious secondary infection.

Finally, cost may be a factor in treatment decisions. Often, parents have no other choice but tooth extraction for their child because they cannot afford conventional root canal therapy. In contrast to the multivisit and lengthy appointments needed for root canal therapy, vital MTA pulpotomy can be accomplished in 1 appointment at significantly less cost by using amalgam or composite resin as the final restoration.[15,16] The success rate of vital pulpotomy in cases of carious exposure is also high, with overall success rates ranging from 72.9% to 99.4%.[10] Thus, for vital teeth, pulpotomy with MTA may be a useful alternative to root canal therapy, not only for children but also for young adults.[13]

Traditionally, when MTA was used, the pulpotomy was performed in 2 visits to allow the MTA to set. ProRoot MTA (Dentsply Sirona) requires 4 or more hours to set completely, with the benefit that it "solidifies to form a strong impermeable barrier that fully cures over a four-week period."[17] Although newer, faster-setting calcium silicate cements have become available, ProRoot MTA remains the most tested and biocompatible product.[18]

Two negative aspects of MTA are difficulty in manipulating the material and its tendency to discolor tooth structure.[5,19]

Table 1. Experimental groups (n = 10 per group).

Group	Cotton	MTA	RMGI	Amalgam
1	2 mm placed over entire pulp chamber floor and in each canal orifice	1-2 mm placed over the cotton covering the pulp chamber floor	None: control group	Condensed over MTA, filling pulp chamber
2	2 mm placed over entire pulp chamber floor and in each canal orifice	1-2 mm placed over the cotton covering the pulp chamber floor	1-2 mm placed over MTA	Condensed over RMGI, filling pulp chamber
3	Placed in each canal orifice only	1-2 mm placed over the cotton in the canal orifice area	1-2 mm placed over MTA and entire pulp chamber floor	Condensed over RMGI, filling pulp chamber
4	Placed in each canal orifice only	1-2 mm placed over the cotton in the canal orifice area	1-2 mm placed over MTA only; none on pulp chamber floor	Condensed over RMGI and pulp chamber floor, filling pulp chamber

Abbreviations: MTA, mineral trioxide aggregate; RMGI, resin-modified glass ionomer.

However, discoloration of posterior teeth is not a concern if crown coverage is indicated.

A 2012 study showed that resin-modified glass ionomer (RMGI) cement could be applied over MTA immediately, with minimal effects, before placement of the permanent restoration.[20] This approach allowed vital pulpotomy using MTA to be completed in 1 visit. The RMGI layer prevented the MTA from being dislodged into the pulp tissue during the final restorative procedure, especially if amalgam—and its mechanical condensation—was used. Witherspoon recommended that RMGI be used to cover and protect the MTA for a 1-visit vital pulpotomy.[16] Eid et al reported that RMGI could be applied over freshly mixed MTA with minimal effects on the MTA or the MTA-RMGI interface.[20]

To the authors' knowledge, no study has been published showing the effect of amalgam condensation on unset MTA with glass ionomer coverage. Is RMGI effective at protecting unset MTA from distortion and preventing damage to underlying pulp tissue during amalgam condensation? The specifics of the protocol with the use of glass ionomer are also unclear: Does RMGI need to cover the entire dentinal floor of the pulp chamber, or just the MTA, which covers the canal orifices only? Thus, the aim of this study, which used an in vitro extracted tooth model, was to (1) observe if any deformation of unset MTA placed over simulated pulp tissue occurred after amalgam condensation, with or without a protective layer of RMGI; (2) determine the mean thickness of the RMGI and MTA layer that resisted the condensation forces of amalgam; and (3) suggest a clinical protocol for placement of MTA in a 1-visit pulpotomy procedure using amalgam as the restorative material.

Materials and methods

Tooth collection

Extracted third molars with intact crowns and no caries were collected in accordance with a protocol approved by an institutional review board. No patient identifiers were associated with the teeth, which were stored at 4°C in 0.9% phosphate-buffered saline with 0.002% sodium azide to inhibit microbial growth. Each tooth was accessed and the tissue was removed from the pulp chamber to the level of the canal orifice; the tooth was then stored in the phosphate-buffered saline solution at 4°C until the start of the study.

Simulated pulpotomy procedures

All restorative procedures were performed using a standard operating microscope in a laboratory hood. The surgical environment was simulated with room temperature conditions and use of a rubber dam.[21] The temperature and humidity were recorded before each procedure. Forty prepared teeth were randomly assigned to 4 groups of 10 teeth each (Table 1).

Group 1 (negative control)

Simulated tissue (shredded and moistened cotton pellet pieces) was placed approximately 2 mm deep across the pulp chamber floor and into each canal orifice. A 1- to 2-mm layer of MTA mixed with sterile water was placed on top of the simulated tissue and spread across the pulpal floor. The tooth was then immediately restored with condensed amalgam (Dispersalloy Dispersed Phase Alloy, Dentsply Sirona), placed according to the manufacturer's instructions.

Group 2

Simulated tissue (cotton) was placed across the pulp chamber floor, and a 1- to 2-mm layer of MTA was placed on top and spread across the floor. This step was followed by placement of a 1- to 2-mm layer of RMGI (Vitrebond, 3M ESPE) on top of the MTA; the RMGI was then light cured for 30 seconds. The tooth was then restored with condensed amalgam.

Group 3

Simulated tissue (cotton) was positioned in the canal orifices only, and then a 1- to 2-mm layer of MTA was placed only over the simulated tissue in the orifices. A 1- to 2-mm layer of RMGI was then placed over the MTA and across the pulpal floor and light cured for 30 seconds. As in the other groups, teeth in group 3 were restored with condensed amalgam.

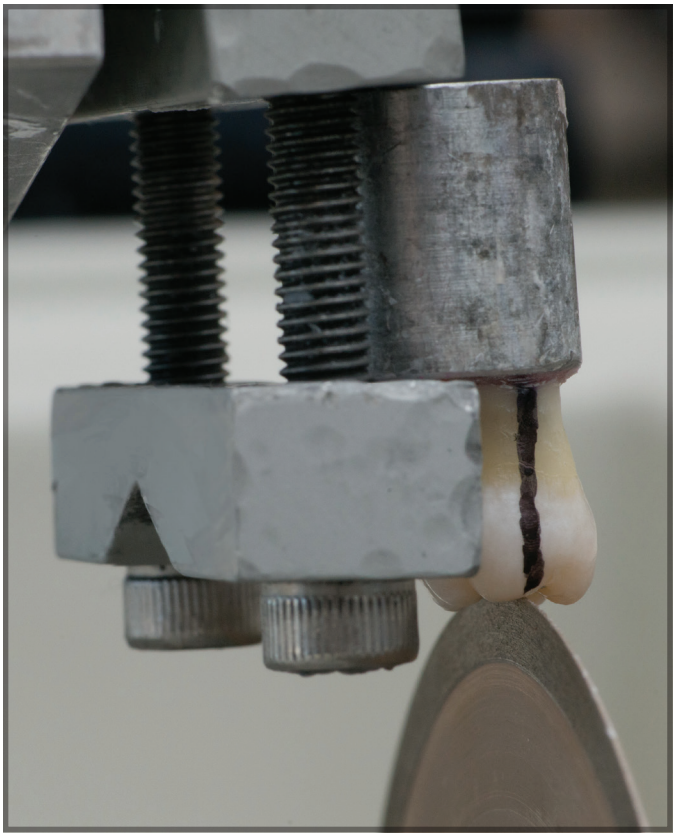

Fig 1. Sectioning of a tooth with a water-cooled diamond blade saw.

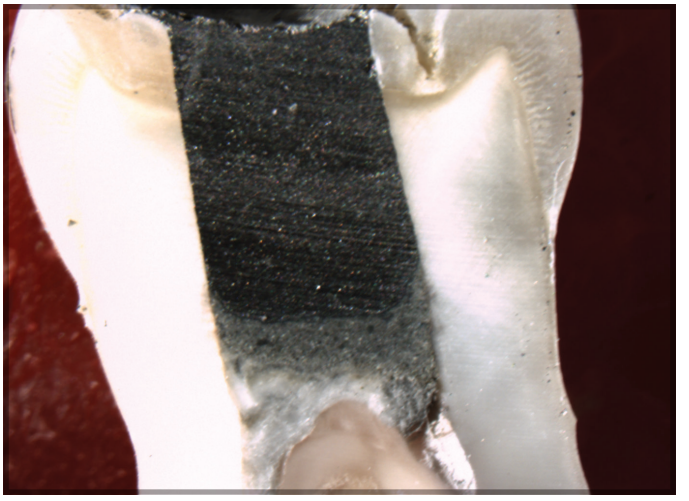

Fig 2. Sectioned pulp chamber filled with amalgam (group 1 specimen). Note the layer of cotton in the canal orifice below the layer of mineral trioxide aggregate (MTA), which was undisturbed (original magnification 1×).

Group 4

Simulated tissue (cotton) was deposited in the canal orifices only, and a layer of MTA, estimated at 1-2 mm in depth, was placed over the canal orifices. A 1- to 2-mm layer of RMGI was then placed only over the MTA in the canal orifices and light cured for 30 seconds. Condensed amalgam was then used to restore the tooth.

Preliminary data collection

Before any experimental data were collected, amalgam condensation force was measured and calibrated by means of multiple trial runs on a prepared tooth on multiple days until a consistent condensation force with minimal variation was established. The tooth was mounted in acrylic and placed in a jig that was approximately the same size as the acrylic block. This apparatus was stabilized by 4 screws and polyvinyl siloxane impression putty placed on a force plate that was attached to a digital scale with an accuracy of 0.1 g. Each condensed force was recorded until the amalgam restoration was completed on the mounted tooth. Based on the preliminary testing and calibration, the mean force used for amalgam condensation was 450 g.

Interface analysis

Following a 7-day setting period in 100% humidity at 37°C, the apical two-thirds of the roots of each tooth were removed with a high-speed diamond bur, and a line was drawn across the 2 largest canals before tooth sectioning. For maxillary molars, the line typically was drawn from the mesiobuccal canal to the palatal canal. For mandibular molars, the line typically was drawn from the mesiobuccal canal to the distal canal. Each specimen was sectioned along the drawn line with a precision sectioning saw (IsoMet 1000, Buehler) with a water-cooled diamond blade (Fig 1).

The cut sections were photographed under a light microscope (E800, Nikon) at 1× magnification to which a digital camera was attached (Nikon SMZ 1500) (Fig 2). The width of the narrowest section of the RMGI layers in groups 2 through 4 and of the MTA layer in group 1 was measured using a computer-based system (Analysis image processing software, v 3.1, Soft Imaging System) (Fig 3). The photographs were used to evaluate the MTA-RMGI. A interface to determine whether the interface was intact (score 0) or the interface and simulated pulp tissue were deformed (score 1).

Results

Analysis revealed that the MTA layer was deformed in 40% of specimens in group 1, which was the control group with no RMGI layer. In contrast, the MTA layer was deformed in 10%-20% of specimens in groups 2 through 4, which had RMGI layers of varying configurations (Table 2). Based on frequency distributions and a Pearson chi-square test, there was a significant difference ($P < 0.05$) between group 1 and the other 3 groups but no significant difference ($P > 0.05$) between groups 2 through 4. However, it is worth noting that group 3, with MTA over each canal orifice and RMGI over the entire pulpal floor, performed best; only 10% of specimens exhibited deformed MTA.

The mean measurement of the narrowest portion of RMGI in specimens that had an intact (score 0) MTA-RMGI interface was 0.43 mm; in contrast, the mean measurement of the narrowest portion of RMGI in specimens with a deformed (score 1) MTA-RMGI interface was 0.16 mm. For specimens with an MTA-amalgam interface (group 1), the mean measurement of the narrowest portion of MTA in specimens with a score of 0 was 1.19 mm; those with a score of 1 had a mean MTA layer thickness of 0.57 mm.

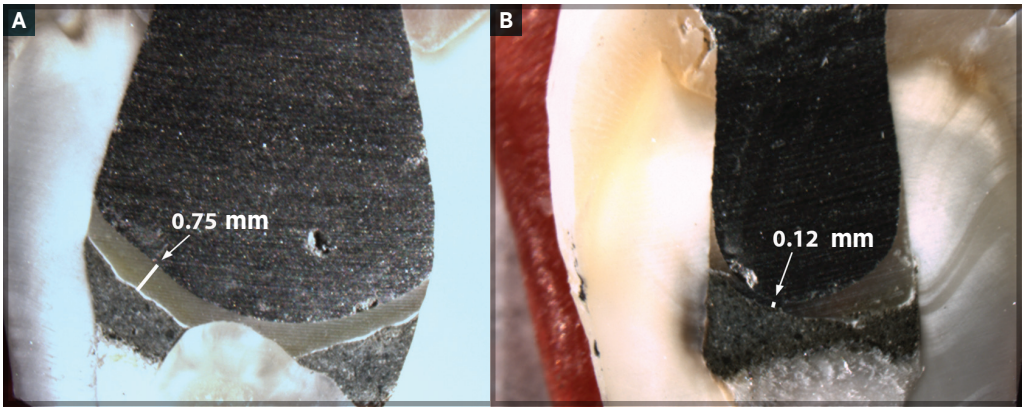

Fig 3. Measurement of resin-modified glass ionomer (RMGI) layer on tooth specimens (original magnification 1×). The white line indicates the narrowest section of RMGI. The arrow points to the measurement of that white line. A. Intact MTA-RMGI interface (score 0). B. Deformed MTA-RMGI interface (score 1).

Table 2. Frequency distribution (%) of intact (0) and deformed (1) interfaces.

	Score	
Group	0	1
1[a]	60	40
2	80	20
3	90	10
4	80	20

[a] Statistically significant difference from the other 3 groups ($P < 0.05$; Pearson chi-square test).

Discussion

The current protocol for MTA vital pulpotomy suggests the use of composite resin as the final restorative material.[1-4,10,11,16] To the authors' knowledge, no studies in the literature mention amalgam as the final restorative material for MTA vital pulpotomy. As a result, although numerous studies have demonstrated the success of MTA in vital pulp therapy, none has reported the exact thickness of the RMGI layer needed to protect the MTA layer under amalgam condensation for 1-visit treatment. Amalgam is an excellent material for restoration of posterior teeth because of its compressive strength, longevity, and simplicity of placement compared with composite resin.[15,22]

Under the conditions of this in vitro study, amalgam condensation over unset MTA was achieved during vital pulpotomy procedures. The results showed no statistically significant difference between groups 2 through 4 as long as some type of RMGI layer was applied to protect the MTA layer before amalgam condensation. The average success rates for these groups were between 80% and 90%. The mean thickness of the RMGI layer was 0.43 mm in specimens with intact interfaces in groups 2 through 4; although the initial intention was to place a 1- to 2-mm layer of RMGI, these findings indicate that a thinner layer is acceptable. Further, the study results suggested that the MTA remained undisturbed as long as the RMGI layer was at least 0.43 mm thick.

The higher than expected success rate of 60% in group 1 (MTA only) was also surprising. However, specimens in group 1 with a score of 0 (intact) had a mean MTA layer thickness of 1.19 mm, whereas those with a score of 1 had a mean MTA layer thickness of 0.57 mm. These results suggest that perhaps amalgam can be condensed on top of MTA without the intermediary layer of RMGI as long as the MTA layer is at least 1.19 mm in thickness. However, these results do not account for the moisture content in MTA and its potential effect on amalgam setting.

One limitation of the present study is that the measurements were performed on a macrostructural level using photographs obtained with a light microscope. Perhaps an expanded study using scanning electron microscopic analysis would validate these findings. Moreover, the use of dichotomous scores of 0 and 1 to rate intact or deformed interfaces might be too simplistic; a more technologically advanced approach to assigning scores would increase the precision of a future study.

The results of this in vitro study showed that amalgam can be used successfully as a final restoration after MTA vital pulpotomy as long as the aforementioned MTA or RMGI thickness criteria are met. However, further studies with a larger sample size are needed to confirm these findings.

Conclusion

The low percentage of deformed interfaces in this extracted tooth model suggests that RMGI may protect unset MTA during amalgam condensation after vital pulpotomy, regardless of the manner in which the RMGI is applied—over the MTA covering the pulp stumps only or additionally across the pulp chamber floor. Based on the results of this study, a minimum RMGI thickness of 0.43 mm is recommended to protect against the force of amalgam condensation. If MTA is used without a layer of RMGI under the amalgam restoration, a minimum MTA thickness of 1.19 mm is suggested.

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Disclaimer

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Prevention and management of life-threatening complications during dental implant surgery: a clinical case series

Raid Sadda, DDS, MS, MFDRCSI ■ Aram R. Sadda, DDS, MS

Complications can occur during implant placement; thus, clinicians should be aware of all potential outcomes, and staff members should be fully prepared to respond in case of emergency. A thorough medical history, precise surgical technique, knowledge, and skill are essential to prevent complications. The most serious complications, which could threaten the patient's life, are airway obstruction, bleeding, aspiration of the implant or its parts, infection, cavernous sinus thrombosis, nerve injury, and mandibular fracture.

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Key words: airway, aspiration, bleeding, cavernous sinus thrombosis, dental implant, mortality

The purpose of this case series is to discuss options for prevention and management of complications associated with surgical implant placement. Many of these complications can be resolved without serious problems. However, the most serious complications, which can be life-threatening, are airway obstruction, bleeding, aspiration of the implant or its parts, infection, cavernous sinus thrombosis, nerve injury, and mandibular fracture.

The 4 cases presented in this article were chosen on the basis of the following criteria. First, each case had the potential to threaten the patient's life, either intraoperatively or postoperatively. Selection criteria were based on the severity and urgency of the situation, with an emphasis on hemorrhage, airway obstruction, and cavernous sinus thrombosis (CST). Second, all patients were classified as ASA I according to the American Society of Anesthesiologists system and were otherwise healthy, with no morbidities that would contraindicate implant placement.[1] Third, there were no mortalities as a result of the complications.

Management options for each of these cases, including existing techniques as well as new methods for prevention and management, are described.

Case reports

Case 1

A 62-year-old man was referred to the Department of Oral and Maxillofacial Surgery for stage 2 implant surgery. The patient denied having any significant medical history, and the results of the physical examination were within normal limits. Surgery was performed under local anesthesia (2% lidocaine with 1:100,000 epinephrine).

During the procedure, the implant screwdriver was lost inside the patient's mouth, but he was unsure if he swallowed or aspirated it. The patient was immediately referred to the hospital, where a chest radiograph revealed the screwdriver in the lung (Fig 1). The patient was admitted to the hospital. Under general anesthesia, an attempt was made to remove the screwdriver with a bronchoscope. However, the procedure failed, and open chest surgery was performed. A few days after surgical removal of the screwdriver, the patient was discharged from the hospital and scheduled for regular follow-up visits. No postoperative complications developed.

This patient was unable to determine if he swallowed or aspirated the implant screwdriver. Extreme caution should be taken by clinicians when handling implants and their components inside the mouth. If the implant or its

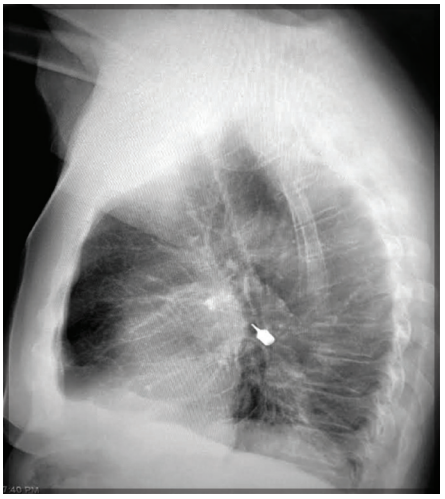

Fig 1. Case 1. Chest radiograph showing aspiration of a screwdriver in the chest.

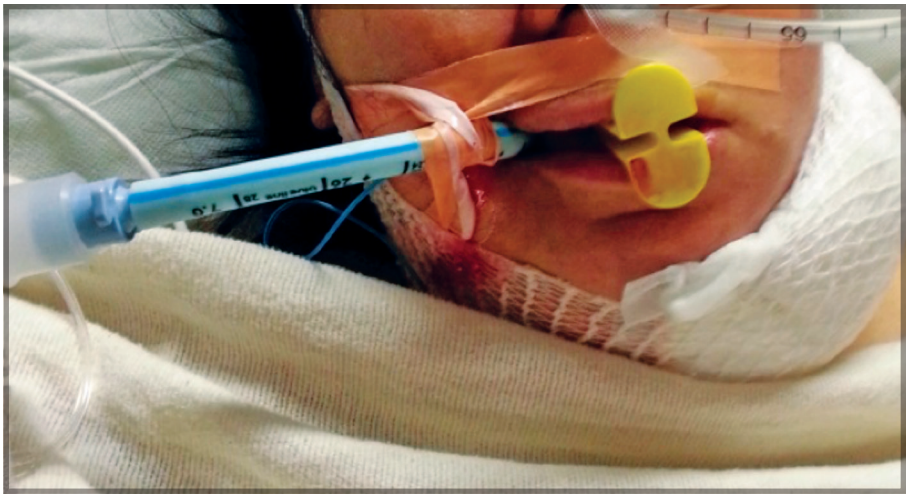

Fig 2. Case 2. Insertion of the endotracheal tube. (Courtesy of Dr Ed Miller, Hartsdale, New York.)

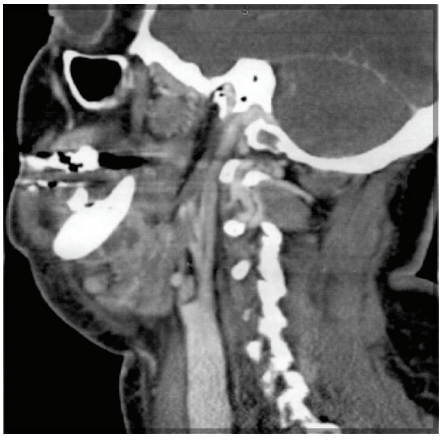

Fig 3. Case 2. Computed tomographic scan showing the sublingual and submandibular hematoma.

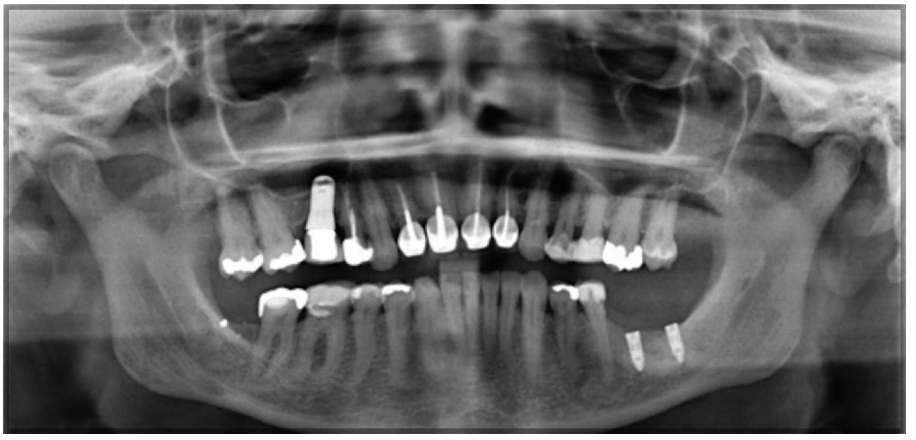

Fig 4. Case 2. Panoramic radiograph showing 2 implants and the perforation of the lingual plate.

components move from the floor of the mouth to the larynx, acute airway obstruction can result, or the object can settle in the bronchus or lung. Management becomes a burden to the patient and surgeon, leading to further complications that require more extensive treatment.[2]

To avoid this outcome and the consequent complex management, gauze should be placed as an oropharyngeal screen before insertion of the implant or its components. Most implant components accommodate placement of a floss ligature to allow retrieval of the device. Although patients may not be able to identify an aspirated implant component, the operator can use the ligature to retrieve it.

If the patient aspirates an implant or a component, he or she should be referred to the hospital immediately for chest and abdominal radiography to verify ingestion or aspiration and to localize the object. If the components are aspirated, they should be removed within 24 hours; otherwise, bronchoscopy will be more difficult, leading to further chest complications, such as infection. If bronchoscopy is unsuccessful, open chest surgery is necessary to remove the device.

Case 2

A 35-year-old woman was referred to the Department of Oral and Maxillofacial Surgery with a complaint of difficulty breathing. The patient denied having any significant medical history. Physical examination of the floor of the mouth revealed marked erythema and enlargement. The intraoral examination showed signs of a large sublingual hematoma extending to the submandibular region and moderate-to-severe airway obstruction.

The patient was transferred immediately to the hospital intensive care unit. Under sedation, an endotracheal tube was inserted to prevent airway compromise (Fig 2). A computed tomographic (CT) scan revealed a severe sublingual and submandibular hematoma (Fig 3). A panoramic radiograph confirmed perforation of the lingual plate of the left mandible at the site of implant surgery (Fig 4). Monitors were used to record the patient's vital signs, and intravenous antibiotics were administered. Under general anesthesia, an extraoral incision was made, and the hematoma was evacuated through the insertion of multiple drains. The patient tolerated the procedure well. She was discharged from the hospital a few days later and

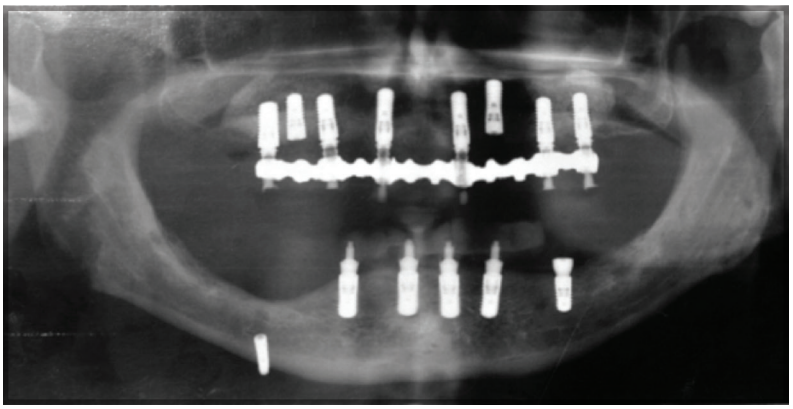

Fig 5. Case 4. Panoramic radiograph showing the implant in the submandibular space.

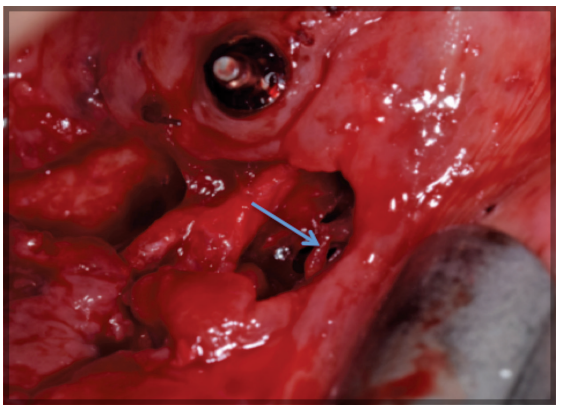

Fig 6. Case 4. Localization of the mental nerve (arrow).

attended regular follow-up visits for further evaluation. No postoperative complications occurred.

The arterial blood supply to the floor of the mouth is formed by anastomosis of the facial and lingual arteries. Intraosseous hemorrhage is not a serious event and can be controlled by compressing the area with a directional indicator, an abutment, or the implant itself.[3] Injury to the blood vessels may occur after surgical manipulation or tearing of the lingual periosteum, and such injuries can lead to severe airway obstruction that requires endotracheal intubation or emergency tracheotomy.[4]

Applying a pressure pack, hemostatic agents, cauterization, digital compression, or ligation of the bleeding vessel can control hemorrhage of ruptured maxillofacial blood vessels. The clinician should avoid making an incision over the hematoma because it may lead to further bleeding. Exploration of the external carotid artery to ligate the lingual or facial artery is contraindicated because of the collateral anastomosis; injury to this area can jeopardize the patient's life.[5] The surgeon must identify and ligate the bleeding artery and then transfer the patient to the hospital without delay to secure the airway.[6]

To prevent life-threatening hemorrhage, it is necessary to expose the lingual plate during surgery or palpate for any perforation of the bone through the soft tissue. If a perforation with severe bleeding is observed during surgery, redirection or removal of the implant is necessary, along with bimanual compression at the site of perforation. If possible, a cone beam CT (CBCT) scan with surgical stent should be used for treatment planning in patients with a narrow mandibular ridge because the correct angle of implant insertion can be calculated, leading to a more predictable outcome. However, implants can be placed without the use of a CBCT scan if the surgeon can visualize the surgical field by reflecting a lingual mucoperiosteal flap.

Case 3

A 38-year-old woman was referred to the Department of Oral and Maxillofacial Surgery for stage 1 surgical placement of a dental implant to replace a missing maxillary right first molar. The patient denied having any significant medical history, and the results of the physical examination were within normal limits.

A panoramic radiograph revealed a distance of 8 mm from the floor of the maxillary sinus to the alveolar crest, indicating the need for a bone graft procedure. Through a crestal approach, a Summers osteotome was used to elevate the maxillary floor for placement of a bone graft and an implant with a length of 10 mm. The procedure was successful, and there were no complications during surgery. No antibiotics were prescribed.

Three days later, the patient returned with a complaint of discomfort and heaviness in the right side of her face. An examination of the mouth showed no swelling or dehiscence of the wound, and a panoramic radiograph revealed a normal sinus. Antibiotics and analgesics were prescribed. Two days later, the patient returned with a unilateral severe headache, erythema of the eye, proptosis, and swelling of the eyelid. The patient was admitted to the hospital and diagnosed with a CST due to infection.

Cavernous sinus thrombosis is an unusual complication that rarely results from an infected tooth or an implant. It is a life-threatening infection that requires aggressive medical and surgical care. However, CST may develop as a consequence of a superiorly spreading odontogenic infection via a hematogenous route. Bacteria from a contaminated implant may travel from the maxilla to the cavernous sinus in 2 ways: posteriorly through the pterygoid plexus and emissary veins or anteriorly via the angular vein and inferior or superior ophthalmic veins.

The clinical signs and symptoms include some or all of the following: redness and swelling of the eyelids, ophthalmoplegia, skin hemorrhage of the nose and eyelid, burning and tingling sensation of the forehead, proptosis, fever, restlessness, and severe headache. A CST is difficult to diagnose from plain film imaging and physical signs. One limitation in diagnosis is the lack of immediate symptoms associated with the infection. In this case, the patient did not have a CST initially but was at great risk of developing one. All follow-up complaints from patients should be taken seriously, and a thorough examination and imaging studies should be performed immediately. Diagnosis depends on the symptoms and clinical signs as well as on careful imaging analysis by experts. Immediate management of a CST requires intravenous antibiotic treatment to prevent the spread of infection.

The greatest obstacle to preventing CST is the lack of a sterile

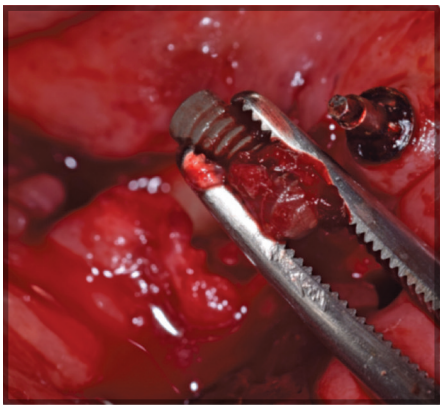

Fig 7. Case 4. Removal of the implant.

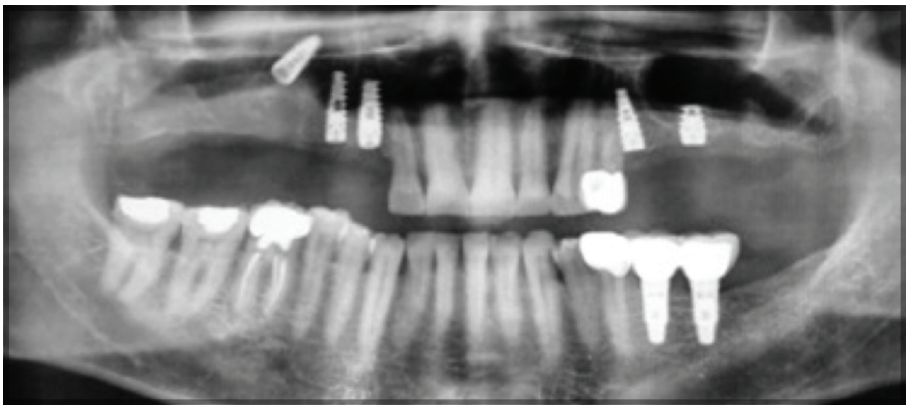

Fig 8. Displacement of the implant into the maxillary sinus during surgery.

field. The oral cavity is not sterile, and, as a result, it is difficult to prevent contamination of the implant and instruments during surgery. The implant and all surgical instruments should be kept sterile until the implant is inserted in the bone. Doing so will greatly minimize the risk of contamination and subsequent development of CST due to infection.

Case 4

A 62-year-old man was referred to the Department of Oral and Maxillofacial Surgery for removal of an implant from the right submandibular space. The implant was displaced to the right posterior atrophic mandible during insertion (Fig 5). The patient denied having any significant medical history, and the results of the physical examination were within normal limits.

Under local anesthesia, a mucoperiosteal flap was raised to localize and protect the mental nerve (Fig 6). The implant was palpated intraorally and extraorally, pushed upward, and then removed with a hemostat (Fig 7). At the 1-week follow-up visit, the patient reported no paresthesia of the lip or tongue, and there was no hemorrhage or airway obstruction.

Direct trauma to the nerve or injury to the blood vessels in the submandibular area could cause paresthesia, severe bleeding, and possible airway obstruction. The major reason for repositioning the inferior alveolar nerve is to prevent injury during implant placement in an edentulous posterior atrophic mandible. In addition, the utmost care should be taken to avoid displacing the implant into the soft tissue or submandibular space. Injury to the lingual artery results in sublingual hematoma and severe airway obstruction. Overpenetration occurs when the lingual or buccal plates are thin, causing the implant to escape the bone marrow and settle in the soft tissue. Immediate removal of the implant is indicated because of potentially fatal outcomes from submandibular space infection and airway obstruction.

When the mandibular width is in question for implant placement, proper radiographic evaluation should take place before surgery. In addition to a panoramic radiograph, a CBCT scan is a great tool for measuring the buccolingual width of the mandible prior to surgery. The appropriate implant size and positioning angle can be calculated, and a surgical stent can be created to guide the operator in proper placement.

Other life-threatening complications

Displacement of the implant into the sinus

A dental implant can easily be displaced into the maxillary sinus in the posterior maxilla during insertion (Fig 8). Immediate implant insertion should be performed only if the residual bone is stable and deep enough to ensure primary stability.[7] When the bone volume and quality are inadequate to support an implant of sufficient length, a bone augmentation procedure of the posterior maxilla should be performed. A wider implant also improves stability and helps to prevent perforation of the maxillary sinus.

A displaced implant in the maxillary sinus can travel farther into the deeper craniofacial cavities, causing an infection, tissue necrosis, and an adverse reaction to the foreign body, along with the risk of foreign body aspiration.[8] Cavernous sinus thrombosis, described in case 3, is the most serious, life-threatening complication.

Excessive force by the operator also can cause implant dislodgment into the maxillary sinus. If this occurs, the implant must be immediately retrieved surgically via an intraoral approach or endoscopically via a transnasal route to avoid inflammatory complications.[9]

Migration of the implant into the sinus

Migration of the implant into the maxillary sinus is uncommon, but it can result in life-threatening complications if it becomes displaced into the cranial cavities. The following mechanisms have been proposed to explain why an implant migrates into the maxillary sinus: changes in intrasinal and intranasal pressure; autoimmune reaction to the implant, causing destruction of the bone around the implant and compromising osseointegration; and resorption produced by an incorrect distribution of occlusal forces.[10]

An implant that has migrated into the maxillary sinus must be immediately removed surgically by means of a Caldwell-Luc or crestal approach or endoscopically via a transnasal approach. The immediate complications are similar to those resulting from surgical displacement of the implant; however, the migration scenario poses a greater risk because the complication will not be detected until the patient is reexamined. This interval allows enough time for the implant to migrate into critical structures.

The migrating implant may exit the sinus and travel into the ostium, leading to the possibility of aspiration; if that occurs, thoracic and abdominal radiographs should be obtained. If the implant has been aspirated, immediate removal is indicated, as described in case 1.

Migration of the implant rarely occurs; thus, prevention strategies are limited. Although clinical findings might suggest shorter reevaluation intervals, determining the indications for them is difficult.

Fatal air embolism during implant surgery

For an air embolism to occur, there must be an open vessel, a gradient between extravascular and intravascular pressure, and a source of air.[10] Bone is vascular, and injection of an anesthetic agent into the periodontal ligament resembles a direct intravenous injection. The intraosseous venous plexus in the mandible gives rise to large veins in the interdental septum. The septal veins drain into the inferior alveolar vein and eventually into the pterygoid plexus. Alternatively, they can drain into the facial vein and, ultimately, the internal jugular vein.

The risk of developing an air embolism increases when the pressure of the extravascular air is greater than the intravascular venous pressure. Implant surgery requires the handpiece to be attached to an implant motor and not to an air compressor. Davies & Campbell reported that 3 patients experienced cardiac arrest during oral surgery and subsequently died.[10] Patients who collapse as a result of an air embolism lose consciousness, rapidly develop cyanosis, lose their pulse, and quickly develop dilating pupils. These complications could be attributed to the handpiece's having delivered a lethal volume of air at the time of surgery. To prevent this complication, the surgeon should not use a pressurized handpiece to drill into the bone or a pressurized air-water syringe to clear debris from the bone or the tooth canals.

Conclusion

Although life-threatening complications are uncommon, dental implant placement is not free of risks. The cases described in this article illustrate some of the complications that can occur. The clinician should be aware of all potential outcomes and ensure that staff members are fully prepared for an emergency. Taking a proper medical history, using a precise surgical technique, and demonstrating the requisite knowledge and skills are essential to prevent complications. Moreover, prompt recognition and proper management of a developing problem are essential to prevent life-threatening outcomes. The patient should be informed of any possible adverse outcomes before implant placement. With the patient's cooperation and assistance of the dental team, such complications will be reduced to a minimum.

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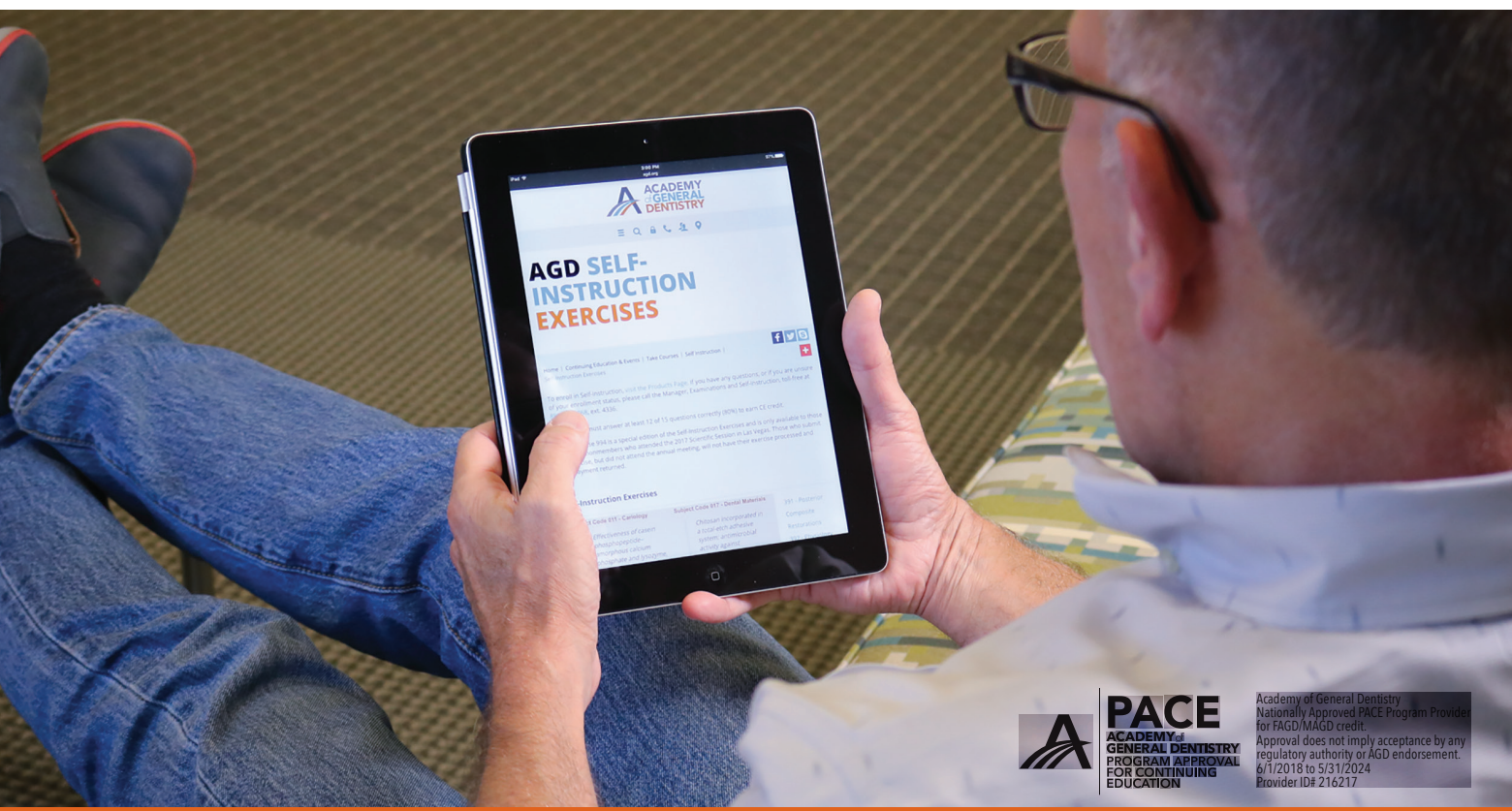

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Effect of previous irrigation with chlorhexidine on the push-out bond strength of a calcium silicate–based material

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Celso Neiva Campos, DDS, PhD ■ Vasudev Ballal, DDS, PhD ■ Renata Antoun Simão, DDS, PhD
Maíra do Prado, DDS, PhD

This study evaluated the effect of previous irrigation with chlorhexidine (CHX) on the bond strength of a calcium silicate–based material, Biodentine, when used for furcal repair. Furcal perforations were produced in 30 extracted mandibular molars. Teeth were divided into 3 groups according to the irrigant used: distilled water (DW), CHX followed by DW (CHX), and CHX followed by ethylenediaminetetraacetic acid (EDTA) and DW (CHX/EDTA). Biodentine was used to repair the perforations. A push-out bond strength test was performed after 7 days, and data were statistically analyzed using Kruskal-Wallis and Dunn tests ($P < 0.05$). The CHX/EDTA group showed significantly lower values than the DW and CHX groups ($P < 0.05$). The failure mode of the DW group was mainly mixed, while that of the CHX group was cohesive. The CHX/EDTA group exhibited adhesive and mixed failures. Irrigation with CHX prior to furcation repair did not result in a statistically significant difference, compared to the use of DW, in the push-out bond strength of Biodentine.

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Key words: chlorhexidine, dentin, root canal irrigants, shear strength, tricalcium silicate

A furcation perforation is an opening in a tooth's furcation at the periodontal ligament. It is characterized as a complication that may occur during endodontic treatment or space preparation.[1] The perforation must be repaired as soon as possible to avoid microbial contamination and consequent development of endodontic-periodontal lesions.[2,3]

Various materials are indicated for the repair of furcation perforations, including amalgam, Cavit (3M ESPE), composite resin, glass ionomer cement, calcium hydroxide, Super EBA (Keystone Industries), and mineral trioxide aggregate (MTA).[1,4,5] MTA has been used extensively for furcation repair due to its high sealing capacity, excellent biocompatibility, and ability to set in the presence of blood.[6,7] However, the negative characteristics of this material include a long setting time and difficulty in handling.[8,9]

New materials composed of calcium silicate have been developed with the objective of lessening the deficiencies exhibited by MTA.[10] Biodentine (Septodont) is composed of tricalcium silicate, dicalcium silicate, calcium carbonate, iron oxide, zirconium oxide, and calcium chloride; calcium chloride is used as an accelerator to reduce the setting time of this material.[11] Biodentine has been suggested as a replacement material for dentin—similar to MTA—to be used as a regenerative material in endodontic procedures for furcation perforation repair, retrograde obturation, and pulp revascularization.[1,12]

The materials used in furcation repairs should allow for good adaptation with dentin and should not fracture or dislocate under occlusal mechanical force or during the condensation of regenerative materials.[13,14] A possible cause for the dislocation of these materials is the loss of seal between material and dentin over time, which results from the degradation of collagenous fibers.[15] This process is attributed to an endogenous proteolytic mechanism that involves the activity of metalloproteinases (MMPs) found in root dentin.[16,17]

Chlorhexidine digluconate (CHX) has been proposed as an irrigant in endodontic treatment due to its antimicrobial activity and ability to increase energy on the dentin surface and because it does not affect the adhesive strength between the restorative material and dentin.[18,19] Moreover, CHX has beneficial effects on the preservation of adhesion between the restorative material and dentin, inhibiting the activity of MMPs on dentin.[20,21]

Therefore, the objective of the present study was to evaluate the effect of irrigation with CHX prior to furcation repair on the bond strength between the bioactive material Biodentine and dentin.

Materials and methods

The study was approved by the Ethics in Research Committee at Federal University of Juiz de Fora, Juiz de Fora, Brazil (1.840.821). A total of 30 extracted permanent human molars were used. The teeth were stored in a solution of sodium azide 0.2% (MilliporeSigma) at 4°C until use.

Specimen preparation

Crowns were removed at the cementoenamel junction with a diamond disc (Horico Dental) under water cooling. Roots were standardized to measure 6 mm from the lower region of the furcation to the end of the root. The apical 3 mm of the root was embedded in epoxy resin, leaving 3 mm of the furcation area protruding from the epoxy resin.

A furcation perforation was produced in each tooth by a cylindrical bur (1.6 mm) that was positioned perpendicular to the furcation and parallel to the long axis of the tooth. A collagen matrix (Hemospon, Technew) was later inserted below the perforation, with the aid of a condenser (Odous De Deus), to serve as a shield for irrigation and placement of the calcium silicate–based repair material.

After the collagen matrix was inserted, specimens were divided into 3 groups (n = 10) according to the irrigant used (Table 1): distilled water (group DW), 2% CHX followed by DW (group CHX), or 2% CHX followed by 17% ethylenediaminetetraacetic acid (EDTA) and DW (group CHX/EDTA). The irrigation procedure was performed with a 27-gauge needle and a 5-mL syringe (Vista Dental).

After the assigned irrigation protocol was completed, Biodentine was applied according to the manufacturer's recommendations. Five drops of the liquid were placed in the powder-containing capsule and then vibrated for 30 seconds at 4000 rpm. Once the material presented a consistency of "glass putty," it was inserted in the perforations with the aid of the condenser. Specimens were then wrapped in wet gauze and stored for 7 days at 37°C with 100% humidity.

Push-out bond strength test

Bond strength was assessed through the push-out bond strength test using a universal testing machine (Instron Brasil). The equipment operated at a speed of 0.5 mm/min with a cylindrical apparatus measuring 1.2 mm in diameter and 20.0 mm in length and a load of 200 kgf per load cell. The greatest force intensity before dislodgment was recorded in newtons. To express the bond strength in megapascals, the load value was divided by the area (square millimeters) of the bonded interface, which was calculated with the formula $A = 2\pi rh$, where π is 3.14, r is 0.75 mm (the perforation was standardized with a diameter of 1.50 mm), and h is the height of perforation.

All fractured specimens were observed under a stereoscope (SMZ800, Nikon Instruments) at 10× magnification to determine the failure mode. This failure mode was classified into 3 types: adhesive (failure in the dentin-material interface); cohesive (failure within the material); and mixed (adhesive and cohesive). The assessment was performed by a single trained evaluator.

Table 1. Irrigants evaluated in this study.

Group	Initial irrigation (3 mL)	Removal of smear layer (1 mL)	Final irrigation (1 mL)
Control	DW	DW	DW
CHX	CHX 2%	DW	DW
CHX/EDTA	CHX 2%	EDTA 17%	DW

Abbreviations: CHX, chlorhexidine; DW, distilled water; EDTA, ethylenediaminetetraacetic acid.

Statistical analysis

The descriptive analysis of data and statistical analyses were performed using SPSS software (version 15.0, IBM). The Kolmogorov-Smirnov test was used to assess the normality of the sample. Bond strength results were statistically analyzed using the Kruskal-Wallis test and Dunn test. The level of statistical significance was 5% ($P < 0.05$).

Results

Table 2 shows the bond strength values of all the groups and the failure mode associated with each. The DW and CHX groups presented statistically similar bond strength values ($P = 0.49$). The CHX/EDTA group presented the lowest values, and the mean was significantly different from groups DW ($P = 0.004$) and CHX ($P = 0.005$).

The DW group presented a mostly (70%) mixed fracture pattern, while the CHX group presented a mostly (80%) cohesive fracture pattern, and the CHX/EDTA group presented both adhesive (~50%) and mixed (~40%) patterns.

Discussion

After repair of furcation perforations, the success of endodontic therapy depends on the thorough cleaning and shaping of the root canal system, adequate coronal restoration, and the resistance of the repair material to fracture or dislocation during condensation of the sealing materials as well as in the face of occlusal mechanical forces.[1] Thus, the bond strength of the material used in furcation repair is an important factor. The push-out test has been widely used to assess bond strength because it is practical, reliable, and efficient.[13,22-24]

Irrigants such as 2% CHX and sodium hypochlorite (NaOCl) are recommended during the chemomechanical preparation of the root canal system.[18] Moreover, the use of acids and chelating agents is also recommended to remove the smear layer formed during preparation.[25] Several studies have evaluated the effect of different irrigants used during chemomechanical preparation on the topography and bond strength of materials for furcation repairs.[1,3,4,26] However, the effect of irrigants prior to repair has rarely been addressed in the literature.

Pace et al carried out a 5-year follow-up on a series of clinical cases in which irrigations with 5% NaOCl, 17% EDTA, and DW were performed prior to the insertion of repair material in furcations, treatment that resulted in clinical and radiographic success.[27] However, previous studies have shown

Table 2. Bond strength values (push-out test) of Biodentine to dentin and fracture patterns of specimens.

	Bond strength (MPa)			Failure mode (%)		
Group	Mean (SD)	Min	Max	Adhesive	Cohesive	Mixed
DW	3.35 (1.43)[A]	0.95	5.55	10	20	70
CHX	4.09 (2.81)[A]	0.59	8.52	0	80	20
CHX/EDTA	1.35 (1.32)[B]	0.12	3.49	50	10	40

Abbreviations: CHX, chlorhexidine; DW, distilled water; EDTA, ethylenediaminetetraacetic acid; Max, maximum; Min, minimum.
Different uppercase superscript letters indicate statistically significant differences ($P < 0.05$; Dunn test).

sodium hypochlorite to have high toxicity when in contact with periradicular tissues.[28,29] Moreover, Alsubait evaluated the effect of irrigation with 2.5% NaOCl on bond strength after inserting furcation repair materials and observed that NaOCl decreased the bond strengths of MTA and Biodentine.[30]

CHX offers antimicrobial activity and the ability to increase energy on the dentin surface; it also plays a role in preserving the adhesion between restorative material and dentin by inhibiting the activity of MMPs. Thus, in view of these advantages and considering the negative effects of NaOCl, the present study was undertaken as the first investigation of the effects on the bond strength between Biodentine and dentin when irrigation with CHX is performed prior to furcation repair.

In the present study, irrigation with CHX prior to furcation repair did not result in a statistically significant difference in dentin–repair material bond strength compared to the use of DW ($P = 0.49$). Mixed fractures predominated in the DW group (70%), while cohesive fractures were mainly observed in the CHX group (80%). These findings demonstrate that, although there was no statistically significant difference in bond strengths between them, the CHX group presented a more favorable fracture mode than the DW group.

The favorable bond strength between the bioactive repair material and dentin, which was demonstrated by the predominantly cohesive failures in the CHX group, can be explained by the various positive aspects of this irrigant. These aspects include the ability of this substance to increase surface energy on the dentin, the fact that CHX does not affect the adhesive strength between restorative material and dentin, and the role CHX plays in the preservation of adhesion between the restorative material and dentin by inhibiting the activity of MMPs on dentin.[18-21]

In the present study, irrigation with CHX and 17% EDTA (group CHX/EDTA) decreased the bond strength between the calcium silicate–based material and dentin. This result may be associated with the demineralizing effect of EDTA on calcium-based materials.[3] Moreover, a chemical smear layer may have formed on the dentin surface.[25] The CHX/EDTA group presented predominantly adhesive (~50%) and mixed (~40%) failures, confirming the negative action of irrigation with CHX/EDTA prior to placement of Biodentine in the perforation.

Thus, the use of CHX as an irrigant prior to sealing of perforations did not result in a statistically significant difference in bond strength between Biodentine and dentin when compared to the use of distilled water, but CHX/EDTA showed the worst bond strength when compared to the other protocols for prior irrigation. However, the cohesive failure mode observed in the CHX group was the most favorable among all groups.

Conclusion

Irrigation with CHX prior to furcation repair did not result in a statistically significant difference in bond strength between Biodentine and dentin when compared to the use of DW.

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The authors report no conflicts of interest pertaining to any of the products or companies discussed in this article.

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Clinical treatment of necrotizing ulcerative gingivitis: a case report with 10-year follow-up

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The aim of this case report is to describe the diagnosis and treatment of a patient with necrotizing ulcerative gingivitis. An 18-year-old man with no systemic problems reported with chief complaints of gingival bleeding during toothbrushing and spontaneous pain. Clinical examination revealed significant plaque accumulation on the surfaces of all teeth as well as papillary necrosis involving mainly the anterior teeth. Treatment included an initial phase of supragingival plaque and calculus removal along with at-home use of 0.12% chlorhexidine gluconate mouthrinse twice a day for 30 days. After the initial phase, subgingival scaling was performed, and regular oral hygiene methods were resumed by the patient. After active therapy was completed, a periodontal maintenance regimen was established, and the patient was recalled for periodontal maintenance therapy. Follow-up occurred weekly throughout treatment, monthly for the first 6 months posttreatment, and 2-3 times a year during the periodontal maintenance therapy. Clinical results after 10 years showed that this approach controlled the acute phase and maintained the patient's periodontal health over time.

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Necrotizing periodontal diseases are considered to be among the most severe inflammatory reactions of periodontal tissues associated with dental plaque. They have a rapid, aggressive onset and a multifactorial, complex etiology.[1-3] A classic example of necrotizing periodontal diseases is necrotizing ulcerative gingivitis (NUG).[4]

Clinically, NUG is characterized by excessive accumulation of dental plaque; highly edematous, hemorrhagic, and inflamed interdental papillae; and, in most patients, tissue necrosis and foul breath, which may be associated with fever and lymphadenopathy.[1] The papillary area is usually covered by a white or grayish layer of soft consistency with an ulcerated gingival margin surrounded by an erythematous halo. Typically the lesion is painful and exhibits spontaneous bleeding. It presents as a limited, rapidly developing lesion that involves only the gingival tissue and does not result in loss of periodontal attachment.[1]

A heterogenous set of spirochetes, fusobacteria, and strains of *Treponema pallidum* and *Bacteroides intermedius* are associated with this pathosis.[1] Host factors, such as psychological stress, immunosuppression, a smoking habit, and poor oral hygiene, are also frequently associated with NUG.[2,5,6]

During World War II, there was a high incidence of necrotizing periodontal disease (for example, approximately 14% of Danish military personnel were affected); however, after the war, the incidence of necrotizing periodontal disease decreased substantially.[1] More recent data have shown prevalence rates ranging from 0.11% in members of the British armed forces to 6.7% in Chilean students (aged 12-21 years).[7,8] A recent review confirmed the low prevalence of NUG (less than 1%).[7] However, despite the current low prevalence, it is important not to underestimate this acute periodontal condition.[7]

Clinical findings aid in the differential diagnosis of NUG from other pathoses such as primary herpetic gingivostomatitis and acute leukemia.[1] Periodontal treatment of NUG involves 2 phases: the initial and maintenance phases.[1] The initial treatment of the disease is directed toward the remission of the acute process, including the removal of the local etiologic agents and relief of the painful condition. In a second phase, periodontal maintenance therapy is consistently implemented and oral hygiene education is reinforced.

The literature has reaffirmed that careful professional maintenance is an integral and important part of periodontal treatment.[1,4] Patients with NUG are susceptible to disease recurrence, mostly as a result of difficulties in controlling the oral biofilm.[4] Therefore, the greatest challenge in treating NUG is to reinforce the patient's education on periodontal health, given that success will depend not only on proper control of the biofilm but also on the patient's modification of

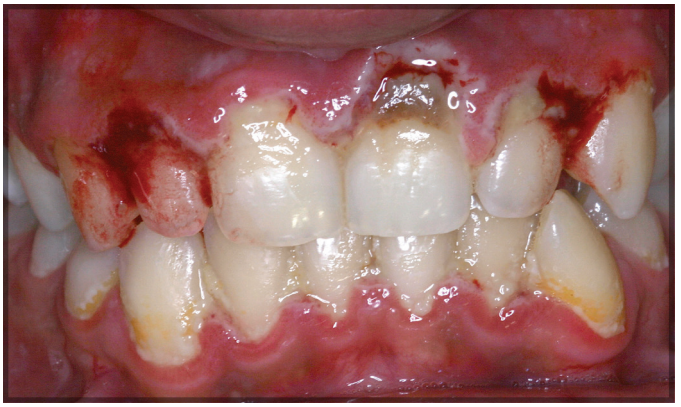

Fig 1. Initial clinical appearance at the first evaluation.

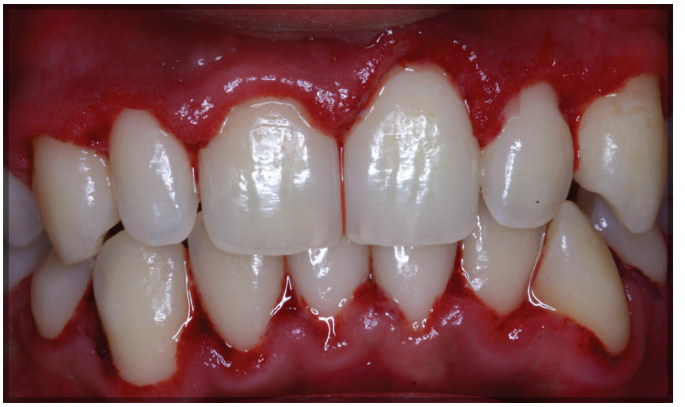

Fig 2. Clinical appearance after gentle supragingival plaque removal during the second appointment.

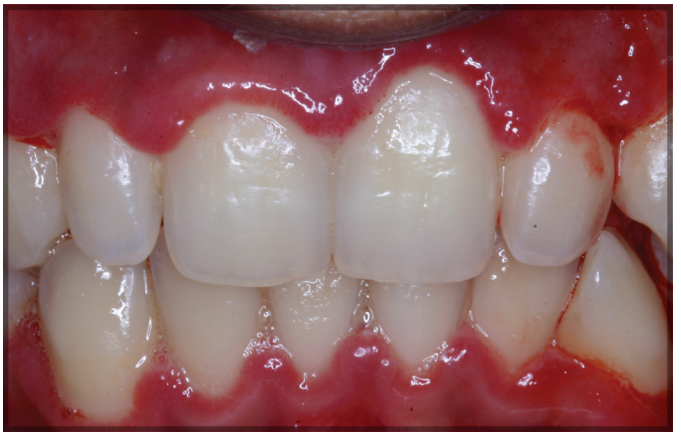

Fig 3. Clinical appearance at the third appointment.

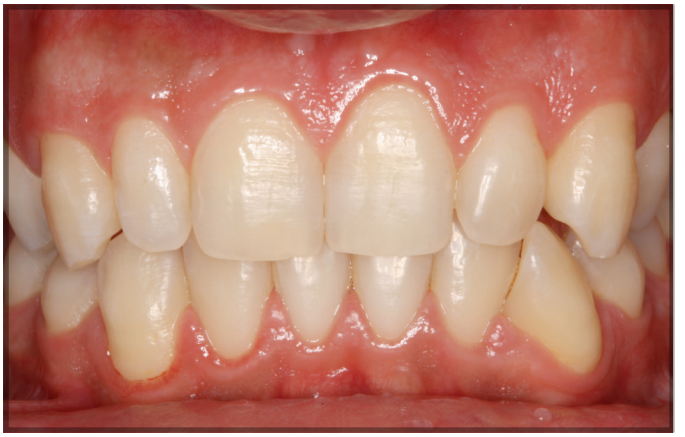

Fig 4. Clinical appearance at the fourth appointment.

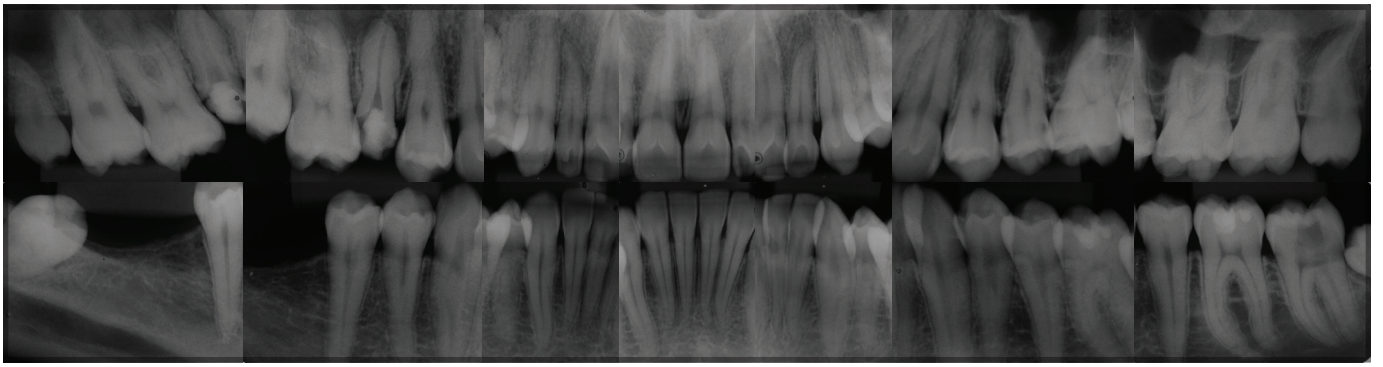

Fig 5. Radiographic evaluation at the fourth appointment, revealing no interproximal bone loss.

behavior and compliance with the periodontal treatment. The objective of the present case report is to describe the successful clinical treatment of a patient with NUG over a period of 10 years of maintenance.

Case report

Patient information

An 18-year-old man with leukoderma was referred for treatment to the School of Dentistry at Federal University of Pelotas, Pelotas, Brazil. His main concerns were gingival bleeding when toothbrushing and pronounced halitosis that caused him embarrassment.

Clinical findings and diagnostic assessment

Clinical examination revealed necrosis and ulceration of the interdental papilla, which were covered by a grayish slough (pseudomembrane). The papilla did not fill the entire interproximal space in some sites, and generalized, extensive accumulation

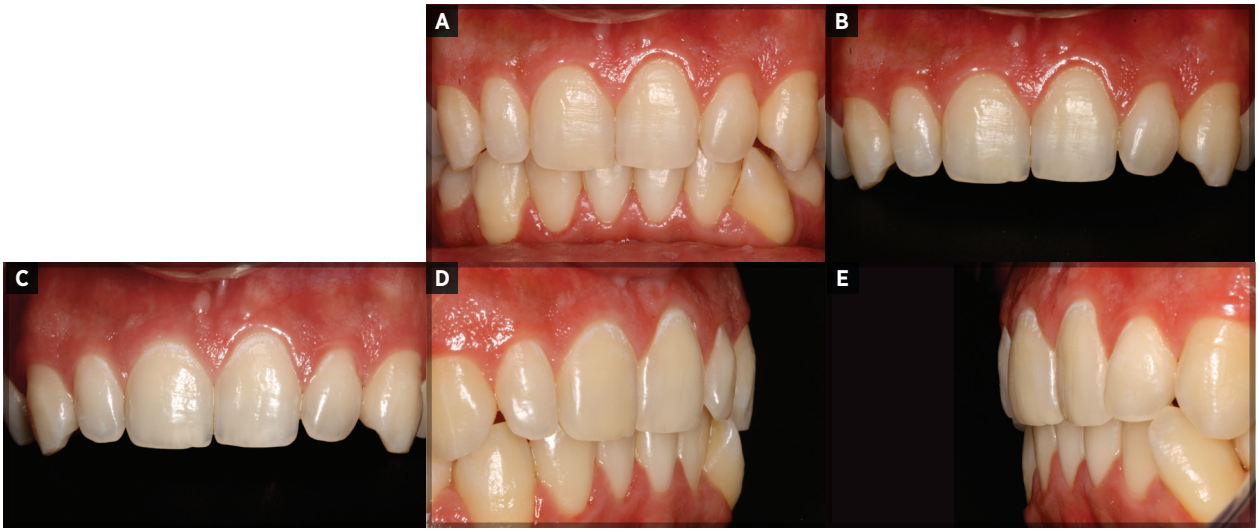

Fig 6. Clinical appearance during periodontal maintenance therapy. A. Six-month follow-up. B. One-year follow-up. C. Two-year follow-up. D & E. Ten-year follow-up.

of oral biofilm was observed on the dental surfaces (Fig 1). The teeth were well positioned in the arch. Radiographic examination was not performed at the first evaluation due to the condition of the soft tissue.

During the physical examination, no systemic condition was found that could predispose the patient to NUG. However, the patient's parents reported that he had been experiencing severe stress as well as psychological pressure at school due to a period of academic probation. Based on the clinical data obtained at the examination, NUG was diagnosed.

Therapeutic interventions

At the second appointment, 7 days after the evaluation and diagnosis, the initial clinical treatment involved the careful removal of the supragingival plaque, aided by topical anesthetics (Fig 2). The patient was instructed to perform extensive atraumatic and careful oral hygiene procedures and to rinse with a 0.12% chlorhexidine gluconate mouthwash twice a day for 30 days.

At the third appointment, 7 days later, supragingival scaling was performed along with supervised brushing and reinforcement of the oral hygiene instructions (Fig 3).

At the fourth appointment, 7 days after the third, subgingival scaling was performed on specific sites. Supragingival scaling, planing, and polishing of the tooth surfaces were also performed along with reinforcement of the oral hygiene instructions (Fig 4). A radiographic examination was performed, and no bone loss was detected (Fig 5). Impressions of the maxillary and mandibular arches were taken for future rehabilitation planning.

A motivational approach to changing the patient's oral hygiene behavior was emphasized by the clinical team from the first evaluation. With regular and effective maintenance of oral hygiene habits by the patient, the inflammatory clinical condition was reversed, and periodontal health was observed within a few weeks.

After the completion of the cause-related therapy phase, the patient was enrolled in a periodontal maintenance program to optimize the therapeutic interventions. The process of educational and motivational intervention began with the presentation of detailed information—through illustrative photographs and pamphlets—to the patient at each session. The educational materials emphasized the signs and symptoms of the disease and their relationship to the presence of bacterial biofilm. The patient was also instructed to be aware of the signs, symptoms, and locations of periodontal disease.

Detailed information about the importance of efficient daily oral hygiene was followed by demonstration of oral hygiene protocols on a model—using a toothbrush technique appropriate for the patient's specific clinical condition—as well as detailed, precise instruction in the use of dental floss. At each clinical session, a dye solution that stains plaque was used as an educational tool to demonstrate the location of bacterial plaque. Plaque-disclosing tablets were given to the patient for weekly home use.

Periodontal clinical control was guided by the patient's adherence to the recall system of weekly follow-up appointments throughout treatment, monthly follow-up for the first 6 months posttreatment, and follow-up 2-3 times a year during periodontal mainenance therapy; at each visit, the needed frequency of attendance was assessed. The findings at multiple follow-up examinations showed that periodontal health and function were successfully reestablished and maintained over time (Fig 6). Clinical and radiographic examinations revealed healthy tissues and no evidence of progressive periodontal attachment loss.

Discussion

Necrotizing ulcerative gingivitis is restricted to the gingival tissue without the involvement of other tissues of the periodontium. Progression of this disease involves the attachment apparatus with consequent tissue loss.[4] Nonetheless, case reports have emphasized that conservative local treatment of NUG without systemic involvement can produce good outcomes. According to this premise, therapies are based on local debridement and scaling and root planing sessions together with good plaque control through a strict oral hygiene regimen; local

antimicrobial therapy, using solutions of 0.1% or 0.2% chlorhexidine, is only required until lesion remission.

The dental literature lacks consensus about an optimal treatment regimen for NUG. Due to its low prevalence, it is difficult to design controlled clinical trials. Most of the currently used treatment modalities are related in case reports and literature reviews.[7,9,10] However, there is evidence proving the importance of prompt intervention with adequate periodontal treatment, which includes careful and superficial mechanical debridement, use of chemical agents (eg, chlorhexidine), establishment of effective oral hygiene habits, and control of any predisposing factors.[3]

The patient must be closely monitored, and if the response to the acute treatment phase is unsatisfactory and the symptoms suggest systemic involvement (ie, fever and/or malaise), the use of systemic antibiotics may be considered.[1,3,7,11] Metronidazole seems to be the first choice due to its action against resistant anaerobes, but the literature shows different dosages and duration regimens (eg, 250 mg, 3 times a day for 7 days, or 200 mg, 3 times a day for 3 days).[1,3,7,11,12] To the best of the authors' knowledge, there was no indication for prescribing a systemic antibiotic during treatment of the patient in the present case. There were no signs of systemic involvement, and the NUG was resolved by proper periodontal treatment.

Patients with NUG are generally young adults with poor oral hygiene. In the present case, the high degree of psychological stress experienced by the patient may be considered a risk factor for this disease.

The initial phase of treatment consists of eliminating or minimizing the acute phase of the disease, characterized by the evolution of tissue necrosis.[1] Once the acute disease process is controlled, scaling and planing, education, and oral hygiene motivation procedures should be intensified.[1,4] The adoption of periodontal treatment planning for the short-, medium-, and long-term should result in a good prognosis. In the medium- and long-term, the main focus should be the strict control of dental plaque.[4] The patient's compliance in performing all the procedures of plaque control is essential to obtaining good results. Motivating the patient and communicating the importance of his or her role as cotherapist in the success of treatment may be the difference between success and failure of periodontal treatment. The information should be passed on to the patient gradually and steadily from the beginning of treatment, so that excellent results can be obtained. This educational stage of treatment is sometimes not valued by the patient as much as it is by the professional, but it is a key step in achieving and maintaining success.

Clinical experience has shown that careful professional maintenance is an integral part of periodontal treatment. Patient education is important in this context also, since success depends not only on the control of biofilm techniques but also on the patient's behavior modification and compliance with the suggested control regimen. In the present case, the patient was instructed about the need of self-care for oral hygiene, and motivational approaches consisted of direct demonstration on models, illustrative photographs, and radiographs. The patient's comprehension during clinical care was satisfactory, since he observed areas with dental plaque after their disclosure and received instructions on the correct use of dental floss and interdental brushes. The challenge of this periodontal treatment was maintaining the patient's adherence to the recall system, which required weekly, biweekly, and monthly follow-up examinations throughout treatment; at each appointment, the need for consistent attendance was explained to the patient.

After a stressful time during the probationary period, the patient became calmer due to his achievements at school. The association between psychological stress and NUG is biologically plausible because the production of high levels of stress hormones, such as cortisol, favors the growth of periodontopathogenic bacterial species.[6,13,14]

Conclusion

In a young man with NUG, use of 0.12% chlorhexidine twice a day for 30 days, in conjunction with weekly coronal polishing and supragingival scaling for 3 weeks and scaling and root planing in the third week, allowed for the control of the acute phase and maintained periodontal health over time. Periodontal maintenance therapy was shown to be adequate for the maintenance of periodontal health over a 10-year period.

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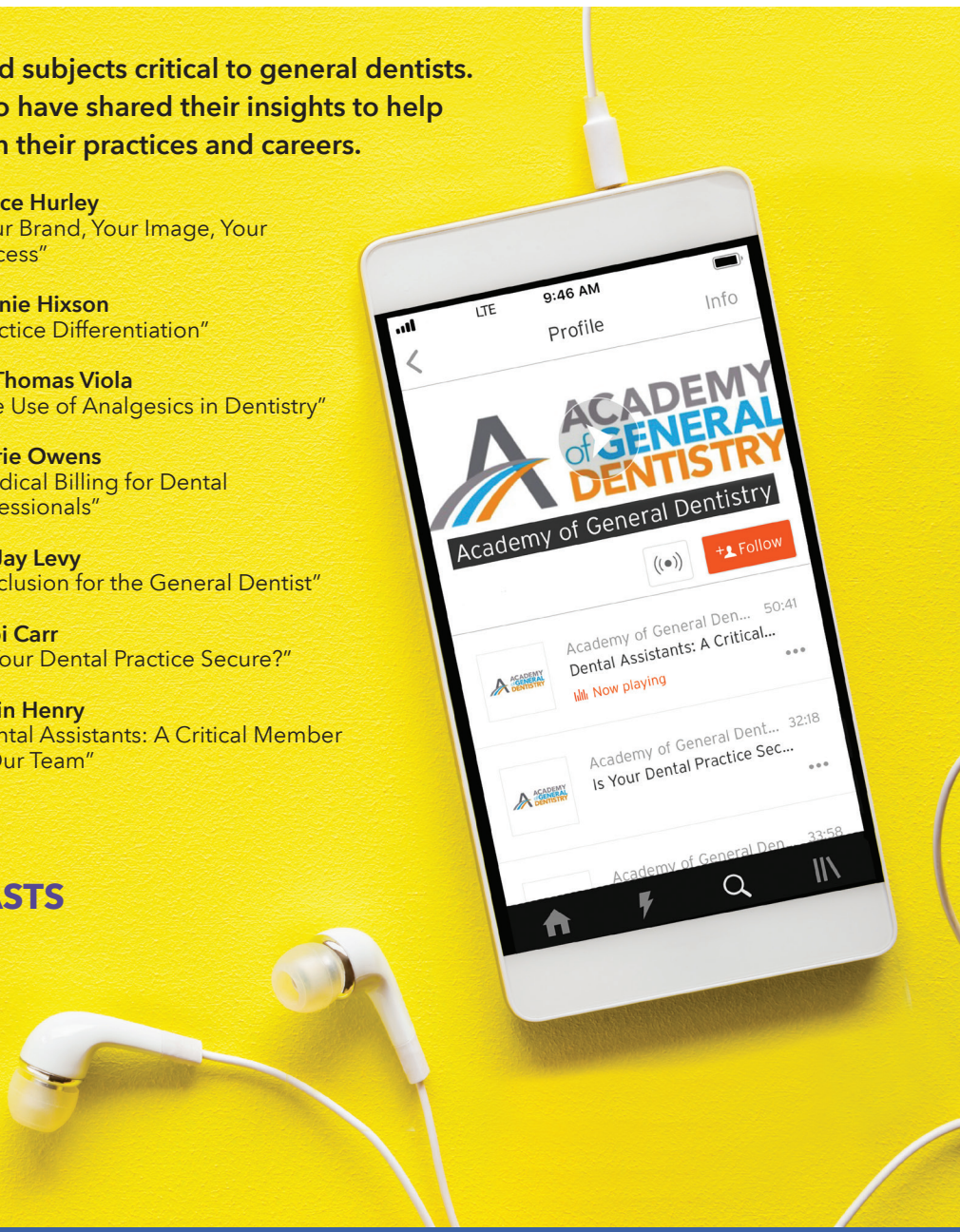

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Effect of gel replacement during in-office dental bleaching: a case report

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In-office dental bleaching allows the dentist to have greater control of the procedure and prevents patients from ingesting chemicals. To obtain optimum results, in-office bleaching usually requires a longer period of application as well as changes of the bleaching agent applied to the tooth surfaces at each appointment. The objective of this case report was to assess, by means of a split-mouth design in a single patient, the final tooth color and tooth sensitivity resulting from 2 different bleaching protocols: 1 application of 35% hydrogen peroxide for 45 minutes and 3 applications of 35% hydrogen peroxide for 15 minutes each. Neither the patient nor 5 individuals who were blinded to the techniques noted a difference in the final esthetic results of the 2 protocols immediately after the procedure. In addition, the patient reported that no tooth sensitivity was associated with either protocol. The results of dental bleaching on both sides were maintained after 15 days. The results shown in the present case report suggest that there may be no need to renew the gel during in-office dental bleaching.

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Key words: hydrogen peroxide, in-office dental bleaching, sensitivity

Patients frequently request dental bleaching because it is an effective, conservative means to improve the esthetics of a smile.[1,2] In addition, studies report that tooth bleaching improves patients' oral health–related quality of life.[3,4]

The effectiveness of tooth bleaching appears to be time and concentration dependent.[5] At-home tooth bleaching is usually recommended for several weeks, depending on the type of dental staining and the concentration of the bleaching gel, which may vary from 5% to 35% carbamide peroxide. This technique is the most common bleaching procedure.[6]

Despite the advantages of the at-home bleaching technique, some patients do not feel comfortable with wearing trays. In-office bleaching is an alternative technique. In-office bleaching with hydrogen peroxide (HP) was first introduced by Abbot in 1918.[7] In-office dental bleaching allows the dentist to have greater control of the procedure and prevents patients from ingesting chemicals.[8,9] During the in-office procedure, bleaching gel is placed on the enamel surfaces and can be illuminated with a light source.

In-office dental bleaching requires a higher concentration of hydrogen peroxide, usually 15%-38%.[6] Moreover, in-office bleaching usually requires a longer period of HP application, during which the bleaching agent on the tooth surfaces is changed to obtain optimum results.[10,11] During in-office bleaching, the HP is usually applied to the enamel surface and left undisturbed for 5-15 minutes; this procedure is repeated 3-5 times during each clinical appointment, depending on the brand of bleaching gel.[12]

The gel is renewed every 5-15 minutes due to the rapid degradation of hydrogen peroxide.[12] However, it has been reported that the mean concentration of active HP remaining in a low-concentration HP gel after 1 hour of contact with the teeth was 32.2%.[13] A similar degradation rate can be expected for a 35% HP gel.[12,14] Because bleaching gel retains substantial activity after 1 hour, a single, prolonged application might produce tooth lightening effects similar to repeated within-appointment applications.[12] This protocol would decrease the costs of in-office bleaching by reducing the amount of material used and shortening chair time.[12]

To date, few in vitro and in vivo studies have evaluated the effects of different protocols for gel renewal during in-office bleaching on the final results in terms of color change, final pH, and dental sensitivity. The purpose of this case report is to describe the final color and tooth sensitivity results obtained in a single patient treated with 2 different in-office bleaching protocols in a split-mouth design. Treatment consisted of 1 application of 35% HP for 45 minutes (1 × 45 minutes) on the patient's right side of the mouth and 3 applications of 35% HP for 15 minutes each (3 × 15 minutes) on the patient's left side.

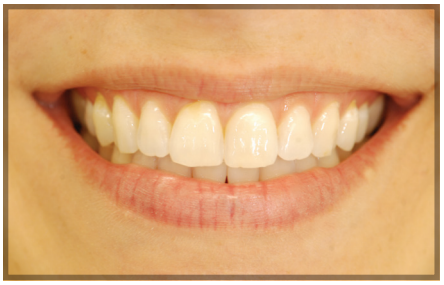

Fig 1. The patient's smile before bleaching procedures reveals tooth discoloration.

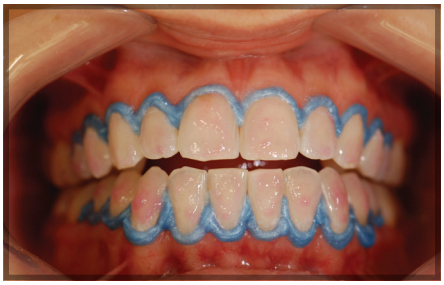

Fig 2. A light-cured resin barrier is positioned to protect gingiva, and bleaching gel is applied.

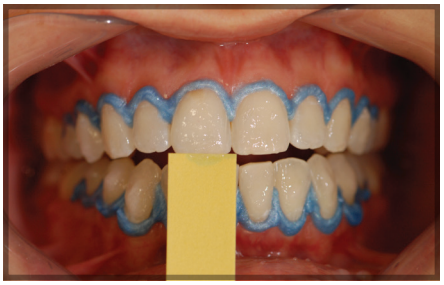

Fig 3. Fifteen minutes after gel application, the edge of the pH measuring paper is positioned on the bleaching gel until the edge of the paper changes color.

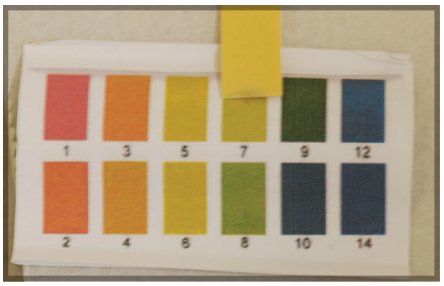

Fig 4. After the pH measuring paper has contacted the bleaching gel, the color on the edge of the paper is compared to the pH scale; the closest color indicates the approximate pH value of the gel.

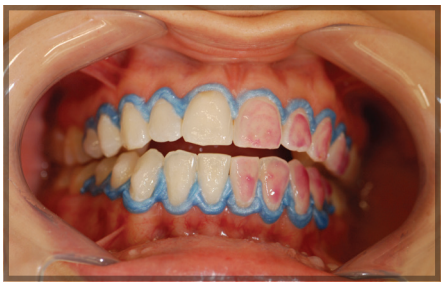

Fig 5. On the patient's left side, the gel is renewed (pink gel). On the patient's right side, the gel is not renewed (transparent gel).

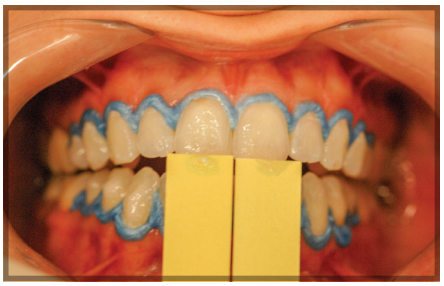

Fig 6. Thirty minutes after the first gel application, the pH was measured on both sides, indicating a pH of approximately 7.0.

Case report

The patient, a 36-year-old woman, was referred to the Postgraduate Clinic of the School of Dentistry, University of São Paulo, São Paulo, Brazil, for dental bleaching. The patient's dental history was obtained, and a clinical examination was performed. The patient, who showed satisfactory oral health and reported no tooth sensitivity, had received in-office dental bleaching 6 years previously. For the proposed bleaching treatment, the HP 35% bleaching gel on the left side of the patient's arch would be changed 3 times (every 15 minutes), in accordance with the manufacturer's instructions. On the right side of the arch, the same HP 35% gel would be kept in place for 45 minutes. The split-mouth approach was explained to the patient, and she provided her informed consent.

Prophylaxis of the teeth was performed with a prophylactic paste and a polishing brush. The patient's smile was photographed to obtain a record of the initial tooth color (Fig 1). The initial tooth color was also registered with a spectrophotometer (VITA Easyshade, VITA North America) that was positioned at the cervical, middle, and incisal thirds of the maxillary incisor and canine crowns.

A light-cured resin barrier was placed on the gingiva to protect the periodontal tissues (Fig 2). A disposable brush was used to apply 35% hydrogen peroxide gel (Whiteness HP 35, FGM Produtos Odontológicos) to the buccal surface of the maxillary and mandibular teeth from the right first premolar to the left first premolar, covering the entire tooth surface.

After 15 minutes, the pH of the peroxide gel was measured with pH measuring paper (J Prolab) on both sides of the mouth (Fig 3). The edge of the pH measuring paper was placed on the bleaching gel until color change was observed on the edge of the pH paper. The final color result obtained on the paper was compared to the closest color of the scale to estimate the pH of the gel (Fig 4).

After the pH was measured, the bleaching gel on the teeth on the left side of the arch was changed following the manufacturer's instructions (Fig 5). On the patient's right side, the same gel was kept on the teeth for the entire 45 minutes.

The pH of the peroxide gel was measured with pH measuring paper again, 30 minutes after initial placement of the bleaching gel, on both sides of the mouth (Fig 6). The gel on the left side of the dentition was renewed a second time (Fig 7). The pH of the gel was measured a final time 45 minutes after the initial application on the right side and 15 minutes after the third application on the left side (Fig 8).

The pH paper showed no variation in pH of the bleaching gel, from the first 15-minute test to immediately after the final bleaching session, in either protocol that was tested. The pH was found to be basic (approximately 7.0) at all times.

After treatment was completed, the patient reported that she was satisfied with the final color result and was not able to detect any difference between the right and left sides of the arch (Fig 9). Immediately and 3 days after the bleaching session, the patient was asked if she had experienced any tooth sensitivity. She reported no sensitivity in any of the bleached teeth.

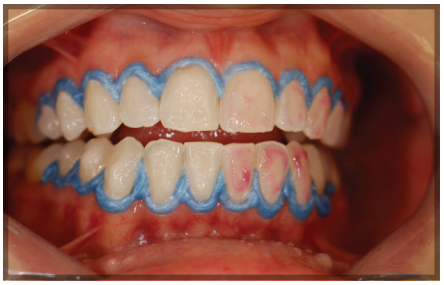

Fig 7. On the patient's left side, the gel is renewed for the second time (pink gel). On the patient's right side, the gel is not renewed (transparent gel).

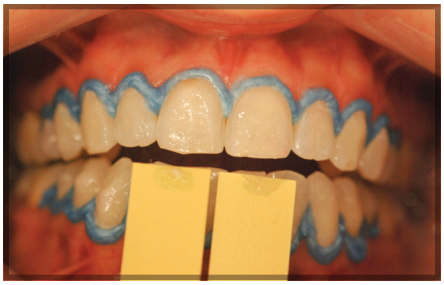

Fig 8. Forty-five minutes after the beginning of the first gel application, the pH is measured again on both sides, indicating a pH of approximately 7.0.

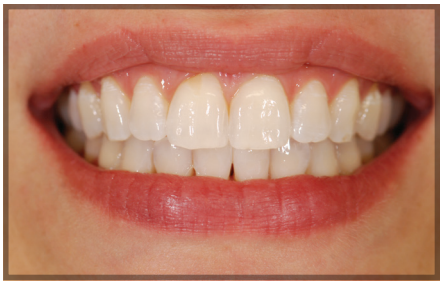

Fig 9. Immediately after the in-office bleaching treatment, there is no difference in color between the left and right sides.

The tooth shades were measured with the spectrophotometer at the end of the bleaching session and 15 days after treatment for comparison to the initial measurements. In all teeth, there was a change in color (Table). The result of dental bleaching of both sides was maintained after 15 days.

Five dentists and dental students who did not participate in the clinical procedure were asked to assess the change and report any difference observed in the final color on both sides. The 5 individuals, who were blinded to the treatments performed in each hemiarch, examined the patient in person. All of the observers reported that they found no clinically visible difference in the color of the 2 sides of the dentition.

Table. Maxillary tooth shades before and after bleaching.[a]

	Central incisor		Canine	
Tooth third	**Right**	**Left**	**Right**	**Left**
Initial shade				
Cervical	B3	A1	A2	A2
Middle	B1	B1	A1	B2
Incisal	B1	D2	D2	D2
Shade immediately after bleaching				
Cervical	A2	A1	B2	A2
Middle	B1	B1	A1	A1
Incisal	B1	B1	B1	B1
Shade 15 days after bleaching				
Cervical	A2	A1	A2	B2
Middle	B1	B1	A1	A1
Incisal	B1	A1	A1	A1

[a]Measured with a digital spectrophotometer (VITA Easyshade). Teeth were bleached with 35% hydrogen peroxide: right teeth, 1 × 45-minute application; left teeth, 3 × 15-minute applications.

Discussion

In-office dental bleaching usually requires a long period of application at each appointment, during which the bleaching agent is reapplied to the tooth surfaces multiple times.[10,11] The present case report described the results of 2 different in-office dental bleaching protocols used in the same patient (split-mouth dental bleaching). No difference was detected in the final tooth color obtained via the 2 protocols. In addition, the patient reported no tooth sensitivity on either of the bleached sides.

Most manufacturers of these types of products recommend that bleaching gel be replaced every 15 minutes.[15] Furthermore, according to manufacturers, the half-life of the bleaching product is usually 10-15 minutes, which means that the bleaching agent has to be replaced after this time frame. However, the literature shows conflicting findings on this topic, and few investigations have studied the ideal protocol for in-office dental bleaching. There is no strong evidence to recommend the renewal of bleaching gel every 15 minutes.

To the best of the authors' knowledge, 2 clinical trials have tested different in-office bleaching protocols to investigate the need to replace the bleaching gel.[12,16] Reis et al tested the same protocols adopted in the present clinical case: 3 × 15-minute applications and a 1 × 45-minute application of 35% HP gel.[12] Their study involved 30 patients (n = 15 per protocol) and did not have a split-mouth design.[12] Contrary to the results of the present single clinical case report, Reis et al concluded that a 35% hydrogen peroxide gel for in-office bleaching should be applied in 3 × 15-minute applications because a 1 × 45-minute application reduced the bleaching speed and slightly increased the intensity of tooth sensitivity.[12]

Vildósola et al applied a 6% HP gel with hybrid LED/laser activation in 30 patients in a split-mouth design.[16] In all patients, half of their arch was treated with a conventional 3 × 12-minute protocol, and the other half was submitted to a 1 × 36-minute application of bleach. These applications were equally effective, and no differences in sensitivity were reported by the patients. Despite the difference in gel concentration and duration of the protocols adopted by Vildósola et al, their study presented the same results as those found in the present case report.[16] Further clinical trials should be performed with the objective of achieving an evidenced-based protocol.

Other studies regarding this topic were performed in vitro.[17-20] All these in vitro studies concluded that renewing the gel during in-office dental bleaching is unnecessary. Caneppele et al concluded that changing the bleaching gel 3 × 10 minutes per session did not affect the efficacy of the treatment in comparison

with 1 × 30-minute and 1 × 40-minute applications.[17] In their in vitro study, Al-Harbi et al also verified that no difference in the bleaching effect could be observed after applying the product in 2 × 30-minute or 4 × 15-minute sessions.[18]

Kwon et al investigated the final bleaching result and amount of HP penetration into the pulp chamber after 2 protocols of in-office dental bleaching: 3 × 20 minutes (n = 40) and 1 × 60 minutes (n = 40).[19] In the 1 × 60-minute group, the authors covered the teeth with a linear low-density polyethylene wrap to prevent dehydration of the gel. There was no difference in the final color for the 2 protocols; however, there was significantly greater hydrogen peroxide penetration into the pulp for the conventional bleaching group (3 × 20 minutes). Color change measures did not appear to be correlated with hydrogen peroxide penetration. Marson et al also reported no difference in lightness change after bleaching when comparing the techniques of a single 1 × 45-minute and 3 × 15-minute applications.[20]

In the present case study, the pH of the bleaching gel in both protocols was measured 3 times: 15, 30, and 45 minutes after the start of treatment. The decomposition of hydrogen peroxide is accelerated by alkalinity.[17] For this reason, some dental bleaching products come in 2 bottles, 1 containing a stable acidic HP solution and the other an alkaline catalyst.[17] When the solutions are mixed, the pH becomes neutral, initiating both activity and degradation of the hydrogen peroxide over time. As the HP degrades, it becomes acidic, decreasing the effectiveness of its action and possibly causing damage to tooth structure.[17]

The potential for structural damage of the teeth would be a justification for changing the HP gel during in-office bleaching.[17] However, decomposition of HP requires a certain period of time if no activator (such as heat) is used.[17] Caneppele et al verified that the pH of 35% HP gel was 6.54 at baseline and 6.30 after 40 minutes; that is, pH did not change substantially after 40 minutes.[17] After 40 minutes, a small, nonsignificant decrease in pH was observed. However, the pH remained within acceptable levels; it was not acidic enough to promote enamel demineralization, and the acidity reduced degradation of the product.[17] In the present case report, the same results were observed for pH measurements. The pH of the bleaching gel showed basic values for both protocols at the beginning of and after bleaching.

Marson et al found only a minor decrease, from 34% to 29%, in the concentration of hydrogen peroxide after 40 minutes.[20] This finding supports the idea that there is no need to replace the gel during a single, in-office bleaching treatment. Caneppele et al reported that only a small, nonsignificant decrease in HP concentration was detected on the tooth surface 40 minutes after gel application, indicating that a small amount of peroxide had degraded.[17] Their result corroborated the findings of other studies in the literature, which determined in vitro that 91%-93% of active HP was still available for bleaching procedures 45 minutes after mixing of 35%-38% HP gels.[12,20] Thus, the rapid degradation of hydrogen peroxide is not a valid rationale for replacing dental bleaching gel every 15 minutes.[17]

Conclusion

No difference regarding the final esthetic results was noted after the use of 2 different bleaching protocols in a split-mouth study of a single patient. In addition, the patient reported no tooth sensitivity associated with either protocol. The results in the present case report suggest that there is no need to renew the gel during in-office dental bleaching. Further studies should be conducted with the objective of determining an evidence-based protocol.

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Short-term aging and the dentin bond strength of adhesive systems

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The aim of this study was to compare the effects of 2 aging methods on the dentin bond strength of different adhesive systems, including a universal adhesive. Seventy-two third molars were sectioned to create flat midcoronal dentin surfaces, which were randomly assigned to 12 groups (n = 6 each) according to the aging method (conventional aging, defined as 6 months of water storage; accelerated aging by means of a pH-cycling method; or negative control [immediate bond strength]) and adhesive system (Adper Single Bond 2, Clearfil SE Bond, Prime & Bond 2.1, or Scotchbond Universal). Composite resin blocks were constructed on the flattened dentin surfaces after application of the appropriate adhesive, and the specimens were stored in water for 24 hours. Specimens from the control group were immediately sectioned into resin-dentin sticks (0.8 mm^2) and subjected to a microtensile bond strength test. Specimens from the experimental groups were sectioned and tested after undergoing the assigned aging method. Data were analyzed with 2-way analysis of variance and a Tukey test ($\alpha = 0.05$). The study findings showed that neither aging method significantly affected the dentin bond strength ($P = 0.917$). Of the 4 adhesives, Adper Single Bond 2 had the highest bond strength value after aging ($P < 0.001$). Scotchbond Universal adhesive demonstrated statistically significantly higher bond strength values than Clearfil SE Bond and Prime & Bond 2.1, which had statistically similar values. Adhesive failures at the resin-dentin interface or adhesive failures mixed with cohesive failure of the adjacent substrate predominated in all groups. The 2 aging processes did not result in degradation of the adhesive interface or jeopardize the dentin bond strength of any of the adhesives tested.

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Key words: bond strength, dentin, microtensile, universal adhesive

The ongoing development of commercially available adhesive systems demands intensive in vivo or in vitro evaluation of their properties. Because in vivo studies are expensive and time-consuming and require patients' compliance, laboratory tests are an effective alternative to assess some adhesive properties.[1] Some of these tests are dynamic and try to replicate alterations in the oral environment (eg, thermal conditions and masticatory loading); other tests are static and evaluate bonding degradation over time by means of water storage or other aging methods.

Most adhesive systems perform well when the immediate bond strength is assessed.[2,3] However, bonding durability seems to be a problem for some materials, and diminished bond strength or increased nanoleakage have been observed after a long period of storage.[4-6] Water storage is the most common aging method used to evaluate the degradation of adhesive properties, as it attempts to mimic saliva in the oral environment.[2] However, degradation of adhesive properties leading to diminished bonding requires at least 6 months of water storage.[7] Some authors have suggested that 1 year of water storage or daily water change is needed.[8]

Some alternatives to water storage are available for inducing degradation of the adhesive interface.[7,9] Some authors advocate the use of aging solutions, such as propionic acid, acetic acid, or ethanol, to accelerate bonding degradation and assess the long-term effectiveness of adhesive systems.[9] However, other researchers initiate degradation by means of caries induction on the mineralized tissues near the adhesive interface, as it is one of the most commonly observed conditions in the oral environment. Several methods are available to reproduce caries in vitro.[10] Regardless of the method, caries induction consists of alternating cycles of demineralization and remineralization. This pH fluctuation is also constantly observed in the oral environment via ingestion of beverages or acid production resulting from plaque accumulation.

Different approaches to assessing aging of adhesive properties are documented in the literature. One method consists of exposing an entire restoration to in vitro aging models and then preparing the specimens for the test, while another method consists of preparing the specimens and then immersing the sectioned specimens in different aging solutions. In the latter scenario, more surfaces are exposed to the aging solution; hence, this approach seems reasonable to accelerate bonding degradation.[11] In an attempt to produce more durable interfaces, some manufacturers have added functional monomers, antibacterial agents, and fluoride to their products. However, controversy exists regarding the beneficial effects of some of these properties, especially for prevention of secondary caries.[12,13]

Few data are available regarding the amount of time needed for water storage—if the water is not changed daily—or whether

Table 1. Adhesive systems and application modes.

Adhesive system	Composition	Type	Mode of application[a]
Adper Single Bond 2 (batch: N508311)	*Etchant:* 37% phosphoric acid *Bond:* Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator, methacrylate, functional copolymer of polyacrylic and poly(itaconic) acids, 10 wt% of 5 nm-diameter spherical silica particles	Etch-and-rinse	1. Actively apply etchant for 15 s. 2. Rinse for 10 s. 3. Blot excess water. 4. Actively apply 2 consecutive layers of adhesive for 15 s. 5. Gently air dry for 5 s. 6. Light cure for 10 s.
Clearfil SE Bond (batch: primer, 012333A; bond, 01865A)	*Primer:* MDP, HEMA, hydrophobic dimethacrylate, camphorquinone, water, *N,N*-diethanol toluidine *Bond:* MDP, HEMA, Bis-GMA, hydrophobic dimethacrylate, camphorquinone, *N,N*-diethanol-*p*-toluidine, colloidal silica	Self-etching	1. Actively apply primer to the tooth surface and leave in place. 2. Dry with an air stream to evaporate the volatile solvents. 3. Actively apply bond to the tooth surface. 4. Create a uniform film using a gentle air stream. 5. Light cure for 10s.
Prime & Bond 2.1 (batch: 922355F)	UDMA, PENTA, resin R5, camphorquinone, EDAB, BHT, bisphenol A, cetylamine fluoride, acetone	Self-etching	1. Actively apply the first coat of adhesive to the entire surface and wait for 20 s. 2. Gently air dry for 5 s. 3. Repeat steps 1 and 2. 4. Light cure for 10 s.
Scotchbond Universal (batch: 509806)	*Etchant:* 37% phosphoric acid *Bond:* MDP, HEMA, dimethacrylate resins, methacrylate-modified polyalkenoic acid copolymer, ethanol, water, filler, initiator, silica	Self-etching	1. Actively apply adhesive to the entire surface for 20 s; if necessary, rewet the disposable applicator. 2. Direct a gentle air stream over the adhesive for 5 s or until it no longer moves and the solvent is completely evaporated. 3. Light cure for 10 s.

Abbreviations: BHT, butylated hydroxytoluene; Bis-GMA, bisphenol A glycidyl methacrylate; EDAB, ethyl-4-dimethylamino benzoate; HEMA, 2-hydroxyethyl methacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; PENTA, dipentaerythritol penta-acrylate monophosphate; UDMA, urethane dimethacrylate.

[a]According to the manufacturer's instructions.

accelerated aging by pH cycling is effective in assessing bonding degradation. Therefore, the present study compared the dentin bond strength of 4 adhesive systems, including a universal adhesive, submitted to 2 aging methods and a negative control condition (immediate bond strength). Two null hypotheses were tested: (1) The aging processes would result in bond strengths similar to the immediate bond strength, and (2) the adhesive systems tested would exhibit similar bond strengths regardless of the aging method used.

Materials and methods

Tooth selection and preparation

The study protocol was reviewed and approved by the Institutional Ethics Committee at Federal University of Santa Maria, Santa Maria, Brazil. Seventy-two caries-free third molars were obtained from an institutional tooth repository and stored in distilled water at 4°C for up to 3 months after being disinfected in aqueous 0.5% chloramine-T solution.

A slow-speed diamond saw (Labcut 1010, Extec) was used under copious water irrigation to section each tooth in the middle of the crown, perpendicular to the long axis, to obtain flat midcoronal dentin surface. The surrounding enamel was removed with a diamond bur in a high-speed handpiece under copious water irrigation (No. 3146, KG Sorensen). A standardized smear layer was obtained by polishing the tooth specimen with a 600-grit silicon carbide paper under running water for 60 seconds.[14]

Experimental design

Teeth were randomly allocated into 12 groups (n = 6 each) according to the adhesive system tested (Adper Single Bond 2, 3M ESPE; Clearfil SE Bond, Kuraray America; Prime & Bond 2.1, Dentsply Sirona Brasil; or Scotchbond Universal, 3M ESPE) and aging method (conventional aging by means of 6 months' water storage, accelerated aging by pH cycling, or negative control [24 hours' water storage to assess immediate bond strength]).

Bonding protocols

All adhesives were applied by a single trained operator according to the manufacturers' instructions (Table 1). Three layers of composite resin (Filtek Z250, 3M ESPE), 2.0 mm each, were then applied to the tooth specimen. Each layer was light cured for 40 seconds with a monitored LED curing unit (Emitter C, Schuster) at 600 mW/cm^2. All specimens were stored in distilled water at 37°C for 24 hours before the sticks were obtained.

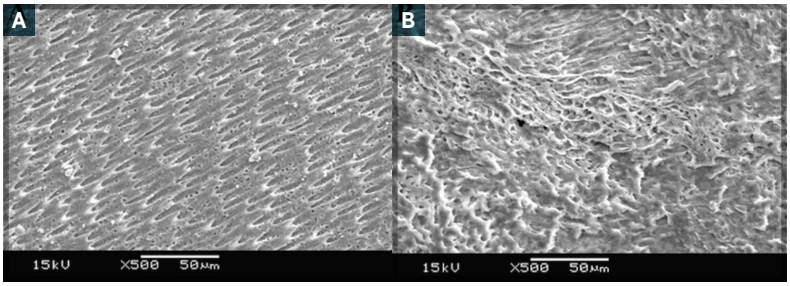


Figure. Representative fractured specimens treated with Adper Single Bond 2 adhesive system. A. Specimen from the negative control group exhibiting a regular surface and normal tubule opening. B. Specimen from the pH cycling group exhibiting intertubular porous zones with irregular surfaces resulting from the demineralization process.

Table 2. Microtensile bond strength (MPa) for all adhesives and aging methods (n = 6 per group).

	Adper Single Bond 2		Scotchbond Universal		Clearfil SE Bond		Prime & Bond 2.1	
Aging method	Mean (SD)	PF/TS	Mean (SD)	PF/TS	Mean (SD)	PF/TS	Mean (SD)	PF/TS
Negative control	51.38 (11.88)^{A}	0/67	31.54 (7.08)^{B}	4/56	31.84 (7.47)^{C}	3/76	28.38 (10.66)^{C}	1/88
pH cycling	49.71 (7.72)^{A}	0/60	36.45 (4.41)^{B}	0/75	27.77 (8.73)^{C}	6/86	26.40 (10.15)^{C}	2/70
Conventional aging	45.60 (15.07)^{A}	0/66	41.34 (4.07)^{B}	0/51	23.31 (6.40)^{C}	2/78	28.52 (10.74)^{C}	0/76

Abbreviation: PF/TS, number of pretest failures/number of specimens tested.
Different letters indicate statistically significant differences between groups ($P < 0.05$; Tukey test).

Specimen preparation

After the 24-hour storage period, all bonded specimens were sectioned in 2 directions, perpendicular to the adhesive interface, with a water-cooled diamond saw (Labcut 1010, Extec) to obtain sticks with a cross-sectional area of 0.8 mm^2, as measured with a digital calipers (Carbografite, Equipamentos Industriais).

Negative control group

The specimens in the negative control group underwent microtensile bond strength testing immediately after the 24-hour storage period.

Conventional aging group

After sectioning, the sticks from each tooth in the conventional aging group were placed in polypropylene centrifuge tubes and stored in distilled water at 37°C for 6 months. The water was not changed during the storage period.

Accelerated aging group

After sectioning, the sticks from each tooth in the accelerated aging group were placed in polypropylene centrifuge tubes and underwent pH cycling for 14 days. The sticks were immersed in a demineralizing solution (2.2mM calcium dichloride [CaCl2], 2.2mM monosodium phosphate [NaH2PO4], and 0.05M acetic acid; pH = 4.5) for 8 hours and then in a remineralizing solution (1.5mM CaCl2, 0.9mM NaH2PO4, and 0.15mM potassium chloride; pH = 7.0) for 16 hours.[15,16] After each cycle, the solutions were changed, and the sticks were rinsed with deionized water and blotted dry. Solutions were measured periodically with a pH meter.

Microtensile bond strength testing

After undergoing the assigned aging method, each resin-dentin stick was attached to a testing jig with cyanoacrylate and stressed at a crosshead speed of 1 mm/min until failure in a universal testing machine (EMIC DL 1000, Instron Brasil Equipamentos Científicos). The microtensile bond strength values (MPa) were determined by dividing the measured force (N) registered at the failure point by the bonded area (mm^2).

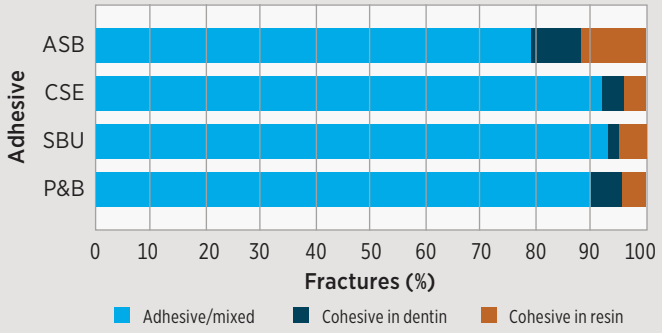
Failure mode analysis

Debonded specimens were evaluated under a stereomicroscope at 40× magnification to classify the failure as adhesive/mixed (failure at the resin-dentin interface or adhesive failure mixed with cohesive failure of the adjacent substrate) or cohesive (failure exclusively in dentin or composite resin).[16]

Morphologic analysis

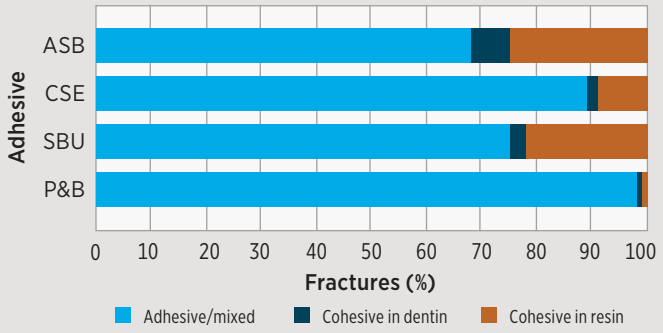
A scanning electron microscopic (SEM) analysis was performed to confirm dentin demineralization in the specimens submitted to artificial caries induction via pH cycling. One stick from each experimental group was selected and prepared for SEM analysis. Sticks were immersed in ethylenediaminetetraacetic acid solution (0.7M; pH = 7.4) for 5 minutes, followed by immersion in sodium hypochlorite (0.34M; pH = 12.3) for 3 minutes.[17] The sticks were then dehydrated in ascending

Chart 1. Fracture pattern distributions in the negative control group.



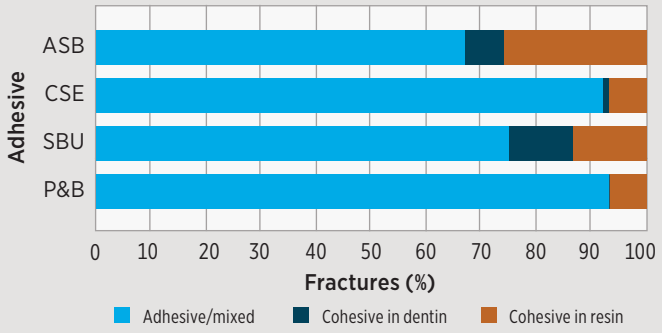
Abbreviations: ASB, Adper Single Bond 2; CSE, Clearfil SE Bond; P&B, Prime & Bond 2.1; SBU, Scotchbond Universal.

Chart 2. Fracture pattern distributions in the pH cycling group.



Abbreviations: ASB, Adper Single Bond 2; CSE, Clearfil SE Bond; P&B, Prime & Bond 2.1; SBU, Scotchbond Universal.

Chart 3. Fracture pattern distributions in the conventional aging group.



Abbreviations: ASB, Adper Single Bond 2; CSE, Clearfil SE Bond; P&B, Prime & Bond 2.1; SBU, Scotchbond Universal.

degrees of ethanol (30%, 50%, 70%, and 80% for 5 minutes each and 90%, 95%, and 100% for 10 minutes each). The sticks were gold sputtered and underwent SEM analysis (JSM-T330A, JEOL) at 15 kV and 500× magnification.

Statistical analysis

The experimental unit in this study was the tooth. Thus, the microtensile bond strength values of all the sticks from the same tooth were averaged for statistical analysis. The mean microtensile bond strength for all groups was expressed as the mean of the 6 teeth in each group. The sample size of 6 teeth per group was estimated before the study based on 80% power, a coefficient of variation of 20%, and an assumption of a 2-sided 5% significance level for comparisons.

Only specimens with adhesive/mixed failures were included in the statistical analysis. Pretest failures that occurred during specimen preparation were included in the statistical analysis with a value of 0 MPa.

The microtensile bond strengths were analyzed by a general linear model 2-way analysis of variance (adhesive systems vs aging method) and a post hoc Tukey test at a significance level of 0.05. Statistical analysis was performed using Minitab software (version 17, Minitab).

Results

The Figure shows representative fractured specimens from the negative control and accelerated aging (pH cycling) groups (Adper Single Bond 2 adhesive). A uniform surface and normal tubule opening can be seen in the noncycled specimen. In the pH cycled group, disorganization and loss of continuity in dentinal areas are observed, clearly reflecting the demineralization process.

Specimens that underwent accelerated aging by pH cycling or 6 months of water storage exhibited bond strength values that were statistically similar to those in the negative control group (ie, specimens tested immediately after being sectioned) ($P = 0.917$). Although there was no interaction between the adhesive system and aging method ($P = 0.314$), a statistically significant difference was observed among the adhesive systems ($P < 0.001$). Of the 4 adhesive systems, Adper Single Bond 2 had the highest bond strength values ($P < 0.05$). Scotchbond Universal exhibited statistically significantly higher bond strength values ($P < 0.05$) than Clearfil SE Bond and Prime & Bond 2.1, whose values were statistically similar (Table 2).

The 3 failure modes are shown in Charts 1-3. Adhesive/mixed failures were predominant; however, cohesive failures in dentin and resin were observed in all tested groups.

Discussion

Restorative materials are continually challenged in the oral environment by saliva, caries, and erosion as well as other chemical, mechanical, and thermal processes. One frequently occurring process is pH fluctuation resulting from alternating cycles of demineralization and remineralization. Thus, 2 aging methods were used in this study, with the aim of potentially accelerating bonding degradation and comparing the results with those of a negative control group (immediate bond strength values). The results revealed that neither accelerated aging by pH cycling nor 6 months of water storage (conventional aging) generated sufficient degradation on the adhesive interface to

jeopardize the bond strength for any of the adhesive systems tested. Thus, the first null hypothesis could not be rejected.

The literature describes various aging methods and solutions to accelerate bonding degradation, such as thermocycling, water storage, sodium hypochlorite, propionic acid, acetic acid, and ethanol.[5,7,9] Although these methods differ in several aspects, all attempt to produce bond stress along the interface, leading to microdefects that might induce the breakdown of the adhesive interface. However, no consensus exists regarding study methodology, especially for thermocycling and water storage, as different numbers of cycles and months of water storage have been suggested. In addition, it is not well established if the water must be changed regularly to induce aging or if it can be left unchanged during the aging period.

Moreover, researchers have proposed alternating cycles of pH change as an accelerated aging method in an attempt to induce degradation near the adhesive interface.[12,13] In this study, no difference was observed in the bond strength values of specimens in the pH cycling group and those in the negative control group; however, dentin demineralization was observed near the adhesive interface, confirming the effectiveness of artificial caries induction, although it was not sufficient to jeopardize the dentin bond strength of the adhesive systems.

The use of pH cycling or other artificial caries induction models as an aging method has produced inconsistent results; however, its use is based on the premise that the acid challenge could produce erosion and crack formation on the adhesive surface, leading to its deterioration.[18] Deng et al compared several artificial aging methods, including pH cycling, and observed that after 15 cycles of demineralization and remineralization, a statistically significant difference was found for Adper Single Bond 2 and G-Bond.[7] Although the study consisted of 1 more cycle than that in the present study, less time (6 hours) was used for demineralization than in the current protocol (8 hours). On the other hand, Pedrosa et al did not find statistically significant differences between One-Up Bond F Plus, Clearfil SE Bond, and Clearfil Protect Bond, which is in accordance with the present results.[13] Hence, uncertainty remains with respect to whether more cycles of pH challenge would induce more degradation of the interface, as no study, to the authors' knowledge, has assessed more than 15 pH cycles.

Water storage is a frequently used aging method, as it is an easy and inexpensive way to evaluate adhesive degradation. However, uncertainty remains regarding the amount of time needed or whether a daily water change is necessary to produce degradation. Storing dentin sticks in water may contribute to adhesive degradation as hydrolysis of the filler-matrix interface is expected over time, which may decrease the mechanical properties of the material.[19]

Another important factor is that some adhesive components may contribute to their stability and, thus, interfere in the degradation process; for example, the 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer can produce stable chemical bonds over time.[20] Consequently, this study tested 4 adhesive systems composed of different monomers. None of the adhesives demonstrated statistically significantly lower bond strength values after 6 months of water storage. Some researchers have suggested that the water needs to be changed daily to accelerate degradation.[8,21] Although the results of the present study cannot confirm these findings, the authors speculate that, in the absence of frequent water changes, more than 6 months of water storage is needed to generate enough degradation with most adhesives.[19]

Antibacterial agents have been incorporated in some restorative materials because they contribute to remineralization of adjacent lesions in patients with high caries risk and reduce the occurrence of secondary caries that might weaken the adhesive interface.[22] Therefore, Prime & Bond 2.1 was included in this study to determine whether fluoride had a beneficial effect on bond strength after artificial carious lesions were induced. After 14 cycles of demineralization/remineralization, no statistically significant difference was observed for this adhesive, which is in accordance with other study findings.[23] However, because none of the adhesives in the study demonstrated diminished bond strength values, the effect of fluoride on the durability of adhesives requires further investigation.

Clearfil SE Bond and Scotchbond Universal contain the functional monomer MDP, which has been reported to establish a durable chemical bond to hydroxyapatite and, consequently, could lead to stable adhesion and less degradation over time.[20] Adper Single Bond 2 contains the polyalkenoic acid copolymer, which can establish a chemical bond to some degree but cannot self-assemble into nanolayers as does the MDP monomer.[24] Prime & Bond 2.1 is a fluoride-containing adhesive that can aid in remineralization of adjacent areas; however, the beneficial effect on the adhesive interface is still controversial.[12,13]

It appears that formation of an adequate hybrid layer is necessary for establishing immediate bond strength and for durability of the interface, as Adper Single Bond 2, the only adhesive system in this study with a separate acid conditioning step, had the highest bond strength of all adhesives tested; as a result, the second null hypothesis is rejected. Nevertheless, all of the adhesives tested maintained their bond strength after undergoing accelerated aging by pH cycling or 6 months of water storage.[13,25] Hence, all 4 adhesives are appropriate for clinical purposes.

Conclusion

Accelerated aging of bonded tooth specimens by means of pH cycling and 6 months of water storage did not degrade the adhesive interface or jeopardize the bonding stability of the 4 adhesive systems tested.

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Disclaimer

The authors report no conflicts of interest pertaining to any of the products or companies discussed in this article.

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Tanya M. Gibson, DDS

Oropharyngeal ulcer

A 25-year-old man presented to the oral surgery clinic for extraction of a nonrestorable maxillary left second molar with divergent and dilacerated roots. When the patient returned the following week to have his sutures removed, this 0.5-cm yellowish ulcerative lesion, which was surrounded by an erythematous halo, was noted on the left soft palate (Figure). On palpation, this lesion was not indurated and did not have rolled borders.

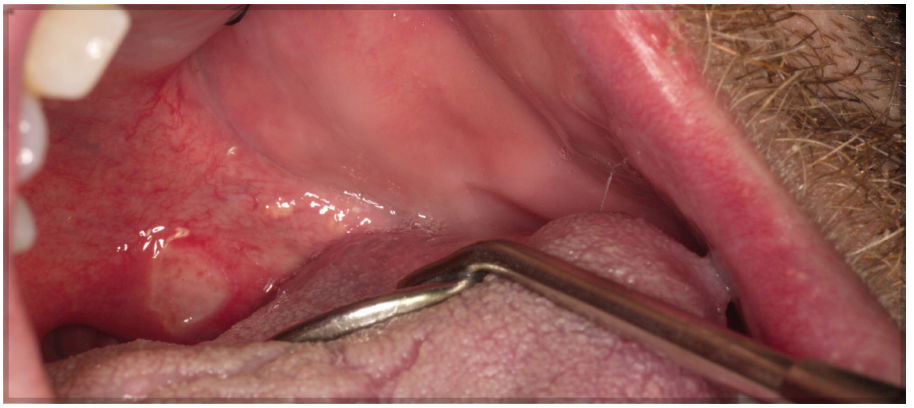

Figure. A 0.5-cm yellowish ulcerative lesion surrounded by an erythematous halo is located on the left soft palate.

Which of the following is the most appropriate diagnosis?

A. aphthous stomatitis
B. erythema migrans
C. recurrent herpetic infection
D. squamous cell carcinoma

Diagnosis is on page 78

Gingival bump

(Case courtesy of Dr Kelley Thompson, Leawood, Kansas.)

A 90-year-old man presented for evaluation of a reddish nodular gingival mass, located buccal to the mandibular right first molar, that has been enlarging over the past 4 months (Fig 1). A periapical radiograph of the area did not reveal any intraosseous pathologic lesion (Fig 2). The lesion was not present at his previous hygiene appointment. A biopsy was performed, and the histopathologic findings consisted of normal oral epithelium overlying a proliferation of invasive, well-formed glandular epithelium with luminal necrosis.

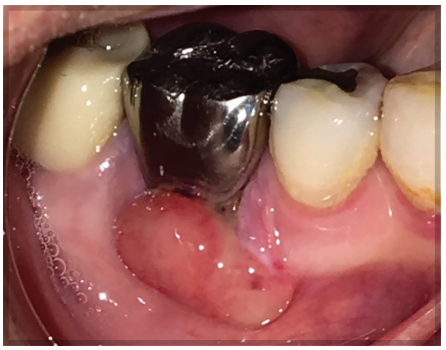

Fig 1. Reddish nodular gingival mass buccal to the mandibular right first molar.

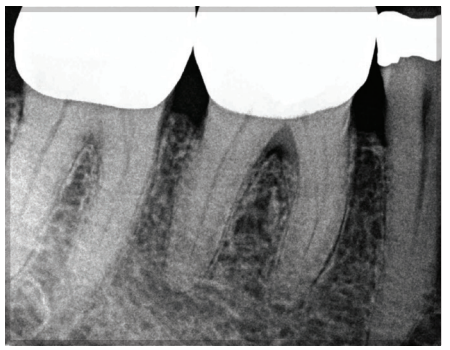

Fig 2. Periapical radiograph of the first molar, devoid of an intraosseous pathologic lesion.

Which of the following is the most appropriate diagnosis?

A. metastatic adenocarcinoma
B. peripheral giant cell granuloma
C. peripheral ossifying fibroma
D. pyogenic granuloma

Diagnosis is on page 78

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Oropharyngeal ulcer

Diagnosis

A. aphthous stomatitis

Aphthous stomatitis (*canker sore*) is a common oral mucosal pathosis. It generally occurs on the freely movable soft tissue that is not attached to bone. Frequent locations for aphthous stomatitis include the buccal mucosa, labial mucosa, soft palate, and ventral and lateral surfaces of the tongue. There are 3 clinical subtypes of aphthous stomatitis: minor aphthae, major aphthae, and herpetiform aphthae. The minor variant typically measures less than 0.5 cm and resolves without scarring within 1-2 weeks. The major variant measures greater than 0.5 cm and may resolve with scarring within several weeks. Herpetiform aphthae appear as clusters of small ulcerations measuring 0.1-0.3 cm and resolve without scarring within 1-2 weeks. All types can recur at undetermined intervals; however, the recurrence intervals of the herpetiform variants tend to be shorter.

An average of 20% of the population is affected by aphthous stomatitis; however, a prevalence range of 5%-66% has been reported.[1] The etiology is unknown, but associations with allergies, genetic factors, blood abnormalities, immunologic reactions, infectious agents, nutritional deficiencies, smoking cessation, stress, and trauma have been implicated.[1] Laboratory tests are not useful in diagnosis of aphthous stomatitis. Clinicians generally rely on the classic clinical presentation—a yellowish ulcerative lesion surrounded by an erythematous halo occurring on freely movable soft tissue—to render a diagnosis.

Erythema migrans (*ectopic geographic tongue*) presents as an erythematous atrophic area surrounded by white serpiginous borders that do not wipe off. The map-like lesions of erythema migrans can occur on any oral mucosa surfaces.

An intraoral recurrent herpetic infection can be mistaken for herpetiform aphthous stomatitis because of the clustering of lesions that is characteristic of the clinical appearance of both pathoses. One parameter used to distinguish between the 2 entities clinically is location. Recurrent herpetic infections present as clusters of ulcerations located on the keratinized, bound-down mucosa of the gingiva and hard palate, whereas herpetiform aphthous and other variants occur on the nonkeratinized, freely movable tissue of the oral cavity.

The clinical presentation of squamous cell carcinoma varies and can include a white patch (leukoplakia), red patch (erythroplakia), red and white patch (erythroleukoplakia), or chronic ulceration. On clinical palpation, these lesions tend to be indurated. The acute presentation and nonindurated nature of the ulcerative lesion presented in the case argue against its being the clinical manifestation of squamous cell carcinoma.

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Gingival bump

Diagnosis

A. metastatic adenocarcinoma

Metastasis to the oral cavity is rare and is most often associated with a male predilection and an advanced cancer stage.[1] Metastatic lesions constitute about 1% of all oral cavity malignancies.[1] A practitioner is more likely to encounter a metastatic lesion of the jawbone than of the oral soft tissues.[2] However, when the oral soft tissues are the involved location for metastatic cancer, the posterior gingiva is the most common site.[1] The histologic subtype of malignancies most often encountered in soft tissue metastasis is an adenocarcinoma.[1]

Diagnosing a metastatic tumor in the oral cavity can be challenging. Once it has been determined that the neoplasm most likely represents metastatic disease, the pathologist relies on immunohistochemical (IHC) stains to try to determine the site of origin. In an analysis of 412 soft tissue metastases, Irani reported that primary neoplasms of the lung, liver, and breast are among the tumors most often associated with metastasis to the oral cavity. [1]

For this patient, a battery of IHC stains were performed. Based on the IHC profile, the neoplasm was most compatible with a primary tumor of gastroesophageal or pancreaticobiliary origin. The patient must undergo extensive medical tests to determine the location of the primary tumor.

The peripheral giant cell granuloma, peripheral ossifying fibroma, and pyogenic granuloma are 3 common reactive lesions associated with an increased incidence of recurrence. They often appear as a nodular, sometimes lobulated mass that may be sessile or pedunculated. The peripheral giant cell granuloma and peripheral ossifying fibroma are found exclusively on the gingiva. The pyogenic granuloma can occur on any intraoral or extraoral location but favors the anterior gingiva.[3]

Due to similarities in their clinical presentation, the only way to distinguish among the 3 is the histologic findings. The peripheral giant cell granuloma is characterized by plump mesenchymal cells intermixed with multinucleated giant cells. The peripheral ossifying fibroma comprises a proliferation of fibrous connective tissue with the formation of mineralized product. The pyogenic granuloma exhibits a vascular proliferation reminiscent of granulation tissue.

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SELF-INSTRUCTION ANSWERS

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6/1/2018 to 5/31/2024
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Exercise No. 420

May/June 2018, p. 25

1. **D**	6. **A**	11. **A**
2. **C**	7. **D**	12. **C**
3. **B**	8. **A**	13. **D**
4. **C**	9. **C**	14. **B**
5. **A**	10. **B**	15. **A**

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1. **D**	6. **A**	11. **C**
2. **B**	7. **A**	12. **D**
3. **D**	8. **B**	13. **C**
4. **D**	9. **D**	14. **B**
5. **C**	10. **A**	15. **C**

Exercise No. 422

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1. **C**	6. **C**	11. **B**
2. **D**	7. **B**	12. **B**
3. **D**	8. **C**	13. **C**
4. **B**	9. **A**	14. **C**
5. **C**	10. **B**	15. **B**

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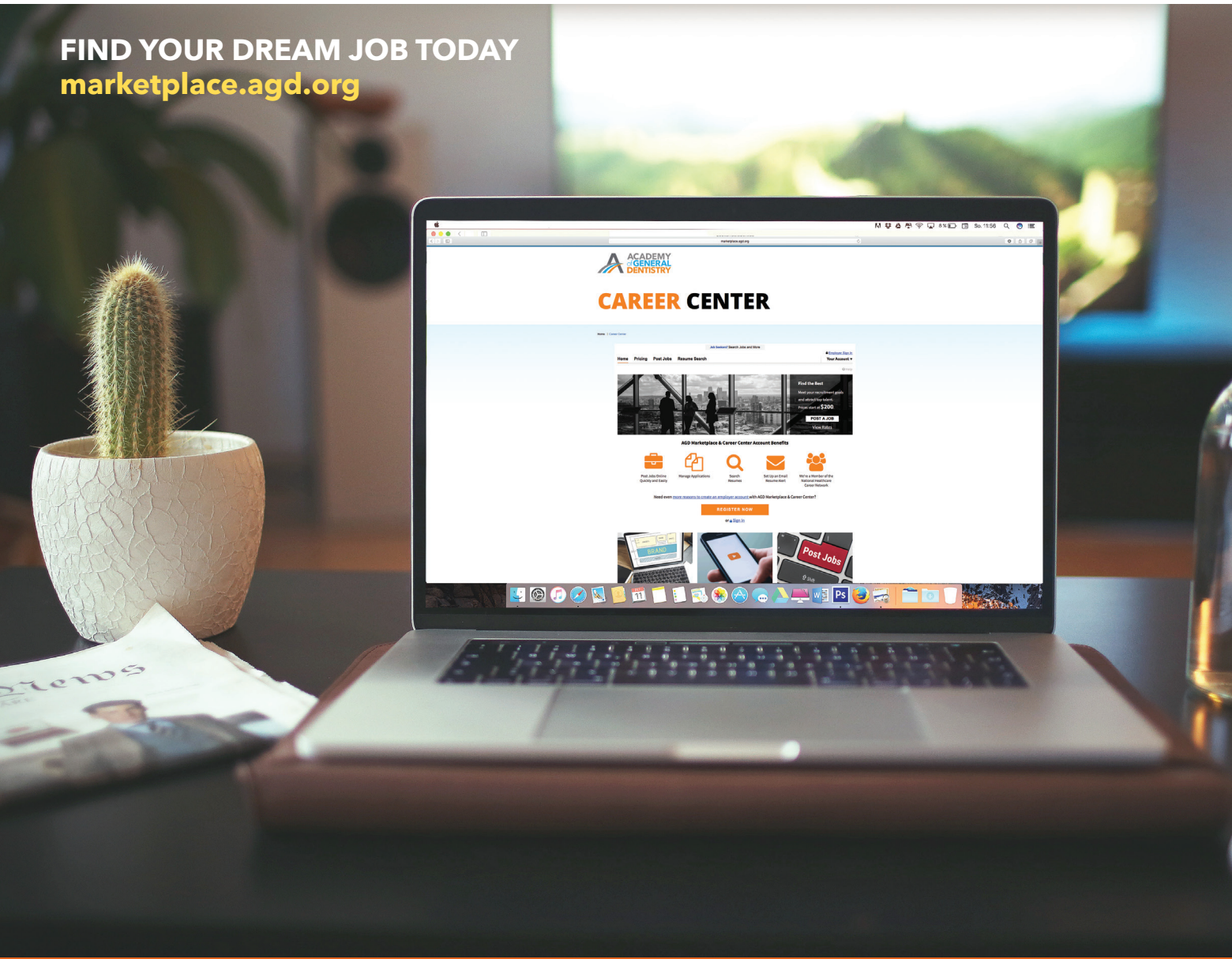

Management of iatrogenic dislodgment of a mandibular third molar into the pterygomandibular space

Vikram Shetty, MDS, MBBS, BDS ■ Padmaraj Hegde, MDS, BDS ■ Sandesh Jain, MDS, BDS

Although the surgical extraction of the mandibular third molar is routinely performed in dental clinics, the precise management of complications associated with it requires thorough knowledge and experience in the field of oral and maxillofacial surgery. Iatrogenic dislodgment of a tooth or its fragment is a rare complication and usually occurs when excessive, uncontrolled forces are applied via elevators. It also is possible that this rare complication may be underreported. This case report describes the retrieval, under local anesthesia, of a mandibular left third molar crown from the posterosuperior region of the pterygomandibular space after iatrogenic dislodgment.

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Key words: intraoperative complications, pterygomandibular space, third molar

Dislodgment of a tooth or a fragment of the tooth is a rare complication during surgical extraction of impacted molars. Nevertheless, dislodgment of third molars into various fascial spaces, including the buccal, lateral pharyngeal, and pterygomandibular spaces, as well as anatomic spaces such as the pterygopalatine fossa, has been reported.[1-9] Displaced tooth fragments of various sizes may migrate to different anatomical spaces.

There are different schools of thought about the delay between dislodgment and retrieval.[8,10,11] Some recommend that the delay in retrieval may favor stabilization of the fragment, whereas others argue that the retrieval attempt should be immediate to avoid risk of complications. This case report describes the immediate retrieval of a mandibular left third molar crown that was displaced posterosuperiorly into the pterygomandibular space.

Case report

A 26-year-old man reported to the Department of Oral and Maxillofacial Surgery, A.B. Shetty Memorial Institute of Dental Sciences, Mangalore, India, complaining of pain, discomfort while chewing, and difficulty in mouth opening of 3 days' duration. A panoramic radiograph showed a distally impacted mandibular left third molar (Fig 1).

The treatment plan was to section the crown from the cervical region along the cementoenamel junction to clear the path of exit and then to remove the roots separately. After sectioning the tooth, a junior resident used a straight elevator to separate the coronal portion from the rest of the tooth. Due to complications from force displacement, the coronal fragment of the tooth was inadvertently displaced posteriorly and disappeared into the tissues.

Although the junior resident was able to remove the distal root, the displaced fragment could not be located. A panoramic radiograph was taken and showed the coronal fragment of the tooth dislodged into the posterosuperior area in the pterygomandibular space on the left side (Fig 2). The mesial root of the mandibular third molar was visible in the alveolar socket. Following this imaging, the mesial root was removed.

To retrieve the displaced fragment, the distal releasing incision was extended medially toward the palatoglossal arch (Fig 3). Blunt dissection was carried out to reach the medial pterygoid muscle. Careful dissection was carried out in the posterosuperior direction, between the muscle and the ramus, to locate the fragment. Once visualized, the fragment was removed from the pterygomandibular space with the help of a long-toothed forceps (Fig 4). The removal was confirmed with a postoperative panoramic radiograph (Fig 5). The incision was closed with resorbable sutures.

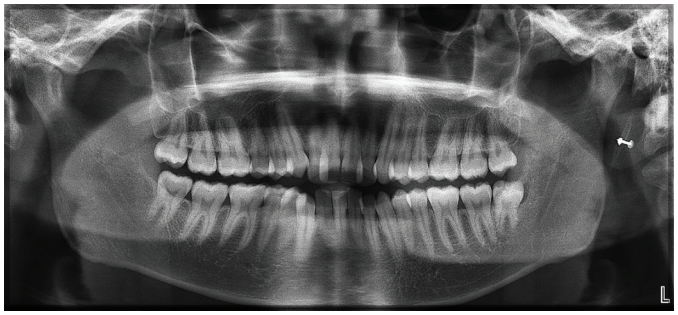

Fig 1. Preoperative panoramic radiograph showing a distally impacted mandibular left third molar.

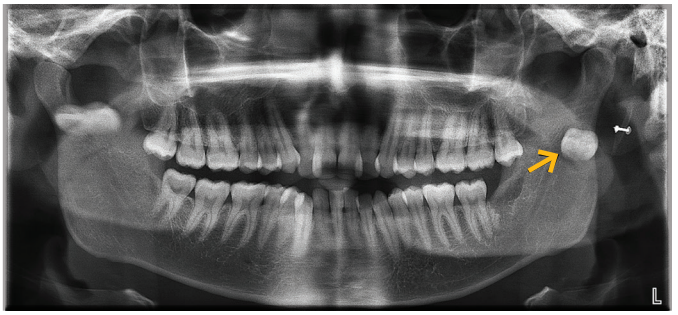

Fig 2. Panoramic radiograph showing the tooth fragment dislodged posterosuperiorly into the pterygomandibular space on the left side (arrow).

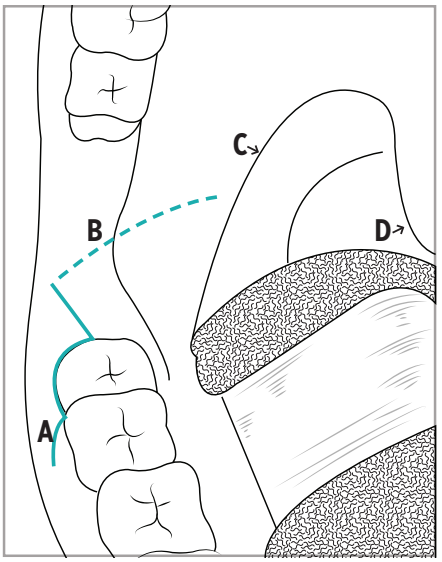

Fig 3. Modification of the incision to gain access to the pterygomandibular space. A, Ward's incision; B, medial extension of the incision; C, palatoglossal arch; D, uvula.

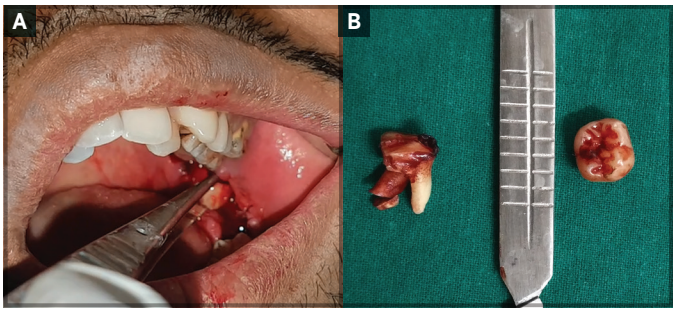

Fig 4. Fragment retrieval. A. Removal of the fragment with the help of a long-toothed forceps. B. Retrieved tooth fragment along with the mesial and distal roots.

The postoperative period was uneventful, and the patient remained asymptomatic during follow-up.

Discussion

A search in PubMed, *[(displacement of tooth) AND pterygomandibular space]*, returned 7 results.[4-9,12] In 3 of 7 cases, fragments were displaced into the pterygomandibular space, and in the other 4 cases, the fragments were displaced into the buccal space, pterygopalatine fossa, lateral pharyngeal space, or submandibular space.[4-9,12] In 4 of 7 reported cases, the displaced fragment was from the mandibular third molar.[4,5,9,12] In the other 3 cases, the displaced fragment was from the maxillary third molar.[6,7,8] In all 3 cases of displacement in the pterygomandibular space, the displaced fragment was from the mandibular third molar.[4,5,9]

Dislodgment of a third molar or its fragment during exodontia is rare.[1,2] However, once a tooth or its fragment is dislodged in any of the potential fascial spaces, it poses a great challenge to accurately locate and remove. Therefore, any patient with a third molar indicated for surgical extraction should be evaluated carefully. Any significant risks (such as distal version and curved or dilacerated roots) that might increase the risk of dislodgment of a tooth fragment or other potential complications should be discussed with the patient beforehand; written informed consent must be obtained.[13]

Surgical extraction of a tooth should always be performed with appropriate instruments under adequate visual access to the surgical area. Bone troughing and tooth sectioning should be performed when necessary, and use of excessive, uncontrolled forces should be avoided.[14] To avoid dislodgment of the third molar, use of the index finger as a guard is recommended while the clinician is using elevators. In addition, the distal releasing incision should always be made over the bone, that is, on the anterior border of the ascending ramus. If the incision is made more medially, the chances of dislodgment increase because the entrance to the pterygomandibular space is very close to the anterior border of the ascending ramus medially (Fig 6).[15]

When the operator discovers that a tooth or its fragments have been displaced during surgical extraction, he or she should refrain from blindly attempting a retrieval. To avoid further grave complications, the treating dentist should always consider referring the patient to an oral and maxillofacial surgeon or to a dental school for retrieval. This region has a complex anatomy, and retrieval of a displaced tooth or fragment is further complicated by the limited access. Any attempts by dentists with limited training may worsen the situation and push the fragment deeper.[13] Retrieval should only be attempted

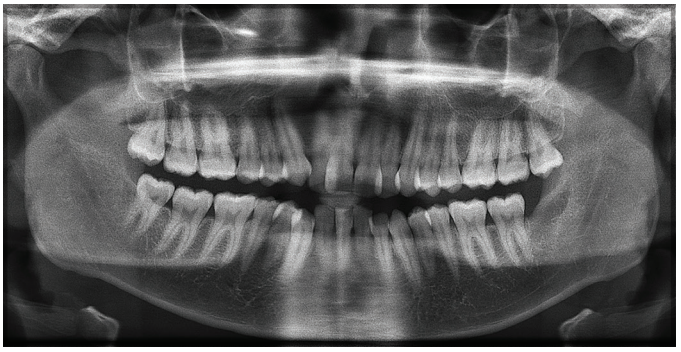

Fig 5. Postoperative panoramic radiograph confirming successful fragment retrieval.

Table. Cases of tooth fragment dislodgment and retrieval previously reported in the literature.

Authors (year)	Space involved	Retrieval	
		Delay	Anesthesia
Papadogeorgakis & Pigadas (1990)[4]	Pterygomandibular	NR	NR
Tumuluri & Punnia-Moorthy (2002)[5]	Pterygomandibular	9 d	Local
Kocaelli et al (2011)[6]	Buccal	1 wk	Local
Lee at al (2013)[7]	Lateral pharyngeal	2 y	General
Özer et al (2013)[8]	Pterygopalatine fossa	1 wk	General
Suer et al (2014)[9]	Pterygomandibular	2 y	Local
Jolly et al (2014)[12]	Submandibular	1 mo	Local

Abbreviation: NR, not reported.

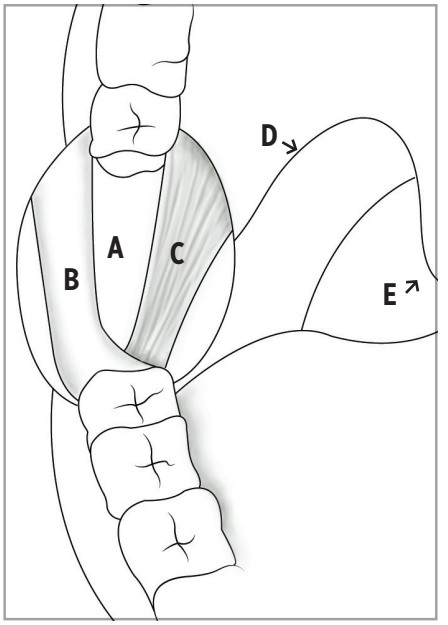

Fig 6. Pterygomandibular space (A), bounded laterally by the medial surface of ramus of the mandible (B) and medially by the medial pterygoid muscle (C); D, palatoglossal arch; E, uvula.

if the fragment is clearly visible and can be grasped easily. It is therefore recommended that the operator immediately halt the procedure; obtain intraoperative radiographs; gather all relevant information, including size, location, and type of fragment; assess the situation; and then decide whether to attempt a retrieval or to refer the patient to a person with the relevant training.[16]

The most appropriate timing for the retrieval attempt is a subject of controversy. Some believe that the delay in retrieval may favor stabilization of the fragment due to fibrosis, whereas others argue that the retrieval attempt should be made during the initial surgical procedure to avoid risks of infection, pain, and trismus and to spare the patient from being subjected to another procedure.[8,10,11] In the aforementioned 7 case reports, most of the authors preferred the option of not delaying the procedure, and the fragment was retrieved when the patient first presented to the maxillofacial surgeon (Table).[4-9,12] Any delay between the dislodgment and retrieval in these cases was solely due to the delay caused by the patient in reporting to the surgeon.

In 1 case, retrieval had to be delayed by 1 week as the patient was febrile at the time of presentation due to infection in the region of dislodgment.[6] The patient was prescribed an antibiotic course for 1 week.[6] This suggests that the risks of complications associated with delaying retrieval to facilitate fibrosis for ease of localization outweigh its advantages, and the authors therefore recommend that fragments be retrieved as early as possible after dislodgment. In the present case, the retrieval was performed immediately after the fragment was located on the radiograph, and the fragment was retrieved with relative ease. All the possible outcomes of delay, including the ease of retrieval due to fibrosis as well as the increased risk of infections, trismus, and patient discomfort, should be weighed when the clinician is making a decision about the management of a tooth displaced into a fascial space.

The pterygomandibular space is bound anteroposteriorly by the pterygomandibular raphe and the parotid gland with its capsule; lateromedially by the ascending ramus of the mandible and medial pterygoid muscle; and superoinferiorly by the lateral pterygoid muscle and pterygomassetric sling. Anteriorly, there is a small gap between the medial pterygoid muscle medially and deep tendon of temporalis muscle laterally, which provides the entrance to the pterygomandibular space.[15] Intraoral access to the pterygomandibular space can be achieved via an extended lingual mucoperiosteal flap from the ramus to the premolar region, but this approach has a risk of lingual nerve damage and provides a narrow field.[5,14,17] If the fragment is displaced posterosuperiorly in the pterygomandibular space, as in this case, the authors recommend extending the distal releasing incision in a medial direction toward the palatoglossal arch to reach the medial pterygoid muscle and then performing a blunt dissection to gain access to the tooth or its fragment. However, as each case is unique, no single technique of retrieval can be used in all circumstances. The surgeon must improvise

according to the situation, and a thorough knowledge of the regional anatomy is essential in attempting a retrieval.

Author information

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The influence of impression coping splinting on the accuracy of the open-tray technique

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Aspasia Sarafianou, DDS, Dr Dent

The objective of this study was to examine the effect of splinting of the impression copings on the accuracy of the cast when the open-tray technique is used. An epoxy master cast with 3 implants was fabricated. The first 2 implants were parallel to each other and perpendicular to the horizontal plane (implants A and B), and the third implant (implant C) had a 25-degree inclination. A passively fitting metal framework that was fabricated over this master cast was used to measure accuracy of fit. Ten casts were fabricated from this epoxy resin master cast with the use of polyether material and the open-tray technique. For the first 5 casts, the impression copings were splinted with dental floss and autopolymerizing acrylic resin; in the next 5 casts, the impression copings were not splinted. The metal framework in the master cast was fixed in the new specimens, and the microgap between this prosthesis and the implant analogs was evaluated. The specimens were observed under an optical microscope, and microgap measurements were made on photographs taken at a standardized magnification of 40×. The inclined implant C had the smallest mean microgap among the 3 implants, but the differences were not statistically significant. Microgaps for all 3 implants were smaller when they were splinted, but the difference from the mean of the nonsplinted counterpart was statistically significant only for the inclined implant. The results suggest that there is no clinical advantage in splinting the impression copings for parallel implants. On the other hand, when the implants are not parallel, splinting of the impression copings can result in greater accuracy of the fabricated cast.

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The accuracy of the master cast for implant restorations is an important factor to achieve the needed precision of fit between the implant abutments and the prosthesis. The first report concerning the accuracy of an implant impression was published in 1985.[1] The authors used the open-tray technique and performed simultaneous intraoral splinting of the implant impression copings with acrylic resin.

Since that time, 2 implant impression techniques have been established in clinical practice: the open-tray and closed-tray techniques, each combined with the indicated impression copings. With the open-tray technique, in cases of multiple implants, the impression copings can be splinted or freestanding. Although numerous studies have examined the implant impression accuracy—and the corresponding accuracy of the working cast—of the open-tray technique, there is no clear clinical guideline about the efficacy of splinting or not splinting the impression posts.[2-16]

In vitro studies by Papaspyridakos et al examined the impression accuracy associated with splinted or nonsplinted implant impression copings when polyether impression material and the open-tray technique were used.[2,3] Splinting of the impression copings with autopolymerizing acrylic resin resulted in more accurate implant impressions.

The greater accuracy of the open-tray technique is supported by many researchers.[4-6] However, not all studies have considered the important parameter of impression coping splinting. Most studies examined implants that were parallel to each other.[4,6,7,9,10] Fewer studies have investigated nonparallel implants.[3,5,8,13]

Reddy et al compared the impression accuracy of the open- and the closed-tray techniques for parallel and nonparallel implants.[11] Both techniques resulted in the same impression accuracy, regardless of the implant inclination.

Studies by Gallucci et al and Mpikos et al have shown that parallel implants result in more accurate impressions than nonparallel implants.[8,12] Mpikos et al examined 4 parallel internal and external connection implants, 1 impression material (polyether), and 2 impression techniques (open and closed tray).[12] The impression technique had no effect on the implant impression accuracy when internal connection implants were used.

Tsagkalidis et al compared the impression accuracy of splinted and nonsplinted impression copings in association with the open- and closed-tray techniques.[13] They found no statistically significant differences between splinting and not splinting for implant inclinations up to 15 degrees. When the inclination of the implant increased, splinting resulted in more accurate impressions.

The current literature does not provide definitive proof as to which implant impression technique is the most accurate.

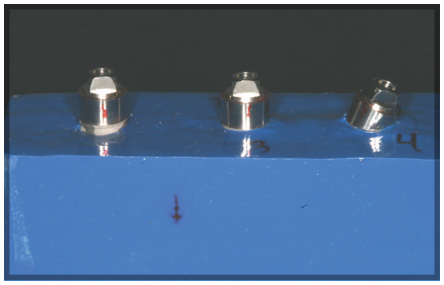


Fig 1. Master cast.

Fig 2. Metal framework used to measure the marginal gap.

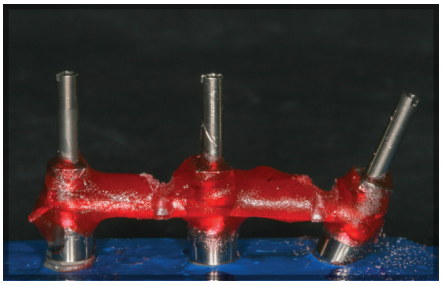


Fig 3. Splinted implant impression posts.

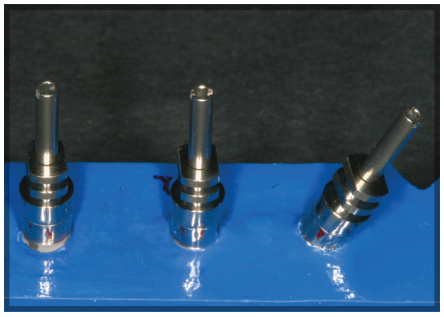


Fig 4. Freestanding implant impression posts.

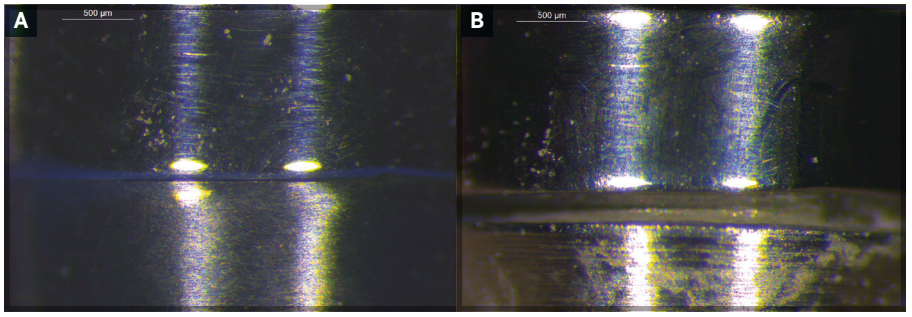


Fig 5. Resulting marginal gaps. A. Parallel, nonsplinted implant (implant B). B. Nonparallel, nonsplinted implant (implant C).

Parameters such as implant type (internal or external connection), impression coping splinting, and implant inclination have a direct impact on the impression accuracy and the resulting precision of the master cast.[14-16]

The objective of this study was to examine the effect of splinted and nonsplinted impression copings on the accuracy of the cast when the open-tray technique is used for parallel and inclined implants. The null hypothesis was that there would be no differences in the accuracy of casts produced from impressions with splinted and nonsplinted impression copings for parallel and nonparallel implants.

Materials and methods

An epoxy resin master cast was fabricated utilizing 3 external connection dental implants with a diameter of 3.4 mm (Xive TG, Dentsply Sirona). The implants were embedded in the epoxy resin with the use of an electronic paralleling device (Fig 1). Two implants (implants A and B) were placed perpendicular to the horizontal plane and parallel to each other (0-degree inclination), while the third implant (implant C) was placed with a 25-degree inclination to the vertical plane.

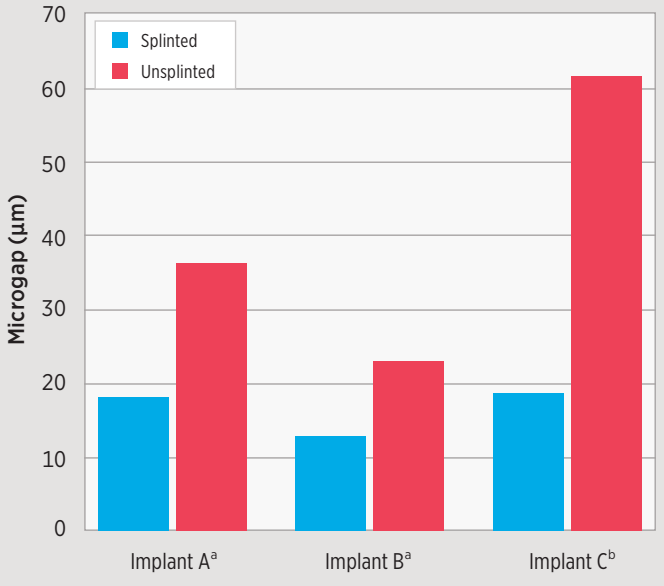
A screw-retained metal framework was waxed, sprued, and cast out of a base metal alloy. After casting, the framework was cut, fit, and soldered to achieve passive fit over the implants (Fig 2). The framework was initially screwed on the first implant analog (implant A) with a torque of 20 N/cm. The resulting initial microgap at the implant-analog surface for implants B and C was measured with the use of an optical microscope (Leica Microsystems), and photographs of the fitting surfaces of all the analogs were taken at a standardized magnification of 40×. The framework was later fixed by the retaining screw on the inclined analog (implant C), and the fit was evaluated accordingly on the other 2 implants (implants A and B). These initial microgap values were recorded for each specimen, to be used for the calculation of the final microgap value.

Rotary instruments were used to create 5 nonparallel, 2-mm-deep grooves on the sides of the master cast surface to allow precise orientation of the custom tray. A light-polymerizing resin tray material (Triad, Dentsply Sirona) was used for the fabrication of 2 custom impression trays, 1 for each impression technique tested.

Closed-tray transfer copings (Xive TG impression posts D, 3.4-4.5 mm, Dentsply Sirona) were connected to the implants on the epoxy resin cast. The consistency of the impression material thickness was ensured by injecting addition silicone material (Exabite II NDS, GC America) around the copings, creating a consistent 2-mm space. The tray material was packed over the silicone relief and carefully positioned over the copings on the master cast until the orientation grooves were completely engaged. Light polymerization was performed with a visible light–curing device (Triad 2000, Dentsply Sirona) for 6 minutes. Following polymerization, the trays were stored at room temperature for 24 hours according to the manufacturer's instructions. The same custom tray was used for all 5 impressions in each group. Polyether tray adhesive material was applied on the inner surface of every custom tray and allowed to dry for 30 minutes to ensure uniform treatment for all specimens.

Long open-tray transfer copings (Xive TG impression copings, Dentsply Sirona) were connected to the implants with a torque of 20 N/cm, according to the manufacturer's instructions. A polyether impression material (Impregum Penta, 3M ESPE) was used for all impressions. The material was mixed in a special

Chart. General mean microgap for implants A, B, and C (n = 5).



[a]No statistically significant difference between splinted and non-splinted implants ($P > 0.05$; analysis of variance).

[b]Statistically significant difference between splinted and nonsplinted implants ($P < 0.01$; analysis of variance).

Table. Effect of interaction of technique and inclination on general mean marginal microgap of implant C.[a]

Technique	Inclination[b]	Microgap (µm)		95% CI	
		Mean	SE	LB	UB
Splinted	A	37.33	16.77	1.78	72.89
	C	0	16.77	–35.55	35.55
Nonsplinted	A	122.86	16.77	87.31	158.42
	C	0	16.77	–35.55	35.55

Abbreviations: LB, lower bound; UB, upper bound.

[a]The dependent variable is the general mean marginal microgap of implant C.

[b]Framework fixed on implant A (0-degree inclination) or implant C (25-degree inclination).

automixing device (Pentamix 2, 3M ESPE) and syringed around the copings, while the tray was loaded and positioned to engage the orientation grooves. Finger pressure was applied until polymerization was completed.

Ten impressions, 5 for each group, were performed using the open-tray technique. In the first group, the impression posts were splinted by means of dental floss and a 3- to 4-mm-thick band of autopolymerizing resin (GC Pattern Resin, GC America) in the middle of their height (Fig 3). In the second group, the impression posts were left unsplinted (Fig 4). The impressions were visually inspected for the presence of bubbles or other deficiencies and stored at room temperature for 24 hours. They were washed with tap water and dried with an air stream.

External hex implant analogs (Xive TG implant laboratory analogs, Dentsply Sirona) were hand tightened over the impression posts, and the new master casts were fabricated using hard dental stone. Type IV die stone material (Silky Stone, Whip Mix) was mixed with water, in the ratio suggested by the manufacturer, in a vacuum mixing device for 30 seconds. The mixed stone was poured in the impressions and allowed to set for 24 hours. Five specimens (stone casts), each containing 3 implant analogs, were fabricated for each group.

The resulting microgaps were evaluated using the passively fitting cast framework that was fabricated on the initial epoxy resin master cast. The framework was initially screwed on the first implant analog (implant A) with a torque of 20 N/cm. The resulting microgap was measured at the implant-analog surface for implants B and C with the use of an optical microscope. Photographs of the fitting surfaces of all the analogs were taken at a standardized magnification of 40× (Fig 5). Six photographs were taken at the contact surfaces of each implant analog, 2 at each of the mesial, distal, and labial analog surfaces. Three measurements were performed for each photograph, and their mean value was calculated. The photographs were analyzed with the use of a software program (Adobe Photoshop CS4, Adobe Systems). The 3 surfaces of each analog were evaluated, and a general mean value (g-mean) was calculated from the mean values for the microgap on each surface for every implant. The framework was later fixed by the retaining screw on the inclined analog (implant C), and the fit on the other 2 implants (implants A and B) was evaluated accordingly. The final microgap value for each measurement was calculated by subtracting the initial microgap value from the new microgap value.

The microgap values were statistically evaluated by ANOVA and categorical regression analysis with the use of a statistical software program (SPSS 13.0, IBM).

Some details of this experimental method have also been reported in a previous publication.[17]

Results

The g-mean (overall) results from the measurements of the microgap at the implant-framework interface are presented in the Chart. There were differences in the g-mean values of the microgaps for the 3 implants and the 2 techniques (splinted and nonsplinted), but the differences were statistically significant only for the inclined implant (C) ($P < 0.05$; ANOVA).

The Table represents the interaction of the 2 influencing factors, *technique* and *inclination*. When the framework was fixed on implant C (25-degree inclination), no marginal gap value was detected with either technique. When the framework was fixed on implant A (0-degree inclination), the marginal gap value was 37.33 µm when copings were splinted and increased to 122.87 µm for freestanding copings. As indicated by these findings, the marginal gap on implant C was affected by both the inclination and the technique.

A categorical regression test was performed for implants A and C to further investigate the interaction of technique and inclination as well as their impact on the marginal gap. This analysis was not performed for implant B, since no statistically

significant differences were noted on the previous statistical tests. Categorical regression results indicated that, for implant A, the impression accuracy was influenced 98.5% by the inclination of the implants and only 1.5% by the splinting. Implant C was affected 75.0% by the implant inclination and 25.0% by the technique (splinting or no splinting).

Discussion

The purpose of this study was to examine the effect of splinted and nonsplinted impression copings on the accuracy of the cast when the open-tray technique was used for parallel and inclined implants. The null hypothesis was that there would be no differences in the accuracy of casts produced from impressions with splinted and nonsplinted impression posts for parallel and nonparallel implants. The results supported partial rejection of the null hypothesis, indicating that the impression technique has a direct impact on impression accuracy, especially for nonparallel implants.

Al Quran et al compared different impression techniques for parallel implants: closed tray, open-tray nonsplinted, and open-tray splinted.[4] All techniques resulted in accurate impressions, and any differences were clinically acceptable. All the implants in their study were parallel, however, unlike the present study, which included an inclined implant. Moreover, the experimental model in the study by Al Quran et al was complicated, including many special manufacturing techniques.[4] In contrast, the present study used a simpler experimental laboratory model and was more clinically relevant since it incorporated an inclined implant fixture. Nevertheless, the results of both studies suggest that, for parallel implants, the accuracy of the resulting impression is acceptable regardless of the impression technique.

A systematic review by Kim et al suggested that splinting of impression copings resulted in superior impressions compared with other impression techniques, especially when multiple implants are used.[14]

Studies of implant impression techniques present great variety, and researchers follow different experimental methods, materials, and statistical analyses. For this reason, it is difficult to compare the findings of many research projects. If the existing literature is classified by whether or not the implant impression copings were splinted and the type of impression material, the studies of Papaspyridakos et al, Reddy et al, and Kim et al support splinting of impression copings.[2,3,11,14] In contrast, Baig found no statistically significant difference between splinting and not splinting.[6,9] The authors of the present study suggest that the closed-tray technique should be followed only to facilitate clinical procedures, since both techniques have been proven to be of equal accuracy.

In the present study, the gap between the metal framework and the implant analog was calculated through measurement on photographs taken through an optical microscope. This procedure was first applied on this research project and is clinically relevant since it incorporates the use of an inclined implant fixture.

Another factor that prevents direct comparison of different research findings is the implant connection type (internal or external). This parameter could influence impression accuracy in the following manner: On external connection–type implants, the impression coping fits over an external hexagon (0.7-1.0 mm high). On internal connection–type implants, the impression coping fits inside the implant, to a depth of 2-4 mm; therefore, it is harder to remove the coping when the open-tray technique is used.[12] In the present study, external connection–type implants were used. The advantage of this type of connection is that the abutment fits directly over the implant body without any other interference that could result in inaccuracies during measurements.

A systematic review by Papaspyridakos et al, based on 72 in vitro and 4 clinical studies, concluded that the splinted impression technique is more accurate in most cases.[3] Implant angulation also affects the accuracy of the implant impressions. However, there are insufficient studies to test the effect of implant connection type.[3]

Splinting of implant impression copings is a time-consuming procedure that could result in distortion and consequent impression inaccuracy due to acrylic resin shrinkage over time.[18] Nevertheless, the present study suggests that splinting of the implant impression copings results in more accurate impressions and therefore in a more precise fit of the implant restoration, especially when implants are not parallel.

Conclusion

When the open-tray technique and polyether material are used for the impression of parallel implants, impression coping splinting does not result in more accurate impressions. However, splinting of the impression copings results in more accurate impressions when the open-tray technique and polyether impression material are used for nonparallel implants.

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Appendix

Comparison of the accuracy of CBCT effective radiation dose information in peer-reviewed journals and dental media

Diana Hicks, MS, DPhil ■ Michael Melkers, DDS, MAGD ■ Julie Barna, DMD, MAGD ■ Kimberley R. Isett, MPA, PhD
Gregg H. Gilbert, DDS, MBA

Peer-reviewed and professional media articles included in the quantitative and qualitative analyses

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Table A. Peer-reviewed articles included in Chart 4 (quantitative analysis).

Author	Year	Conclusion[a]
Winter et al[1]	2005	<
Scarfe et al[2]	2006	=
Cohenca et al[3]	2007	=
Cotton et al[4]	2007	=
Patel et al[5]	2007	>
Scarfe & Farman[6]	2008	≥
Nesari et al[7]	2009	=
Kau et al[8]	2009	=
Scarfe et al[9]	2009	≥
Chan et al[10]	2010	>
Becker et al[11]	2010	>
Hatcher[12]	2010	=
Larson[13]	2012	>
Hatcher[14]	2012	>
Adibi et al[15]	2012	>
Halazonetis[16]	2012	>
Bornstein et al[17]	2014	≥
Kau et al[18]	2014	≥
Jansen[19]	2014	≥
Lee et al[20]	2015	=
Greenberg[21]	2015	=

[a] Conclusion as to the effective radiation dose of CBCT in comparison to that of conventional radiography.

Table B. Professional media articles included in Chart 5 (quantitative analysis).

Author	Year	Conclusion[a]
Palomo et al[22]	2006	≥
Farman et al[23]	2009	=
Tischler[24]	2009	=
DrBicuspid Staff[25]	2010	>
Hales[26]	2011	>
Hales[27]	2011	>
Dentistry Today[28]	2011	>
Paulhamus[29]	2013	=
Knight[30]	2013	<
Jansen[31]	2014	≥
Farran[32]	2014	>
Strobel Dentistry[33]	2015	=
Farran[34]	2015	=

[a] Conclusion as to the effective radiation dose of CBCT in comparison to that of conventional radiography.

Table C. Statements comparing effective dose from CBCT and conventional dental radiography in journal articles (qualitative analysis).

Author	Year	Statement	Conclusion[a]
Danforth et al[35]	2003	Patient radiation dose is lower than for conventional medical CT, but is similar to that for standard dental radiology.	=
Hatcher et al[36]	2003	CBCT provides high quality of diagnostic images that have an absorbed dose that is comparable to other dental surveys and less than a conventional CT.	=
Hatcher & Aboudara[37]	2004	The entire maxillofacial volume (13-cm-diameter field of view) is imaged and the patient receives an absorbed dose similar to a periapical survey of the dentition.	=
Nakajima et al[38]	2005	The 3DX has a radiological dose effect that is 1/100 of the helical-CT and is comparable with a general dental X-ray unit.	=
Howerton & Mora[39]	2007	The radiation dose absorbed by patient during CBCT is 3-7 times higher than that absorbed when acquiring a panoramic image.	>
Cotton et al[4]	2007	This indicates that the amount of radiation exposure to the patient is comparable to that received from routine diagnostic imaging and is much less as compared with a medical CT.	=
Patel et al[5]	2007	CBCT has a low effective dose in the same order of magnitude as conventional dental radiographs.	=
White & Pharoah[40]	2008	The effective dose from large-volume machines ranges widely, from 2.7 times to 25 times a conventional panoramic examination.	>
Tyndall & Rathore[41]	2008	In the United States, the radiation risks from many CBCT systems would be below those for the most common intraoral full-mouth series examination . . .	<
Miles[42]	2008	If the machine is capable of capturing both the panoramic image alone (low dose to patient) and CBVT data (higher dose to patient) . . .	>
Nesari et al[7]	2009	With respect to CBCT, the amount of radiation for a full head-and-neck scan may be roughly equivalent to a full-mouth set of radiographs, depending on the manufacturer and scan setting.	=
Kau et al[8]	2009	It has been reported that the total radiation is approximately 20% of conventional CTs and equivalent to a full mouth radiographic exposure.	=
Curley & Hatcher[43]	2009	The introduction of CBCT creates the opportunity for clinicians to acquire the highest quality diagnostic images with an absorbed dose that is comparable to other dental surveys and less than a conventional CT.	=
Mah et al[44]	2010	Although studies of radiation dosimetry are not directly comparable, the exposure from CBCT is within the same range as traditional dental imaging. The combination of traditional dental radiographs, particularly in a complete series, can result in a radiation dose that is substantially higher than that of CBCT.	≤
Nervina[45]	2012	A lateral cephalograph or panoramic radiograph does not require as much radiation as a CBCT scan . . .	>
Larson[13]	2012	These rapid advances in CBCT technology have resulted in 3-dimensional images that have about 2% or less of annual background radiation, with only slightly more than conventional orthodontic imaging without any supplemental radiographs. If full-mouth intraoral radiographs are taken to assess the periodontal status of adults, CBCT imaging typically reduces the patient dose.	≤
Adibi et al[15]	2012	These researchers found that i-CAT CBCT delivered a higher dose to the patient than a typical panoramic radiograph by a factor of 5-16.	>
Bornstein et al[17]	2014	With the increased use of CBCT imaging in dental practice, clinicians must be made aware that patient radiation doses associated with CBCT imaging are higher than those of conventional radiographic techniques.	>
Kau et al[18]	2014	However, compared with a conventional lateral cephalogram, a panoramic radiograph, and any supplemental films that are required, the radiation dose of CBCTs is still relatively higher.	>
Lee et al[20]	2015	Therefore, the use of traditional radiographs like a complete radiographic series may result in a radiation dose that is higher than that of a CBCT imaging study.	<
Hans et al[46]	2015	Several CBCT manufacturers, with a combination of partial rotation around the patient's head, low settings, and pulse technology where radiation only happens when taking images, created a CBCT scanner that takes a 3D image with less radiation to the patient than a panoramic radiograph.	<

Abbreviations: 3D, 3-dimensional; CBCT, cone beam computed tomography; CBVT, cone beam volumetric tomography; CT, computed tomography.

[a] Conclusion as to the effective radiation dose of CBCT in comparison to that of conventional radiography.

Table D. Statements comparing effective dose from CBCT and conventional dental radiography in professional media (qualitative analysis).

Author	Year	Statement	Conclusion[a]
Farman et al[47]	2007	The NewTom 3G system also has an automatic exposure control device which selects the starting intensity of the X-ray beam, depending on the size of the patient, and modifies the anodic current according to the density of the transversed tissues (maximum value, 15 mA). This reduces the patient-absorbed dose to approximately that of a film-based periapical survey of the dentition or 1 to 7 times that of a single panoramic image.	=
Farman[48]	2009	While the dose can be equal to or even less than a traditional panoramic exposure for small FOV systems, it would take the combination of up to six such small FOV images to provide a full panorama of the teeth, or three to six times the dose needed for the standard panoramic, to say nothing of the time to stitch adjacent volumes and examine the full dataset.	>
Farman[49]	2009	. . . Imaging Sciences International's iCAT is equivalent to approximately two panoramic images for standard exposure regimens.	≥
Farman[50]	2010	Small FOV systems can provide limited (ie, "focused field") volume images of several teeth for approximately the same dose as two traditional intraoral radiographs. Given that multiple traditional images at different angles could be needed to evaluate an endodontic problem, small FOV CBCT might actually result in a dose savings to the patient.	<
DrBicuspid Staff[25]	2010	Radiation doses to patients and potential doses to employees and other persons arising from the use of dental cone-beam CT, although lower than from medical CT equipment, can be significantly higher than from conventional dental radiography equipment, the HPA noted.	>
Kincade[51]	2010	"In contrast, the cone-beam CT device used in our study results in only a threefold higher dose [compared with] digital panoramic tomography."	>
Hales[26]	2011	. . . using the J Morita Veraviewepocs 3De, the patient is exposed to the lowest radiation dose on the market. A single 40 × 40 mm 3D scan exposes the patient to 0.029 mSv. This is approximately the same amount of radiation a patient would receive with 9 digital periapical films (0.003 mSv).	>
Kincade[52]	2011	This means we can use it on a more routine basis without exposing patients to radiation beyond what they would typically get with a full-mouth radiographic exam using D-speed film.	=
Kincade[53]	2011	For instance, the dose from a panoramic machine is much lower than that of a large-volume cone-beam CT examination, so a panoramic examination is preferable in most circumstances when an overview examination is needed with a new patient.	>
Dentistry Today[28]	2011	The amount of radiation produced by 3D CBCT imaging varies substantially depending on the machine used and the field of view exposed, and some clinicians may not realize how much higher that radiation is compared to conventional radiographs.	>
DrBicuspid Staff[54]	2012	"Although the radiation doses from dental CBCT exams are generally lower than other CT exams, dental CBCT exams typically deliver more radiation than conventional dental X-ray exams," the FDA states on the new web page.	>
Jablow et al[55]	2012	You cannot justify a CBCT examination, despite its low dose even when a suitable small field of view and suitable exposure factors are used, to examine a 9-year-old for the permanent successors to the primary dentition when a high-resolution, much lower-dose digital panoramic would do the job.	>
Tischler[56]	2012	". . . although patient radiation doses are still far higher than for traditional, non-computed radiographic techniques, a fact that should be taken into account when considering using CTs for dental implants."	>
Gellerman[57]	2013	. . . but do require more radiation exposure than 2D dental X-rays . . .	>
Kincade[58]	2013	"In some cases a TMJ examination acquired with cone-beam CT can be accomplished at one-half the effective dose of an intraoral full-mouth series radiographic examination," the study authors wrote.	<
Quirk[59]	2014	Other [i-CAT 3D] features include . . . QuickScan+ technology that offers a lower dose when high resolution is not needed, at a dose comparable to 2D pan.	=
Farman[60]	2015	i-CAT FLX from Imaging Sciences International offers full-dentition 3D imaging at a dose lower than a 2D panoramic X-ray with QuickScan+.	<
Lucier Pryles[61]	2015	Small field-of-view CBCT technology largely obviates this need by providing an accurate, three-dimensional representation of endodontic pathology at a radiation dose comparable to several radiographs.	≥
Spindel[62]	2016	Unfortunately CBCT scans are the radiation equivalent of at least a full series of dental X-rays and often expose patients to even greater exposure levels.	>

Abbreviations: 2D, 2-dimensional; 3D, 3-dimensional; CBCT, cone beam computed tomography; CT, computed tomography; FDA, US Food and Drug Administration; FOV, field of view; HPA, UK Health Protection Agency.

[a] Conclusion as to the effective radiation dose of CBCT in comparison to that of conventional radiography.

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