Conservative Management of Dental Caries using Silver Nitrate and Atraumatic Restorative Treatment in Remote Rural Setting


Managing dental caries is challenging, especially in remote, underserved areas of the world. Promising results were achieved using silver nitrate and atraumatic restorative treatment for lesion preparation and restoration.

Wine and Dental Destruction

Kevin C. Lee, B.A.; Louis Mandel, D.D.S.

Acidity of wine can cause dental erosion, while its components may lead to excessive staining of teeth. Case of patient whose amount, manner and timing of wine consumption caused these dental problems. Case report

A Unique Occurrence During Treatment of an Intraoral Arteriovenous Malformation


Vascular lesions demand heightened attention by all practitioners throughout the planning and diagnostic phase, during surgical treatment, as well as postoperatively. AVM of tongue in 13-year-old girl is described. Case report and discussion

Concept of Minimally Invasive Indirect Veneers

Manuel S. Thomas, B.D.S., M.D.S.; Swati Pralhad, B.D.S., M.D.S.; Alok Kumar Basaiwala, B.D.S.

MIVs are ultrathin porcelain veneers that can be cemented onto labial surfaces after no or minimal tooth preparation. If after thorough evaluation, they are considered appropriate, they are highly beneficial, offering conservation of tooth structure, absence of postoperative sensitivity and bonding to enamel, among other positives.

Effect of Surfactants on the Efficacy of Root Canal Irrigants


A review of the effects of adding surfactants to established root canal irrigants and new surfactant-containing root canal irrigants to achieve complete disinfection of the root canal system.
Opioid Abuse and Entitlement to Freedom from Pain

“Painless Dentist.” The sign hung tilted on the wall in the foyer of the office of my childhood dentist. It showed an arrow pointing downstairs to an empty storage area, although my dentist practiced upstairs. At the time, it provoked nothing more than a knowing chuckle from my parents and me. We got the irony and the reality. Completely pain-free dentistry did not exist. On one hand, we absolutely trusted that our doc would do everything medically possible to safely minimize our dental discomfort. However, we harbored no illusions, whether fostered by the dental profession, pharmaceutical companies or society in general, regarding the existence of pain or discomfort in our oral healthcare or, for that matter, our lives. We built our expectations upon the principle of “no pain, no gain.” We accepted that we might suffer pain as part of a procedure, or a process of growth or self-improvement. We certainly did not claim any entitlement to a pain-free life.

Today, Americans increasingly exhibit a growing sense of entitlement or right to certain benefits, services or possessions without accepting responsibility for earning or doing what is necessary to obtain them. For years, this “gain without pain” view of life, fanned by the fires of commercialism, has pervaded our society. It now appears this entitlement view has expanded to include patients’ freedom from pain. Doctors, rather than correct the misconception, out of compassion, responded with a war against pain.

In the 1980s, chronic pain sufferers complained that the healthcare profession undertreated them. In the 1990s, the medical community began to assess the subjective symptom of pain as an objective sign, without any device that could objectively measure it. Standards required the use of a pain scale. Pain then grew from a private experience into a political patients’ rights issue, with sanctions against providers for inadequate pain control. Medicare and Medicaid published patient surveys with questions asking whether a patient’s pain was well controlled and whether the staff did everything it could to help the patient with his or her pain. These patient surveys placed pressure on providers to prescribe since, ultimately, the survey results tied provider reimbursements to patient satisfaction with pain control. Doctor rating websites established a public forum for patients dissatisfied with their providers’ pain management skills to post poor ratings. Ultimately, the healthcare community began to believe patients actually did have an entitlement to freedom from pain and that healthcare could safely deliver it. The dialogue shifted to how we could avoid pain and suffering at all costs. The costs mounted, with increasing substance abuse, overdoses and dependency.
Dentistry did not contribute as a major player to the crisis. We primarily manage acute pain on a short-term basis and rarely treat chronic pain with extended release and long-acting opioids. However, while dentistry is not a key part of the problem, it does not mean we cannot be part of the solution. Over the past decade, dentistry has made great strides in dropping from the second most frequent opioid prescriber to fifth, with a 5.7% decrease in opioid prescribing rates. Moving forward, in the context of contemporary drug-seeking behavior, dentists must prescribe opioids only as a last resort and utilize our states’ drug monitoring programs to identify doctor-shopping patients. In addition, when good clinical judgment requires the use of controlled substances, we must inform patients of the highly addictive qualities of these substances and instruct them on the proper handling of unused portions.

Most importantly, dentistry must do its part to dispel the myths. Educate patients that freedom from pain does not always translate into quality oral healthcare and that compassionate care may require dentists to deny opioids to demanding patients.

Despite dentistry’s technical success in pain control and our noble desire to manage our patients’ pain, we must recognize the clinical, ethical and legal limits involved. Clinically, we must balance effective pain control with abuse potential. Ethically, we must deny a patient’s autonomous request for pain medication, when such request may harm the patient. Legally, recognize that overprescribing to the point of addiction falls below the standard of care. Finally, in an era where patients maintain a sense of entitlement to freedom from pain, dentists must redefine compassionate quality care to include the existence of pain when there is no safe method to eliminate it.

The sign hung tilted on the wall in the foyer of today’s dental office should more appropriately read, “Safe Pain Management Dentist.”

ENDNOTES
Conservative Management of Dental Caries Using Silver Nitrate and Atraumatic Restorative Treatment in Remote Rural Setting

A Reduction to Practice


ABSTRACT
Managing dental caries remains a challenge to clinicians—more so when treating caries in remote, underserved areas of the world. The purpose of this article is to report preliminary results of an effort to reduce to practice the best features of silver nitrate (SN) anti-caries effect and atraumatic restorative treatment (ART) for lesion preparation and restoration. The modifications made to two approaches have practical applications to school-based outreach programs hoping to respond to the dire need for preventive and conservative restorative methods in parts of the world where access to the dental office is unobtainable.

Dental caries is the most prevalent non-communicable infectious disease that affects humans.1 It is readily managed in a modern dental office. In many parts of the world, however, dental infrastructure is scarce or non-existent. In remote areas, caries management is further hampered because children living in these areas often exist on subsistence diets of mainly carbohydrates. Adversities accompanying malnutrition and other perinatal events can damage tooth formation, leading to severe early childhood caries (S-ECC), predominantly in the form of hypoplasia.1 The impact and effectiveness of short-term dental outreach programs are enhanced by the use of atraumatic restorative treatment (ART) and silver nitrate. These applications can be suitable for any dental practice.

With a need to refine treatment in remote environments, clinicians have devised a variety of practical approaches to manage caries. The best known approach, ART,2,3 involves manual instrumentation of lesions and restoration with glass ionomer (GIC). Follow-up studies attesting to its efficacy exceed three years.2 It is endorsed and has been adopted by the World Health Organization (WHO) and is covered in a practice manual for field operations.

Dating back to over a century, G.V. Black3 described in detail the use of silver nitrate (AgNO₃; SN) primarily for managing caries in children. Black described performing conventional cavity preparation on children with the words “none of us likes to hurt a child.” SN, known for centuries for its antibacterial properties and low toxicity,4 remains widely used today in medicine, primar-
ily as an antimicrobial for managing burns and apthous ulcers. It remains a standard of care for applications to newborn’s eyes for preventing ocular infections (1% SN) stemming from vertically transmitted venereal diseases.

Following Black’s lead, Shultz-Haudt excavated Class II lesions and found an 82% caries arrest rate after a single application of SN, as compared to 17% without. SN remained the treatment of choice, as described by Howe at the Forsyth Dental Infirmary until the 1960s. For reasons that are not clear, SN fell out of favor, likely because of increased access to dental care, improved technologies, growing patient desire for esthetic restorations or, perhaps, because it stained the lesion, clothing and hands black.

More recently, an in vitro study reported the anti-caries effects of four chemotherapeutic agents: ammoniated silver nitrate, silver fluoride/stannous fluoride, silver diammine fluoride (SDF) and chlorhexidine. Using artificially generated caries of extracted permanent third molars, the authors showed that ammoniated silver nitrate and silver fluoride/stannous fluoride were effective in arresting caries progression, while SDF and chlorhexidine were no different than a water control.

In recent years, silver nitrate has received renewed popularity as an anti-caries agent by Duffin. Using a 25% solution, he applied SN to the lesion, followed by fluoride varnish. NaF varnish contributed both retention and the benefits of fluoride. Results reported by Duffin exceeded expectations, compared to any antimicrobial available. His results sparked interest in randomized controlled trials (RCTs).

For decades in Japan, 38% SDF enjoyed widespread use as an anti-caries agent. It has been popular as well in China, Brazil and Australia. The Federal Drug Agency (FDA) reviewed its use in the U.S., through the efforts of Peter Milgrom, and found that SDF promises to be transformative with regard to caries management. Its approval as a medical device by the FDA for root-caries sensitivity is being used “off-label” for caries arrest. Three randomized clinical trials (RCT) support the efficacy of SDF in arresting caries.

The goal of this observational study was to take to the field a range of dental armamentarium, techniques, restorative materials and formulations of silver-containing solutions, then reduce to practice a practical approach for application in remote, non-dental settings, thus distinguishing one or two approaches to be used for conducting a proper RCT. We set out to measure
spoon excavators to remove food and superficial carious dentin. Clean cotton pellets were used to dry and remove blood or saliva from the prepared lesion and to visualize the pulpal floor. Care was taken not to remove all caries or to expose pulp, except the enamel margin interface if a GIC restoration was to be placed.

Two basic regimens were implemented after lesion debridement and preparation: 1. SN with and without NaF varnish or SDF alone; 2. SN/SDF via the ART approach (SN-ART). The ART protocol, as documented in the WHO manual,3 consists of lesion debridement using hand instruments and placing a restoration, usually a glass ionomer. Implemented on the second visit to Jamaica was the “opener” (Figure 1B). As noted by Frencken, hand excavation requires a fair amount of effort. The opener, unlike excavators or hatches, works by fracturing unsupported enamel to gain access to proximal and occlusal lesions. Final treatment assembly is shown in Figure 2.

Caries proximal to pulp were left to avoid exposure. Single-surface lesions surrounded by sound enamel were ideal for SN-ART, due to retention. Proximal lesions where access and retention were limited received the SN/SDF treatment.18, 19 Primary teeth were mostly treated with either SN, SN-NaF varnish (Duffin procedure) or SDF alone and the treated lesion left unrestored. In some instances, primary teeth received the SN-ART, depending upon the clinician’s judgment as to the retentiveness and accessibility of the prepared lesion.

The two silver solutions used were SN (50% AgNO₃; Gordon Laboratories; Henry Schein) and SDF (38% Ag(NH₃)₂F; Elevate Oral Care, Florida). Solutions were dispensed as a drop into a disposable

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Summary Data of Treatment Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. Patients</td>
<td>154</td>
</tr>
<tr>
<td>Mean Age (years)</td>
<td>13.0</td>
</tr>
<tr>
<td>Total No. Surfaces</td>
<td>561</td>
</tr>
<tr>
<td>Total No. Teeth</td>
<td>389</td>
</tr>
<tr>
<td>Adult/Children</td>
<td>21/133</td>
</tr>
<tr>
<td>Primary/Permanent Teeth</td>
<td>287/102</td>
</tr>
</tbody>
</table>

Figure 1. SN-ART treatment of open-caries lesion. A. pre-treatment; B. post-treatment after SN and light-curing; C. final GIC restoration.

Methods

Study Population and Selection Criteria

The treatment period consisted of two sessions, two years apart. Twenty-one adults and 133 children from one of five rural community health centers received one of the dental procedures described below. The ages of the patients ranged from 21 to 72 for adults, and 3 to 20 years for children. Demographics are given in Table 1.

All patients were citizens of Jamaica and lived in the central region, within 75 miles of St. Ann’s Bay. Parental consent for treatment was obtained by school administrators prior to the visit and again as verbal consent from adults and/or children at the appointment time. Patients having readily visible caries lesions and tentatively determined not to have pulp involvement were selected for treatment. They were seated in available chairs or pews for future examination and treatment. Young children reclined their heads into the clinician’s lap, usually unaccompanied by their mothers, as most sites were within the local community. The study protocol was approved by the Institutional Review boards of the University of Colorado for author SK and New York University for authors PWC, SV and RC.

Instrumentation, Equipment and Treatment Approaches

No formal assignment scheme to treatment group was attempted, as this was an observational study based on a subjective evaluation of each patient’s needs. Teeth selected included smooth surface, proximal and occlusal surfaces extending into dentin, without pulpitis, apical abscess or chronic pain. In the absence of an air or water syringe or rotary instruments, selected quadrants were isolated with disposable cotton rolls in holders (Isolator, Pascal) (Figure 1A). The lesion was debrided using appropriately sized
plastic well. Each patient received all or portions of one drop of SN or SDF. Solutions were applied with a large or small micro-brush applicator (Bendabrush, Centrix). The main restorative material used was Fuji Filling LC (GC Corp., Japan). In some cases, IRM (Dentsply) was used for teeth deemed borderline exposure or pulpal-sensitive.

For Class II lesions, a disposable retainer and matrix (Omni Matrix, Green Winged: Ultradent) was used and the GIC placed with a pre-loaded syringe (C-R syringe, Centrix). The GIC selected came in a two-portion syringe cartridge and, after mixing, placed and light-cured for 20 seconds. A polyacrylic acid conditioner supplied by the manufacturer was applied briefly; excess polymer was removed with a cotton pellet. The GIC was applied with either a two-bladed plastic instrument or a Centrix syringe to small or more-difficult-to-access lesions. GIC was adapted with the plastic instrument.

For deep lesions, GIC was placed incrementally, polymerizing each layer for 20 seconds (Fusion 3.0 curing light, Dentlight). Coating was applied and the occlusion checked (Figure 1C).

Results and Discussion

The goal of this observational study was to reduce to practice two caries treatment approaches suitable for remote field conditions. We describe a self-contained method for treating children and adults in areas without electricity and no dental operatory amenities. For primary teeth, the goal is to arrest caries long enough to allow them to naturally exfoliate. For permanent teeth, the goal is to resolve lesions with a GIC restoration. Over 500 surfaces were treated, mostly in children with primary teeth (Table 1). To our knowledge, no side effects have been reported by any of the treated adults or children.

When successful, extractions are avoided or forestalled. SN/SDF treatment in children can limit anxiety, preserve dentition, improve mastication and increase confidence, thereby improving the child’s overall health and quality of life.20 Remarkably, SN-treated lesions left unrestored remained intact with their black Ag coating for two years, as seen in Figure 3.

We placed GIC restorations after SN/SDF treatment in permanent teeth, compared to primary teeth (Table 2), for two reasons: 1. lesions tend to be larger and more accessible in permanent teeth; 2. lesions in permanent teeth and young adults are more likely to progress to eventual extraction, something we wanted to avoid. One drawback is that SN/SDF can sometimes stain the GIC and/or be apparent at the cavosurface margin. This can be minimized by removing excess SN/SDF with a cotton pellet and reducing the silver with a curing light. Thus, we were able to set the SN/SDF quickly and visualize the Ag layer before proceeding, thereby eliminating the need for a NaF varnish for retention.

We had both SN (50% AgNO3) and SDF (38% Ag(NH3)2F) available to use in the field. There was no difference noted in the application of either SN or SDF, as both turned black after being light-cured for 10 seconds. From a cost perspective, the cost per drop of SN is about 1/10th the cost of SDF (Table 2). SN also has a higher concentration of available Ag than SDF—377,650 ppm vs. 254,600 ppm (Table 2). Final selection between SDF or SN must await proper side-by-side comparisons. So far, only SDF has the backing of RCTs.

Figure 2A. Final armamentarium for treatment field kit: glass ionomer restorative material with applicator (3M-ESPE Fuji); battery-powered curing light; gauze; dry angles; cotton pellets; cotton rolls and holder; 2-well disposable dish; 50% AgNO3 solution (Gordon Labs, Schein Dental); disposable retainer and matrix holder; college pliers; small and large dental excavators; ART cavity opener (see panel B). (Not shown is alternative to SN, silver diammine fluoride solution from Elevate Oral Care; Florida).

Figure 2B. ART Opener (Schein Dental).

Figure 2C. Appearance of applicators saturated with AgNO3 in various states of chemical reduction. Swab on left shows colorless AgNO3 as it appears fresh from bottle. Middle swab shows AgNO3 in partially reduced form as AgO2, brown in color. Swab on right shows AgNO3 exposed to air and light in form of elemental or metallic Ag. Relative potency in terms of caries arrest remains untested. Desired goal is to form thick protective layer of metallic Ag covering exposed dentin. Higher concentrations of AgNO3 (saturated solutions) as described by G.V. Black may form thicker layers of Ag but irritate soft tissue and pulp.

Figure 3. Appearance of unrestored lesions after two years with single application of 50% SN. Note teeth were still intact despite extensive caries. Black stain indicates intact protective coating of metallic Ag. Retreating these lesions with AgNO3 or SDF would be prudent but opportunity did not present itself. Notice preservation of arch space that otherwise would be lacking if teeth were extracted.
In retrospect, placement of the GIC restorations was challenging—for example, selecting the appropriate restorative material with properties such as tolerance to moisture, ease of placement, preferably one-step, and not requiring external activators, such as a triturator for amalgams. Moisture-sensitive materials like compomers or BisGMA resins were ruled out because of the inability to rinse and dry teeth. GIC has been the material of choice for ART, largely because of its tolerance to moisture. Unlike the hand-mixed, chemically activated GIC, we found these materials set much too fast, especially in tropical climates such as Jamaica. We chose a dual-cured GIC, which gave us longer working time and a viscosity that facilitated placement in some of the more restrictive preparations, including proximal surfaces.

Although the GIC we used closely matched the shade of the tooth, the manufacturer does not recommend it for Class I occlusal lesions, as it lacks compressive strength. Our protocol involved the use of a battery-charged curing light, which requires recharging. In past outreaches, we could charge with either solar panel units or at a central location with electricity. A portable CO₂ air syringe would prove useful in the future, as it is self-contained and does not require a compressor.

In addition to setting the GIC, a key role of the curing light is to reduce Ag⁺ to metallic Ag. Using natural light to reduce Ag was first reported by G.V. Black; silver precipitates to the carious dentin, facilitating the visualization of the colorless SN solutions. The area turning black confirmed the presence of the metallic Ag layer. Our observations were that higher concentrations of SN (>50%) would result in a thicker protective layering of metallic Ag. In fact, Black used a saturated solution of SN, at around 250% concentration. He also cautioned against using such high concentrations near the pulp. The conversion of Ag⁺ to metallic Ag is key to the anti-caries ability of the two Ag formulations. Further side-by-side comparisons are needed to show how best to achieve the outcome. This chemical reduction reaction occurs with both SN and SDF and is accelerated by exposing SN or SDF to visible light from a light-curing unit. This layer of Ag attaches to dentin, its organic components—e.g., collagen—and likely obtunds the dental tubules, which explains Ag’s ability to relieve tooth sensitivity associated with root surface caries.

**TABLE 2**

<table>
<thead>
<tr>
<th>Item</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>inexpensive compared to SDF; can be made by local pharmacist; over century of safe use; 377,650 ppm Ag in 50% solution.</td>
<td>Lack RCTs to support efficacy; dispensing is cumbersome in field conditions.</td>
</tr>
<tr>
<td>SDF</td>
<td>High quality control[13]; reimbursable as fluoride application; 254,600 ppm Ag.</td>
<td>High fluoride content, (44,800 ppm). Should not be used in conjunction with NaF varnish.</td>
</tr>
<tr>
<td>GI</td>
<td>Doesn’t set until light cured; ease of dispensing and mixing under field conditions; high-quality product.</td>
<td>Expensive; shelf life limited after opening; needs to be used with conditioner.</td>
</tr>
<tr>
<td>Curing Light</td>
<td>Reduces Ag⁺ to metallic Ag in seconds; activates setting of GI.</td>
<td>Expensive; fragile; needs electrical power.</td>
</tr>
<tr>
<td>NaF varnish</td>
<td>Used to retain SN, may confer additional preventive effects.</td>
<td>Reducing Ag⁺ to metallic Ag can be accomplished by using curing light so NaF may be unnecessary. Cost at $2.50 per unit dose and marginal anti-caries effective on caries active children[22] is consideration for budgeted outreach programs. Use with SDF is contra-indicated due to additive F levels.</td>
</tr>
</tbody>
</table>
In the case of SN, we no longer use NaF varnish to retain SN as prescribed by the Duffin technique. Although the addition of fluoride to either SN or SDF conveys the additional benefit associated with fluoride's anti-caries effect, that additional benefit can be questioned in light of recent RCT with caries-active children. The additional cost of NaF varnish in outreach programs needs to be weighed when cost is a consideration. Exposure of young children to high concentrations of fluoride is also of concern.

In teeth that are to be exfoliated soon, a single treatment may suffice. But for teeth with several more years before exfoliation, multiple applications, as yet to be determined, would forestall adverse pulpal involvement. Further efficiency can be made with portable field chairs, as used in the military, modified for children. This would reduce operator fatigue and be part of an ongoing quarterly program for reapplication of treatment. Moreover, a properly trained local oral healthcare worker could perform re-applications.

In summary, we feel the approach described here greatly outweighs the usual practice of extracting teeth, both permanent and deciduous. For the latter, extractions on young children have future consequences, including trauma to the child, post-surgical pain, partial loss of the ability to masticate food, and loss of space, resulting in malocclusion in the permanent dentition. SN/SDF with and without GIC is built into this approach and based on clinical judgment.

It has been shown for over a century that silver is effective in preventing and arresting caries in primary and permanent teeth. While discoloration is an adverse effect, this therapy is an affordable, easy-to-use method for caries management. The use of SN has been widely accepted in pediatric dental practices. We urge general practitioners to research the topic and techniques and judge whether it is appropriate for use in their practices.

The authors thank the Jamaica Ministry of Health and HealthCare International for assisting and providing the opportunity for this manuscript. Queries about this article can be sent to Dr. Cunningham at rpc3@nyu.edu.

REFERENCES

ABSTRACT

The acidity of wine can cause dental erosion. Furthermore, its constituents may lead to excessive staining of teeth. The authors report the case of a patient whose amount, manner and timing of wine consumption caused these dental problems.

Dental erosion is associated with the loss of superficial tooth substance from either acid exposure or chelation; it is independent of bacterial processes. Common features of dental erosion may include sensitivity of the exposed dentin, "cupping" concavities of enamel cusps and extruding restorations resulting from the loss of adjacent hard tissue. In severe circumstances, teeth may become disfigured, fracture along thinned incisal edges, and the erosions may extend into the pulp.

Intrinsic causes of dental erosion originate either from acid challenges, such as gastroesophageal reflux and bulimia, or from diminished salivary volume and buffering capacity. However, an extrinsic etiology is more commonly implicated in dental erosion. Although cases involving industrial pollutants (sulfuric acid) and improperly chlorinated swimming pools (hydrochloric acid) have been reported, dietary factors are typically the extrinsic cause of erosion. Frequent and high consumption of fruits (citric acid), candies (citric acid), carbonated beverages (citric and phosphoric acids), pickled foods (acetic acid), and even the misuse of some over-the-counter oral medications (ascorbic and acetylsalicylic acids) are all known initiators of dental erosion.

The mineralized dental tissues (enamel, cementum, dentin) are susceptible to acid erosion. Saliva concentrations of calcium and phosphate are normally supersaturated relative to the enamel hydroxyapatite and help to maintain its structural integrity. When acid exposures lower the oral pH below hydroxyapatite’s critical pH of 5.5, salivary salts become undersaturated, and enamel begins to experience demineralizing changes. Demineralized structures are soft, and are particularly susceptible to wear from attrition and abrasion.

Because of the presence of tartaric and malic acids, wine possesses a pH 3.0—3.8, far below the critical value for enamel decalcification. White wines have been reported to be slightly more acidic than red wines. Sparkling wines additionally contain carbonic acid but, surprisingly, have not been found to be any more erosive than white wines. Professional winemakers and wine tasters sip and swill wine for prolonged periods of time and are especially vulnerable to the damaging effects of the acidic wine on the dentition.

Although the dental erosive properties of wine are well-established and acknowledged, there are only a few reports evaluating the consequences of wine consumption on the dental structures. And most of these reports involve the dental damage found in professional wine tasters. The purpose of our case report is to call the profession’s attention to the fact that the problem may become manifest in wine enthusiasts apart from professional tasters, and it may even be compounded by excessive staining.

Case Report

A 61-year-old male was referred to Columbia University’s Salivary Gland Center because his general dentist had noted multiple cervical restorations, dental staining, and unusual diffuse labial irregularities of the maxillary and mandibular dentition’s enamel (Figure 1). A salivary abnormality was thought to be implicated and served as the impetus for the referral.
A medical history indicated the patient was in excellent health. He had no systemic diseases that could be related to saliva/salivary gland problems. Intraorally, the mucosa appeared normally moist, pink and well-perfused. All salivary ducts were patent and expressed a clear salivary flow when the salivary glands were aggressively pressured extraorally. Whole resting salivary volume was measured and found to be within normal limits (0.4mL/min; normal 0.3—0.4), while the pH, performed in the early afternoon, was reported to be 7.1 (normal range in oral cavity 6.7—7.3).24-26 The dental examination revealed congenitally missing maxillary lateral incisors and multiple cervical composite restorations involving many maxillary and mandibular teeth. Dental staining was noted and was especially pronounced along the margins of the cervical restorations and on the enamel surfaces of the mandibular incisors (Figure 1). Irregular enamel loss was evident, and a pitted-surface, most advanced on the labial surfaces of the maxillary central incisors, was present (Figure 2).

Questioning revealed that beginning in his late teens, the patient adopted the routine of accompanying dinner with a glass of wine. By the age of 20, his intake increased to three to four glasses of red or white wine each evening, a habit that he still maintains. For the past 10 years, the patient reported enjoying an additional two glasses of sparkling wine on Saturday and Sunday evenings. He has the practice of continually sipping and swilling his wine, often drinking more red than white, over a period of three hours after dinner before brushing his teeth and retiring for the night. In the absence of abnormalities of saliva, such imbibing of wine clearly points to a diagnosis of dental erosion and staining as a consequence of the manner of wine consumption.

**Discussion**

Wine tasters who sip and swill wine are vulnerable to wine erosion by virtue of their tasting techniques. During tastings, wine may remain in the oral cavity for 15 seconds to several minutes per tasting.17 A decrease in the oral pH, below hydroxyapatite’s critical value, results. Conversely, if acidic beverages are rapidly swallowed, there are minimal changes in the salivary pH and teeth are less likely to experience erosion.27 The acquired enamel pellicle is a thin biofilm of salivary proteins that naturally collects on exposed tooth surfaces.28 Along with the intrinsic buffering capacity of saliva, the acquired pellicle functions to protect the underlying enamel from acidic challenges.29 Unfortunately, the practice of retaining wine in the mouth overwhelms this protection and in our patient, proved to be the key to the susceptibility to erosion.

Our patient admitted to consuming a variety of red, white and sparkling wines in a protracted manner akin to that of a professional wine taster. For at least 40 years, the patient has sipped and swilled his nightly wine before brushing his teeth. Following this acid exposure, an intensified period of enamel demineralization follows.
tion and softening occurs. The labial aspects of anterior teeth are poorly protected by the lips and are most prone to dietary erosion.1,30 Toothbrushing during this period of softened enamel and demineralization has probably contributed to the abnormal pitted enamel pattern seen on the labial surfaces of the maxillary and mandibular anteriors. Furthermore, extensive cervical erosions, mandating numerous composite restorations, resulted from the acid effects of the wine and subsequent toothbrushing.

Dental staining may originate either intrinsically or extrinsically. Intrinsic stains, such as those caused by the use of tetracycline during tooth development, are incorporated into the tooth structure. Extrinsic stains are confined to the outer surface. Some molecular components of red wine stain teeth and restorative resins by adhering to surface deposits.31-33 These staining molecules have been shown to absorb into the acquired pellicle and thicken the pellicle surface with chromogenic material that is difficult to remove.34 Furthermore, wine’s acidity causes superficial changes to the enamel structure and increases enamel’s susceptibility to extrinsic staining.35 In particular, cracks and defective margins allow chromogenic molecules to accumulate in areas that are less accessible to toothbrushing. Our patient favored red wines, and the consequent extrinsic staining became most pronounced along the margins of the cervical restorations and on the enamel surfaces of the lower central incisors.

In agreement with other reports,6,17 our patient had no subjective hypersensitivities associated with the thinned enamel. It is possible that erosion, a slow progressive process, may allow sufficient time for the protective effects of secondary dentin to develop.6,36,37

Treatment

The practice of sipping and swilling wine should be discouraged. Our patient was instructed to rinse his mouth with water after his last sip of wine and to postpone brushing for one hour to allow for enamel remineralization. Gentle brushing with a soft-bristled toothbrush was advised, to reduce the effects of abrasion.8 Patients with erosive lesions should use fluoridated dentifrices with low abrasivity.38 Fluorides, delivered either as varnishes or in conjunction with dentifrices or mouthrinses, have the ability to reduce enamel solubility.8,16,38 Protective resins16 are useful when applied to dental surfaces. Alkaline mouthrinses11,14,15 are helpful, while the consumption of cheese39,40 and bread41 simultaneously with wine may help combat demineralization and actually promote enamel rehardening. Studies are now investigating the benefits of direct calcium42 and protective laser43 applications. Dental
restorations should be considered if aesthetics and/or sensitivity become an issue.

In addition to frequent dental checkups, patients regularly consuming any alcoholic beverage should also follow-up with their physicians. Degenerative changes in organ systems may be an additional sequela of excessive wine consumption. Specifically, patients should be evaluated for elevated liver enzymes and cirrhotic changes of the liver.

Conclusion

Wine should be suspected as a causal factor in patients presenting with comitant dental erosion and staining. The management of these patients requires reinforcement of healthy behaviors and the introduction of strategies for the buffering of saliva and the remineralization of enamel. Further research is necessary to fully understand the relationship between wine consumption and dental wear.

Queries about this article can be sent to Dr. Mandel at LM7@columbia.edu.

REFERENCES


Kevin C. Lee, B.A., is a research assistant in the Salivary Gland Center at Columbia University and a fourth-year student in the College of Dental Medicine, New York, NY.

Louis Mandel, D.D.S., is director of the Salivary Gland Center, associate dean and clinical professor of oral & maxillofacial surgery, Columbia University College of Dental Medicine, New York, NY.
A Unique Occurrence During Treatment of an Intraoral Arteriovenous Malformation

A Case Report and Discussion


ABSTRACT

This is the report of a case of arteriovenous malformation (AVM) of the tongue in a 13-year-old female patient. The clinical course is outlined; an intraoperative dilemma is discussed; and a review of the literature is presented. Vascular lesions demand heightened attention by all practitioners throughout the planning and diagnostic phase, during surgical treatment, as well as postoperatively. Careful attention to detail can help avoid poor patient outcomes and, even, fatal consequences.

Case Report

A 13-year-old African-American female presented to the emergency department at Nassau University Medical Center, accompanied by her mother, with a chief complaint of “intermittent tongue bleeding.” The mother and patient said the bleeding occurred three to four times in the past two months, and only occurred while eating. The patient and her mother had noticed a “purplish” lesion on the anterior aspect of the dorsal surface of her tongue, which had been growing slowly and corresponded with the location of the prior bleeding episodes.

Each bleeding event was self-resolving without medical intervention or evaluation. The patient had no significant past medical history or allergies and was not taking any medications. There was no history of trauma or recent travel. The patient denied pain. Vital signs were within normal limits. Coagulation studies were within normal limits. Upon clinical exam, the emergency department physician found no active bleeding, and the patient was discharged with a follow-up appointment in the oral and maxillofacial surgery (OMFS) clinic the following morning.

The patient arrived at the OMFS clinic the following day. Extraoral evaluation was unremarkable. Intraoral evaluation disclosed a 1.2 cm x 2.0 cm slightly raised lesion on the anterior aspect of the dorsal tongue surface to the right of the midline. The lesion appeared red-to-purple in color, was firm and nonmobile. The lesion did not blanch under finger pressure. It was nontender and demonstrated intact overlying epithelium without evidence of ulceration (Figure 1). There was no palpable thrill or signs of active bleeding. No additional intraoral lesions or abnormalities were identified.

Consistency in terminology and simplicity of classification of vascular malformations originated with the landmark article in 1982 written by Mulliken and Glowacki.¹,² The diagnosis and treatment of vascular malformations demand heightened attention and the focus of the involved practitioners because of the potential consequences of an error. The risk of massive blood loss remains the most serious complication; therefore, careful planning, accurate diagnostic information and proper surgical technique are paramount. Current literature suggests super-selective endovascular embolization with or without surgery is the ideal treatment option in most cases.¹,³ However, outcome data is limited and the ideal treatment algorithm remains controversial. We present the case of a patient with an arteriovenous malformation of the tongue, along with a review of the literature.
A differential diagnosis was formed on the basis of the patient’s history and physical exam and included, but was not limited to, hemangioma, lymphangioma, vascular malformation (including arteriovenous malformation), hematoma, pyogenic granuloma, granular cell tumor and a benign neural tumor. Prior to biopsy, it is essential to needle aspirate any lesion with the potential of being vascular in nature to exclude high-flow vascular lesions. In general, if needle aspiration returns no blood, formal incisional or excisional biopsy can take place.

Treatment
The patient’s tongue was secured with gauze and anesthetized with 1.5cc of 2% lidocaine with 1:100K epinephrine and injected around the periphery of the lesion. An 18g needle on a 10cc syringe was used to aspirate the tongue lesion centrally. No blood was returned during the aspiration despite redirecting the needle and aspirating. However, upon withdrawing the 18g needle, bright red pulsatile bleeding was seen originating at the aspiration site. Manual pressure with gauze was successful in achieving hemostasis, and the planned biopsy was aborted. The patient was then sent for a computed tomography angiogram (CTA) of the head and neck to further characterize the lesion (Figures 2A, B, 3).

A CTA demonstrated an enhancing hypervascular mass in the right anterior tongue at the most distal aspect of a tortuous and dilated right lingual artery. An additional adjacent dilated tubular structure coursing from the region of the jugular venous system to the region of the lesion was suspicious for a draining vein. The findings were consistent with arteriovenous malformation of the tongue. However, other vascular lesions were not excluded from the differential diagnosis.

The patient was rescheduled for digital subtraction angiography to further characterize the lesion, evaluate collateral circulation, and to confirm and identify feeding and draining vessels. The procedure entailed general anesthesia and Seldinger technique to gain access to the right femoral artery. Guidewires were used to navigate from the femoral artery to the aortic arch, where the right carotid artery was catheterized. Sub-selective catheterization of the right lingual artery was performed, and AP and lateral views of the right lingual artery were obtained. The catheter/guidewire was retracted to the aortic arch and the left common carotid was catheterized to evaluate for potential collateral feeder vessels. AP and lateral views of left common carotid injections were obtained. All catheters and guidewires were then removed and a sterile dressing was applied. The patient was discharged without complications.
The patient returned to our center and was brought back to the angiography suite; general anesthesia was again administered. The right common femoral artery (RCFA) was accessed and a guide-wire was advanced into the RCFA. The right lingual artery was selectively catheterized. Advancement of a microcatheter/guidewire into the distal right lingual artery was attempted; however, the distal lingual artery was unsuccessful secondary to tortuosity and vasospasm of the lingual artery (Figure 5).

Discussion was held between the neuroradiology and interventional radiology team, and in consideration of increased risk for extensive hard- and soft-tissue necrosis of the maxillofacial region, the planned embolization was aborted. At this time a discussion was held with the patient’s parents regarding the risks, benefits and alternatives to surgical treatment without formal embolization. The decision was made to proceed to the operating room.

Angiography demonstrated a vascular nidus measuring approximately 1.5 cm x 1.5 cm in the expected region of the right anterior tongue. The lesion was noted to opacify in the early arterial phase via a prominent right lingual artery (Figure 4A). In the late arterial phase, a dilated and tortuous draining vein was seen coursing posteriorly to the left side of the neck (Figure 4B). These findings were consistent with arteriovenous malformation of the tongue with arterial inflow primarily from the right lingual artery and a single draining vein of significant size. The lesion did not fill upon right internal carotid injection or left common carotid injection. No right-sided internal carotid/external carotid fistula was seen. Such findings could increase the risks of embolic therapy. Treatment options were discussed with the patient and her family. Combined angiographic embolization followed by surgical resection was planned.
The nomenclature applied to the spectrum of vascular anomalies has produced confusion and miscommunication among practitioners for many years. Mulliken and Glowacki’s well-designed classification divides all vascular anomalies into two primary categories: hemangiomas and vascular malformations. Their classification system has been widely referenced in the literature. The International Society for the Study of Vascular Anomalies reclassified these anomalies into two major types: vascular tumors and vascular malformations. Hemangiomas are true neoplasms that develop due to endothelial hyperplasia and grow in size through proliferation of endothelial cells. In contrast, vascular malformations are not neoplastic and do not exhibit hyperplasia. Rather, they develop from irregular formation of vascular plexuses and enlarge by progressive ectasia. Several additional distinguishing characteristics are important when comparing hemangiomas and vascular malformations, as features of each entity affect treatment strategies and management.

Vascular tumors are most commonly juvenile hemangiomas, often referred to as “the tumor of infancy.” They develop due to endothelial hyperplasia and grow by proliferation of endothelial cells. They typically undergo a stage of proliferation during infancy and tend to involute during early childhood. Hemangiomas are reported to undergo regression without any form of treatment in over 90% of cases. Juvenile hemangiomas are often subclassified by their depth (superficial, deep and compound), and are generally not found within bone. Hemangiomas are reported to have a 3:1 to 5:1 female predilection. Unlike vascular malformations, mast cells have been implicated in the angiogenesis that occurs within hemangiomas. The glucose transporter protein 1 (GLUT-1) is identified by immunohistochemical assays and can differentiate a juvenile hemangioma from other similar presenting entities, such as congenital hemangiomas, vascular malformations, pyogenic granulomas and granulation tissue. This is of clinical significance, as hemangiomas in their late stages can be difficult to distinguish from vascular malformations with diagnostic imaging, as well as by basic histologic features.

While vascular malformations are less common than hemangiomas, approximately 40% of vascular malformations occur in the head and neck region. Vascular malformations, which have distinct feeder vessels, can be classified according to the vessel type; they consist of venous malformations, lymphatic malformations and arteriovenous malformations. Despite being present at birth, they are sometimes occult and may not present themselves until later, often in adolescence. This is because they do not undergo involution; rather, they grow with age. Vascular malformations often cease their growth at the end of puberty; however, they do not degenerate. There are numerous sources in the literature that attribute accelerated growth of these lesions to trauma, hormonal changes of puberty and pregnancy, as well as infection.

Discussion
The nomenclature applied to the spectrum of vascular anomalies has produced confusion and miscommunication among practitioners for many years. Mulliken and Glowacki’s well-designed classification divides all vascular anomalies into two primary categories: hemangiomas and vascular malformations. Their classification system has been widely referenced in the literature. The International Society for the Study of Vascular Anomalies reclassified these anomalies into two major types: vascular tumors and vascular malformations. Hemangiomas are true neoplasms that develop due to endothelial hyperplasia and grow in size through proliferation of endothelial cells. In contrast, vascular malformations are not neoplastic and do not exhibit hyperplasia. Rather, they develop from irregular formation of vascular plexuses and enlarge by progressive ectasia. Several additional distinguishing characteristics are important when comparing hemangiomas and vascular malformations, as features of each entity affect treatment strategies and management.

Vascular tumors are most commonly juvenile hemangiomas, often referred to as “the tumor of infancy.” They develop due to endothelial hyperplasia and grow by proliferation of endothelial cells. They typically undergo a stage of proliferation during infancy and tend to involute during early childhood. Hemangiomas are reported to undergo regression without any form of treatment in over 90% of cases. Juvenile hemangiomas are often subclassified by their depth (superficial, deep and compound), and are generally not found within bone. Hemangiomas are reported to have a 3:1 to 5:1 female predilection. Unlike vascular malformations, mast cells have been implicated in the angiogenesis that occurs within hemangiomas. The glucose transporter protein 1 (GLUT-1) is identified by immunohistochemical assays and can differentiate a juvenile hemangioma from other similar presenting entities, such as congenital hemangiomas, vascular malformations, pyogenic granulomas and granulation tissue. This is of clinical significance, as hemangiomas in their late stages can be difficult to distinguish from vascular malformations with diagnostic imaging, as well as by basic histologic features.

While vascular malformations are less common than hemangiomas, approximately 40% of vascular malformations occur in the head and neck region. Vascular malformations, which have distinct feeder vessels, can be classified according to the vessel type; they consist of venous malformations, lymphatic malformations and arteriovenous malformations. Despite being present at birth, they are sometimes occult and may not present themselves until later, often in adolescence. This is because they do not undergo involution; rather, they grow with age. Vascular malformations often cease their growth at the end of puberty; however, they do not degenerate. There are numerous sources in the literature that attribute accelerated growth of these lesions to trauma, hormonal changes of puberty and pregnancy, as well as infection.
Oral and maxillofacial surgeons are acutely aware of the potential for vascular malformations to occur within bone. Radiographically, they usually appear as ill-defined multilocular or unilocular radiolucent lesions, and can sometimes cause root resorption and expansion of the cortical bone.1 The clinical presentation of an intraosseous vascular malformation of the jaws can include tooth mobility, expansion and gingival bleeding.1 Extraosseous vascular malformations in the oral cavity most commonly occur on the lips, tongue, buccal mucosa and palate.4 These lesions are often painless, may or may not have an appreciable thrill upon palpation, and appear reddish blue in color.4 Clinical workup of any lesion suspected to be vascular in nature should include needle aspiration prior to biopsy attempt, angiographic imaging and consultation with neuroradiology. Angiographic studies will provide information pertaining to the flow of the lesion and determine which treatment approach is most indicated.

Curative treatment of vascular malformations is performed by two general means: surgical resection, and ablation of the nidus. Ablation has been performed in a multitude of ways, and is most commonly performed by “embolization.”15 Embolization refers to intraluminal obstruction of the pathologic vasculature (nidus and/or feeding vessels). Embolization of extracranial AVMs has been performed with particulate agents, liquid embolic agents, gelatin pledgets and coils.15 Embolic agents are generally delivered by endovascular route, although liquid embolics can also be delivered percutaneously. Endovascular delivery is preferred, as an inflammatory reaction induced by local puncture can delay healing.15

There is a paucity of data relating to the management of tongue AVMs. The largest series we identified was published by Slaba et al. in 199816 and includes 25 patients who presented over a span of 12 years. Thirteen of the patients remained asymptomatic and were managed conservatively with clinical follow-up, including annual assessment of Doppler flow characteristics. The remaining 12 patients were treated with embolization as the initial step. Only two patients progressed to require surgical resection. One patient was lost to follow-up.

The remainder of the patients in the Slaba study were stabilized or improved (average follow-up of 3.4 years) with endovascular or image-guided local injection therapies. Of the patients who underwent embolization, polymerizing agents, particularly N-butyl-2-cyanoacrylate (NBCA) glue, demonstrated better efficacy than particle embolization. The authors also report success with sclerosing agents, but they say glues are easier to control. And they warn of increased pain with the application of many sclerosing agents.16

Help Yourself Collect More of Your Revenue

You can record the treatment you provide as revenue, but it’s not meaningful unless you actually collect it.

Reduce your slow paying accounts as well as your write-offs with TekCollect’s A/R solutions, NYSDA’s most recent endorsed service.

TekCollect offers a one-time flat fee of generally less than 5 percent! And NYSDA members receive a 20% discount on pricing.

To receive a free Accounts Receivable Analysis and learn more about the Binary Collection Program and how it can significantly improve your bottom line, please contact TekCollect at (888) 292-3530 or visit them at www.tekcollect.com/Frontend/Content/NYSDA.
An additional novel approach that can be considered for ablation of lesions that are otherwise difficult to treat is stereotactic radiotherapy (SRT). SRT has been used extensively for intracranial AVMs, but there is minimal data on the application of SRT to extracranial AVM. Koyfman et al. report the case of a large AVM with involvement of the tongue that was treated with SRT after failed surgical and neurointerventional management.17 At four years follow-up post-SRT, there was a marked decrease in lesion size and no bleeding episodes from the lesion, which had previously bled multiple times.17

Conclusion
Our case presented a unique challenge in management of a vascular malformation in the tongue of a 13-year-old female because of the inability to embolize the right lingual artery prior to surgical ablation. We elected not to embolize the external carotid artery proximal to the lingual branch because of the risk for extensive hard- and soft-tissue necrosis of the maxillofacial region. Our major dilemma in this case was the decision to proceed to the operating room for local excision without formal embolization of the feeding lingual artery. If the procedure was aborted, there was no guarantee that a selective embolization attempt would be successful in the future.

The patient was under general anesthesia with a secured airway, and all necessary resources were available to surgically treat the patient in a controlled setting. Additionally, the right lingual artery appeared to vasospasm during the embolization attempt, which could potentially limit blood loss during surgery. Wasson and colleagues18 reported an exsanguinating hemorrhage following a third molar extraction. They suggested a temporary vasospasm caused noticeable lessening of blood loss during the incident. Although the vasospasm precluded successful embolization in our case, it could potentially lessen the amount of hemorrhage into the surgical field during surgical removal of the nidus. The femoral catheter was also left in place so that a less selective embolization could be performed in case there was heavy surgical bleeding.

Although embolizing the proximal right lingual artery was not preferred by the interventional radiology service, it could have been performed if bleeding could not be well-controlled during surgical excision. Furthermore, the surgeons felt that careful surgical technique would allow for isolation and ligation of the sublingual artery during excision. If substantial blood loss occurred, the oral and maxillofacial and general surgical teams were prepared to perform an emergent carotid cut down to ligate the external carotid artery.

The patient tolerated the procedure well, and a modest amount of blood loss was easily controlled with local measures. The lesion was removed in its entirety, and the right sublingual artery was isolated and ligated. The patient’s alloderm biological bandage was removed four weeks postoperatively. All underlying tissues appeared healthy. The patient has been followed since the surgery, and there have been no signs of recurrence 14 months postoperatively. The patient reports no deficits in mastication, speech or function.

Queries about this article can be sent to Dr. McShane at mattbmschane@gmail.com.

REFERENCES
Concept of Minimally Invasive Indirect Veneers

Manuel S. Thomas, B.D.S., M.D.S.; Swati Pralhad, B.D.S., M.D.S.; Alok Kumar Basaiwala, B.D.S.

Abstract

Minimally invasive indirect veneers (MIIV) are ultrathin porcelain veneers that can be cemented onto labial surfaces after no or minimal tooth preparation. The benefits of no or minimal veneer preparation are conservation of tooth structure, absence of postoperative sensitivity, bonding to enamel, minimal flexural stresses, no need for provisionals and improved patient acceptance. However, no or minimal preparation veneers should be considered only after thorough functional and aesthetic evaluation. The article presented here illustrates a case of diastema closure using MIIV, to highlight the importance of treatment planning for achieving good results.

Planning for Minimally Invasive Indirect Veneers

Patient Expectation

The first and most important criterion for a procedure to be called successful is patient satisfaction at the end of the treatment. It is important to understand the patient’s expectations with regard to tooth shape, position size and color. The use of study models and mock-ups (digital/on cast/directly on patients) will aid in understanding patient desires. It will also aid the clinician in discussing treatment options with the patient. A patient’s willingness to have tooth preparation done and the amount of money he or she is willing to spend will also influence the veneer modality.

Dental Factors

Dental factors that can determine the type of esthetic treatment modality are listed here.

- **Tooth position.** Several aspects, such as position of midline, spacing or crowding between teeth, incisal edge position and inclination of teeth, have to be considered when treatment planning. MIIV are specifically indicated where the addition of material is required to improve esthetics—for instance, in cases of diastema closure, lingually tipped teeth or excessive buccal corridor space.

- **Tooth color.** If change in color is indicated, then no-prep ultrathin veneers are contraindicated, as they are translucent.

- **Tooth shape.** Undersized teeth or peg-shaped teeth can be considered candidates for MIIV. MIIV in a normal-shaped and size tooth can result in over-contouring.
Tooth condition. Sufficient enamel substrate should be available for the durability of veneers. Relaminating tooth structure can be done with MIIV for a more durable and stain-resistant surface.

Occlusion. When restoring the anterior segment, principles of occlusion should be followed, for the long-term prognosis of the veneers. Reduced overjet (i.e., collapsed vertical dimension) and bruxism are considered unfavorable for veneers in general.

All of the above factors determine the amount of tooth reduction necessary for optimum functional and esthetic results.

Soft-tissue Factors
The smile line can determine the cervical limit of the veneer. The fullness of the lips is another factor that can control the amount of tooth reduction required. The periodontal condition of the patient also plays a role in selection of the veneer type. Since in no-prep veneers there is change in the emergence profile, because there are no margins, the risk of periodontal disease is increased slightly.

Miscellaneous Factors
Another aspect that needs consideration is the skill of the ceramist. Ultrathin veneer preparations require a highly skilled ceramist, as they are fired feldspathic porcelain (refractory die/platinum foil). Most laboratories do not guarantee the longevity of these veneers, as they are very delicate. Any carelessness by the clinician can result in fracture; therefore, it is important to handle indirect restorations with care, especially during the cementation stage. However, since there is virtually no tooth reduction, these type of restorations can be considered reversible.

Case Report
The patient, a young woman in her early 20s, presented with a chief complaint of spaces between her teeth. The patient had no issue with the color of her teeth. Her only concern was her small anterior teeth and gaps between them. All she wanted was for the gaps to be closed in the least possible time with minimal tooth cutting.

After thorough analysis of the patient’s dental factors, through clinical examination and with the use of patient photographs and diagnostic casts, the following favorable and unfavorable observations were made (Figure 1):

- Aligned on the unfavorable side were: diastemas in upper anterior segment; poor width-to-length ratio of the upper incisors; and poor anterior proportion of teeth.
- Working in the patient’s favor were: no midline shift; favorable axial inclination of anterior teeth; adequate enamel substrate; sufficient overjet and acceptable overbite.
- Periodontal evaluation and smile analysis revealed the following unfavorables: asymmetrical gingival zenith position and a gummy smile—the upper lip line exposed more than 2 mm of gingiva.
Favorable findings included: a straight facial profile; competent lips with adequate lip support; good gingival health, with thick gingival biotype; and a consonant smile arc (lower lip line parallels the maxillary incisal edge).

Alternative treatments options were evaluated and discussed with the patient. These included orthodontic correction, direct composite restorations and ceramic veneers. The patient declined orthodontic intervention because of the time involved in extensive treatment periods. She also rejected getting composite restorations because of the difficulty in shade matching and maintenance. She opted instead for porcelain laminate veneers because of their natural aesthetic appearance and history of longevity and ease of maintenance.

The most important tool when planning to alter a patient’s smile using porcelain veneers is an “anatomic wax mock-up.” Fabrication of a wax-up model allows the patient, technician and clinician to visualize the desired modifications, including necessary changes in proportion, shape and position of the teeth. An aesthetic mock-up with white wax was done to create and visualize the desired end result based on the ideal width-to-height ratio of the central incisor (width-to-length ratio of the centrals should be 75% to 80%), as well as the golden proportion (width of each anterior tooth from the facial view is 60% of the width of the adjacent tooth).

Since the position of the patient’s incisal edge was appropriate and any change in the anterior guidance was to be avoided, if the clinician was to obtain the ideal width-to-height ratio he had to increase the crown length gingivally. Modification of the gingival architecture, including movement of the gingival zenith to an ideal position, was replicated on the diagnostic wax-up. The gingival outline in the anterior sextant should follow symmetry and should vertically align with the gingival margin heights of the canine and central incisors. The gingival margin zenith of the lateral incisors should be located approximately 1 mm coronal to the central incisors, with zenith points on the central incisors 1 mm distal to the midline of the tooth and at midline for the lateral incisors and canine.

The diagnostic wax mock-up was transferred into the patient’s mouth with the help of a silicon index (Dentsply Caulk, Milford, DE) and provisional material (ProtempTM 4; 3M-ESPE, St Paul, MN) to fabricate pre-evaluation temporaries. This allowed the clinician to evaluate the aesthetics, the phonetics and even the occlusion. Necessary corrections were made on the temporaries.

Once the size, shape and proportion of the veneers were finalized by the patient and the dentist, preparation guides were fabricated with the temporaries in place to assist in deciding whether the case was additive, reductive or a combination of both. Since this case was mostly additive, meaning tooth reduction would be minimal, a restorative treatment plan with minimum or no prep veneers was initiated.
Treatment Procedure

- **Soft tissue correction.** Anatomic wax-up was used to fabricate a gingival-contour surgical stent to help the periodontist visualize the proposed final gingival contours during surgery (Figure 2B). Gingivoplasty was performed with the help of a soft-tissue diode laser (810 nm, Picasso AMD Lasers) in contact mode, with a power setting of 2 to 4 watts, to achieve the proposed change in the crown length and gingival zenith position (Figure 3).

- **Tooth preparation.** At the patient’s next appointment (after one week), subsequent to the adequate healing of the gingiva, the areas of teeth #6 to #11, which were labially placed to the proposed arch form, were slightly reduced using the pre-evaluation intraoral temporaries as a guide. Only minimal tooth preparation was required with respect to teeth #6, #10 and #11 to bring the upper anterior teeth into the planned arch form, whereas other teeth were left unprepared (Figure 4).

- **Impression and provisionalization.** Since the margins were kept equigingival, gingival displacement was not required. The final impression was made with the addition of silicone using the putty-wash technique. Another advantage of minimal prep veneer preparation is that provisionals are not needed.

- **Fabrication of minimal prep veneers.** In the laboratory, using the guides made from the wax-up, ultrathin translucent veneers were fabricated by sintering fluorapatite leucite glass ceramic (Dentcare Luminers, Kerala, India) (Figure 5).

- **Veneer try-in.** The completed veneers were inspected for cracks or irregularities. They were tried in first with water to verify the fit and shade before the final cementation.

- **Cementation procedure.** After getting approval from the patient, the following cementation steps were initiated:
  1. The tissue surface of the veneer was etched for 10 seconds with 10% hydrofluoric acid gel (Angelus, Londrina, Brazil), rinsed, dried and silanated (Monobond-S; Ivoclar Vivadent, Schaan, Liechtenstein).
  2. The tooth surface was cleaned using pumice. Then with the cheek retractor in place, the teeth were etched with 37% orthophosphoric acid gel for 20 seconds (3M-ESPE, St Paul, MN), thoroughly washed and dried. The bonding agent (3M-ESPE, St Paul, MN) was applied.
  3. The final cementation was done with translucent resin cement (Rely X veneer cement; 3M-ESPE, St Paul, MN). First the centrals were cemented, followed by canine and lat-
erals, respectively. Excess cement was removed with the help of a No. 12 blade after two to three seconds of tack curing of each tooth, followed by light-curing each surface for 30 seconds.

- **Finishing and polishing.** Any remaining resin cement was removed using a small carbide finishing bur. Finally, polishing was done to impart luster with the help of polishing paste applied on a rubber prophy cup.

- **Patient instructions and recall.** The patient was given instructions for proper maintenance and care of the restorations. A one-week recall examination revealed a satisfied patient. Careful planning and execution, with the aid of an anatomic mock-up, can achieve an aesthetically pleasing smile with minimal sacrifice of tooth structure, as seen in the case presented here (Figure 6).

**Conclusion**

Even though the use of minimally invasive indirect veneers is a highly conservative approach that preserves the natural tooth structure, meticulous evaluation and planning, especially through the use of an anatomic mock-up, are critical to achieving good functional and esthetic results. These ultra-conservative veneers should be considered only for cases were the tooth contour has to be modified by addition.

Queries about this article can be sent to Dr. Thomas at manuel2dr@gmail.com.

**REFERENCES**

Effect of Surfactants on the Efficacy of Root Canal Irrigants

A Review


ABSTRACT

The mechanical debridement of the root canal system fails to completely remove debris from the root canal walls. So, one or more irrigants must be used for complete disinfection of the root canal system (RCS). One possible way to improve the bactericidal efficacy of the disinfecting solutions is to incorporate different detergents as surface active agents to help reduce the surface tension and increase the wettability of the solutions. Surfactants have been added to various root canal irrigation solutions. The purpose of this paper is to review the effects of adding surfactants to established root canal irrigants and new surfactant-containing root canal irrigants.

Surface tension is a contractive tendency of the surface of a liquid that allows it to resist an external force. It is revealed, for example, in the floating of some objects on the surface of water—even though these objects are denser than water—and in the ability of some insects (e.g., water striders) to run on the water surface. This property is caused by the cohesion of similar molecules, and is responsible for many of the behaviors of liquids.1

Surfactants

Surfactants are compounds that lower the surface tension of a liquid, the interfacial tension between two liquids or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents and dispersants.2

Surfactants are usually organic compounds that are amphiphilic, meaning they contain both hydrophobic groups and hydrophilic groups.2 Therefore, a surfactant molecule contains both a water-insoluble (or oil-soluble) component and a water-soluble component. Surfactant molecules will diffuse in water and adsorb at interfaces between air and water or at the interface between oil and water, in the case where water is mixed with oil. The insoluble hydrophobic group may extend out of the bulk water phase into the air or into the oil phase, while the water-soluble head group remains in the water phase. This alignment of surfactant molecules at the surface modifies the surface properties of water at the water/air or water/oil interface.3,4

Rationale for Using Surfactants in Endodontics

The mechanical debridement of the root canal system fails to completely remove debris from the root canal walls. So, one or more irrigants must be used for complete disinfection of the root canal system (RCS).5 One possible way to improve the bactericidal efficacy of the disinfecting solutions is to incorporate different detergents as surface active agents, to help reduce the surface tension and increase the wettability of the solutions.
tension and increase the wettability of the solutions. High wet-
tability is thought to enable the disinfecting solutions to better
adapt to dentin and penetrate into the dentinal tubules. It has
been shown that different antibacterial agents with detergents
have lower surface tension values and eradicate bacteria in di-
rect contact faster than agents without a detergent. The reason
for better killing of bacteria by the addition of detergents may be
related to the weakening of the cohesive forces in extracellular
polymeric substance and bacterial membranes.

The survival of bacteria may be partly attributed to their
invasion into dentinal tubules, where they are better protected
from endodontic medicaments than in the main root canal. The
intimacy of this contact depends upon the wettability of the
irrigant on solid dentin; this property of the liquid is strictly cor-
related to its surface tension. The surface tension is the force
between molecules that produces a tendency for the surface area
of a liquid to decrease. This force tends to limit the ability of the
liquid to penetrate a capillary tube. The irrigants for endodon-
tic use should have very low surface tension. The wettability of
the solution governs the ability to penetrate into both the main
and lateral canals, and into the dentinal tubules. By improving
the wettability, an irrigant solution could increase its protein
solvent capability and enable better antimicrobial activity in un-
instrumented areas of RCS.

A search in PubMed found no comprehensive review of the
effects of surfactants on the effectiveness of root canal irrigants.
Therefore, it was decided to review various aspects of adding sur-
factants to root canal irrigants.

**Surfactants and Sodium Hypochlorite**

Modification of NaOCl through the addition of surface-active
agents increases the ability of this irrigant to penetrate the main
root canal in vitro. Cunningham et al. added ethanol to
NaOCl and found it enabled the combination to move further
in the capillary tubes when compared with NaOCl alone, with
mean distances of combinations ranging from 30.15 mm to
45.93 mm, depending on the amount of ethanol contained in
the mixtures. Similar results were obtained by adding the chemi-
cal polysorbate 80 (Dentsply Tulsa Dental, OK) to reduce the surface
tension of NaOCl. The solutions were placed in the pulp cham-
ber of the teeth and allowed to penetrate passively into the root
canals; the average distance from the apex was reduced for the
modified solutions. Most of the significant findings were obtained
after five minutes of experimental time, with the distance from
apex to solution level of 6.4 mm against 2.6 mm for the 2.6% 
NaOCl groups. For the 5.25% NaOCl, the values were 7.7 mm
and 3.6 mm, respectively. A further measurement taken a week
later showed no significant increase of flow into the canals.

A study revealed that sodium hypochlorite with added sur-
face active agent had the lowest contact angle on dentin and was
most effective in tissue dissolution. According to Clarkson et
al., the addition of surfactant alone does not appear to improve
the abilities of NaOCl to dissolve dental pulp tissue. Williamson
et al. revealed that adding 0.1% cetrimide to 2% sodium hypo-
chlorite increased its antibacterial activity.

**Effects of Surfactants on Stability of NaOCl**

The addition of surface-active agents modifies the stability of so-
dium hypochlorite. Information is only available regarding ex-
perimental preparations. And to the best of our knowledge, this
has not been looked into in terms of commercially available prep-
arations within the endodontic literature. Ethanol (JM Loveridge,
Southampton, UK) reduces the free available chlorine (FAC) with
a greater and faster effect with higher alcohol concentration. When
50% ethanol is added to 2% NaOCl, the solutions are almost
depleted from their FAC in 15 minutes, while 30% ethanol
mixtures had a 70% loss after 30 minutes. Mixtures containing
a different agent (Fluorad 99) showed superior stability over a
two-month period when compared to those containing ethanol.
In this investigation, over a one- and two-month period, respec-
tively, the test solution lost less than 5% and 26% of the original
FAC. On completion of these tests, the sample containing Flu-
rorad 99 presented with a color change from clear, light yellow to
dull brown, with a brown deposit formed; furthermore, gas was
present in the solution, and was liberated in the container.

Clarkson et al. assessed the influence of surfactants on the
chlorine loss of NaOCl solutions due to interactions with
EDTA. The time-related effect (between 5 and 18 minutes) of
an EDTA solution (Sybron Endo, Orange, CA) (17%, containing a
surfactant) was tested when in contact with NaOCl prepara-
tions. Findings revealed that products containing surface-active
agents exhibited a markedly lower FAC reduction at some dilu-
tions, and vice versa.

**Tissue Solubility**

Cameron et al. showed that surfactants had no significant ef-
ficacy on the tissue-dissolving ability of NaOCl. However, another
study revealed that NaOCl preparations containing surface active
agents dissolved soft tissue more rapidly than NaOCl contain-
ing no surfactant. Clarkson et al. showed that reduced surface
tension improved the solubility of bovine pulp tissue. On the
other hand, Jungbluth et al. showed that reduced surface
tension did not result in greater soft-tissue dissolution by NaOCl.
This difference can be attributed to the type of pulpal tissues used.
Clarkson et al. used porcine pulpal tissue, whereas Jungbluth et
al. used bovine pulpal tissue.

**Chlor-XTRA**

Chlor-XTRA (Vista Dental Product, Racine, WI) is a sodium hypo-
chlorite-based irrigation solution composed of 5.85% sodium hypochlo-
rite and a detergent to reduce surface tension. Its appearance is clear, light-yellow green. It is completely soluble in water, with a chlorine-like odor. It is 2.6-times more digestive than regular NaOCl. Furthermore, its wetting ability is 2.5-times greater than regular NaOCl. Using the agar diffusion method, Mohammadi et al. demonstrated that Chlor-XTRA was more effective against Actinomyces israelii than NaOCl, chlorhexidine, Tetraclean and Hypoclean.

Jungbluth et al. investigated NaOCl solutions from dental suppliers (Chlor-Xtra), a technical-grade solution and household bleaches. They considered reduction in tissue weight following immersion of the tissues in the solutions, in identical experimental conditions. Chemical assessment of different batches of bottles of Chlor-XTRA showed a marked difference in chlorine content. Subsequently, the authors considered questionable the results in publications where the free available chlorine (FAC) of NaOCl solutions were not evaluated. Stojicic et al. showed results in publications where the free available chlorine (FAC) of NaOCl solutions were not evaluated. Stojicic et al. showed results in publications where the free available chlorine (FAC) of NaOCl solutions were not evaluated.

**Hypoclean**

A major drawback of NaOCl is its high-surface tension, which limits it penetration into canal irregularities and the depth of dentinal tubules. Adding a surfactant to NaOCl can resolve this problem. A modified sodium hypochlorite solution is available from Luciano Giardino in Italy. The modified sodium hypochlorite solution, Hypoclean, is a detergent-based endodontic irrigant composed of 5.25% sodium hypochlorite and two detergents.

Using the agar diffusion method, Mohammadi et al. showed that, compared to NaOCl (5.25%, 2.6% and 1.3%), CHX (2% and 0.2%), Tetraclean and Chlor-XTRA, Hypoclean was the most effective irrigant against Actinomyces israelii, P. aeroginosa, and L. casei. Using the agar diffusion method, Mohammadi et al. demonstrated that Chlor-XTRA was more effective against Actinomyces israelii than NaOCl, chlorhexidine, Tetraclean and Hypoclean.

**Surfactants and Chlorhexidine**

Using a dentine volumetric test, Baca et al. assessed the efficacy of 2.5% sodium hypochlorite (NaOCl), 2% chlorhexidine (CHX), 0.2% cetrimide (CTR) (Sigma-Aldrich Chemie, Steinheim, Germany), 17% EDTA, 7% maleic acid (MA), and regimens of 2.5% NaOCl, followed by 17% EDTA or 7% MA and 0.2% CTR or 2% CHX against E. faecalis biofilms. Findings revealed that a 2% CHX and 0.2% CTR solution showed 100% biofilm inhibition.

**CHX-Plus**

CHX-Plus (Vista Dental Product, Racine, WI) contains proprietary surface modifiers to lower viscosity. Williamson et al. showed a better effect using CHX-Plus than normal 2% CHX against E. faecalis in a simple, monospecies biofilm model. Shen et al. indicated that CHX-Plus killed bacteria much faster in anaerobic, multispecies biofilm than 2% CHX. It has been shown that following treatment for 3 and 10 minutes, CHX-Plus did not lose effectiveness against biofilm bacteria in mature and nutrient-limited phases.

**Cetrexidin**

Cetrexidin (Vebas, San Giuliano, Milan, Italy) is composed of 0.2% chlorhexidine gluconate and 0.2% cetrimide. Cetrexidin (ce-trimethlammonium bromide) is a quaternary ammonium compound and a cationic detergent that is elective against many gram-positive and gram-negative bacteria. Oncag et al. assessed the antibacterial properties and toxicity of 5.25% sodium hypochlorite, 2% chlorhexidine gluconate and 0.2% chlorhexidine gluconate, plus 0.2% cetrimide (Cetrexidin) in vitro and in vivo. According to the researchers’ results, the 2% chlorhexidine gluconate and Cetrexidin were significantly more effective on E. faecalis than the 5.25% NaOCl at five minutes in vitro. Furthermore, in the in vivo study, 2% chlorhexidine gluconate and Cetrexidin were significantly more effective on anaerobic bacteria than the 5.25% NaOCl at 48 hours.

**Q-Mix**

Q-Mix (Dentsply, Tulsa Dental, OK) is another CHX-based root canal irrigant that contains CHX, EDTA, saline and a detergent. The chemical design of Q-Mix prevents precipitation of CHX when together with EDTA and mixed with sodium hypochlorite does not produce the orange-brown precipitate. It has been shown that Q-Mix was more than 1% and 2% NaOCl and 2% CHX.

**Surfactants and EDTA**

**SmearClear**

SmearClear (Sybron Endo, Orange, CA) is a combination of 17% EDTA, cetrimide, polyoxyethylene iso-octylcyclohexyl ether and water. According to Dunavant et al., SmearClear eliminated E. faecalis biofilm more effectively than 2% CHX, REDTA or Bio-Pure MTAD.

SmearClear was introduced to remove the smear layer. It is a 17% EDTA solution that includes a cationic (cetrimide) and an anionic surfactant. Khedmat and Shokouhinejad assessed the efficacy of SmearClear, 17% EDTA and 10% citric acid in smear layer removal. Findings showed no significant differences in the efficacy of the three chelating agents at all levels of the root canals. The comparison of three one-thirds in each group showed no significant difference in the SmearClear and EDTA groups. However, the efficacy of citric acid was significantly less in the apical third compared with the coronal and middle thirds of the canals. Da Silva et al. showed that SmearClear was able to remove the smear layer from the root canals of permanent teeth similarly to 14.3% EDTA. Nelson-Filho et al. revealed no significant difference between EDTA and SmearClear in removing the smear layer from the root canals of primary teeth. On the other hand, Wu et al. indicated that the efficacy of 17% EDTA was better than that of SmearClear.
These conflicting findings can be attributed to differences in the methods of the studies. Nelson-Filho et al.\textsuperscript{38} used primary teeth for their study, whereas two other studies\textsuperscript{37,39} used permanent teeth. Furthermore, Wu et al.\textsuperscript{39} used the thermal field emission scanning electron microscope to evaluate specimens, whereas two other studies\textsuperscript{37,38} used the usual scanning electron microscope.

\textbf{REDTA}

REDTA (\textit{Rath International, Chicago, IL}) is a 17\% EDTA solution—9.25\% mL 5M sodium hydroxide and 100 mL distilled water with the addition of 0.84 g cetyltrimethylammonium bromide (cetrimide) to reduce surface tension.\textsuperscript{40}

\textbf{EGTA}

EGTA (ethylene glycol tetraacetic acid) (\textit{Sigma, St. Louis, MO}) is a polyamino carboxylic acid, a chelating agent that is related to the better known EDTA, but with a much higher affinity for calcium than for magnesium ions. It is useful for making buffer solutions that resemble the environment inside living cells,\textsuperscript{41} where calcium ions are usually at least a thousand-fold less concentrated than magnesium.

The pKa for binding of calcium ions by tetrabasic EGTA is 11.00, but the protonated forms do not significantly contribute to binding, so at pH 7, the apparent pKa becomes 6.91. See Qin et al. for an example of a pKa calculation.\textsuperscript{42}

Çalt and Serper\textsuperscript{43} indicated that the action of 17\% EDTA is stronger than that of 17\% EGTA for removing the smear layer. However, EGTA did not cause erosion of the intertubular and peritubular dentine. Cruz-Filho et al.\textsuperscript{44} reported that 1\% EGTA and 15\% EDTA reduced root dentine microhardness similarly. In a scanning electron microscopy study, Viswanath et al.\textsuperscript{45} demonstrated that both EGTA and EDTA completely removed the smear layer. De Sousa and Silva\textsuperscript{46} reported that EDTA and EGTA presented the same effect on dentine Ca2+ extraction. Tripod et al.\textsuperscript{47} demonstrated that EGTA solubilized more than 60\% of dentine, while EDTA solubilized about 20\% of dentine.

\textbf{Antibiotic-based Irrigants}

\textbf{MTAD}

BioPure (\textit{Dentsply, Tulsa Dental, Tulsa, OK}), otherwise known as MTAD, is a root canal irrigant that was introduced by Torabinejad et al. in 2003.\textsuperscript{11} It is a mixture of 3\% doxycycline, 4.25\% citric acid and a detergent (0.5\% Polysorbate 80).\textsuperscript{48} Several studies have evaluated the effectiveness of MTAD for disinfecting root canals. Torabinejad et al. showed it was effective against \textit{E. faecalis}.\textsuperscript{49-51}
In an ex vivo study, Shabahang et al. showed that the use of MTAD was more effective than 5.25% NaOCl in disinfecting root canals. Torabinejad et al. reported that MTAD was significantly more effective against E. faecalis than NaOCl/EDTA. Using the agar diffusion test, Davis et al. showed that BioPure MTAD had significantly more zones of microbial inhibition than 5.25% NaOCl, 2% CHX and Dermacyn (Oculus Innovative Sciences, Petaluma, CA).

On the other hand, Kho and Baumgartner showed that 1.3% NaOCl/EDTA was more effective than 1.3% NaOCl/EDTA in disinfecting the root canal system. Furthermore, using both in vitro and ex vivo models, Krause et al. showed that NaOCl was more effective against E. faecalis than MTAD. In addition, Tay et al. found that when MTAD is applied to 1.3% NaOCl-irrigated dentin, its antimicrobial substantivity is reduced. They attributed this phenomenon to the oxidation of MTAD by NaOCl in a manner similar to the peroxidation of tetracycline by reactive oxygen species.

Tetracyclines, including doxycycline, readily attach to dentin and are subsequently released without losing their antibacterial activity. The presence of doxycycline in MTAD suggests that MTAD may have some substantive antimicrobial action. In an in vitro study using a human dentin tube model, Mohammadi et al. showed that NaOCl was more significantly greater than CHX and NaOCl. In a study using a bovine dentin tube model, Mohammadi revealed that the substantivity of MTAD was significantly less than that of Tetraclean. Microbial communities grown in biofilms are remarkably difficult to eradicate with anti-microbial agents. And microorganisms in mature biofilms can be notoriously resistant for reasons that have yet to be adequately explained. There are reports showing that microorganisms grown in biofilms could be 2- to 1000-times more resistant than the corresponding planktonic form. Using an apical dentin biofilm model, Clegg et al. indicated that MTAD was not capable of either rendering bacteria nonviable or of physically removing the biofilm.

Dunavant et al. showed that MTAD killed only 16.08% of bacterial cells in the E. faecalis biofilm. Giardino et al. showed that MTAD was not effective in removing biofilm.

Smear Layer Removal
Studies show that current methods of instrumentation, especially rotary instrumentation techniques, produce a smear layer that covers root canal walls and the openings to the dentinal tubules. The smear layer consists of organic and inorganic substances, including fragments of odontoblastic processes, microbiorganisms and necrotic materials. The presence of this smear layer prevents intracanal medication to penetrate into the irregularities of the root canal system and the dentinal tubules. It also prevents complete adaptation of obturation materials to the prepared root canal surfaces.

For the first time, Torabinejad et al. showed that MTAD was an effective solution for removing the smear layer and did not significantly change the structure of the dentinal tubules when canals were irrigated with sodium hypochlorite and underwent a final rinse of MTAD. In another study, they showed that although MTAD removed most of the smear layer when used as an intracanal irrigant, some remnants of the organic component of the smear layer remained, scattered on the surface of the root canal walls. The effectiveness of MTAD to completely remove the smear layer was enhanced when low concentrations of NaOCl were used as an intracanal irrigant before using MTAD as a final rinse. This regimen did not seem to significantly change the structure of the dentinal tubules.

Tay et al. revealed that both irrigants created a zone of demineralized collagen matrices in eroded dentin and around the dentinal tubules, with the mildly acidic BioPure MTAD more aggressive than EDTA. These demineralized dentin zones create the opportunity for dentin hybridization by infiltration of hydrophilic adhesives/sealers. However, the potential consequences of compaction of hydrophobic sealers against air-dried, collapsed collagen matrices, and hydrolytic degradation of incompletely infiltrated matrices remain unresolved. In an ultrastructural study, Tay et al. showed that BioPure MTAD created a thicker demineralized dentin matrix (5 µm to 6 µm) than EDTA (1 µm to 2 µm). De-Deus et al. found that the demineralization kinetics prompted by BioPure MTAD were significantly faster than those prompted by a 17% solution of EDTA.

Tetraclean
Tetraclean (Ogna Laboratori Farmaceutici, Muggiò, Italy), like MTAD, is a mixture of an antibiotic, an acid and two detergents (propylene glycol and cetrimide). However, the concentration of the antibiotic, doxycycline (50 mg mL⁻¹) and the type of detergent (polypropylene glycol and cetrimide) differ from those of MTAD. Giardino et al. compared the surface tension of 17% EDTA, Cetrexidin, Smear Clear, 5.25%NaOCl, MTAD and Tetraclean. The NaOCl and EDTA had the highest surface tension, whereas Cetrexidin and Tetraclean had the lowest values.

Giardino et al. compared the antimicrobial efficacy of 5.25% NaOCl, MTAD and Tetraclean against an E. faecalis biofilm generated on cellulose nitrate membrane filters. Only the NaOCl could disaggregate and remove the biofilm at every time interval tested, although treatment with Tetraclean caused a high degree of biofilm disaggregation at each time interval when compared with MTAD.

Poggio et al. compared in vitro the antibacterial activity of Tetraclean, 5.25% sodium hypochlorite, Cloreximid (0.2% chlorhexidine and 0.2% cetrimide solution) and hydrogen peroxide on E. faecalis, Streptococcus mutans and Staphylococcus aureus using the agar diffusion test. Findings revealed that at room...
temperature, Tetraclean showed significantly higher inhibition of bacteria growth than all other irrigants tested. Preheating at 50°C significantly increased growth inhibition for all the groups tested. At 50°C, hydrogen peroxide volumes and Tetraclean showed significantly higher efficacy than all other irrigants tested. Pappen et al. showed that Tetraclean was more effective than MTAD against E. faecalis in planktonic culture and in mixed-species in vitro biofilm. Giardino et al. evaluated the antimicrobial action of BioPure MTAD (Dentsply Tulsa Dental, Johnson City, TN), Tetraclean, Cloreximiz (a mixture of chlorhexidine (CHX) digluconate and Cetrimide), and 5.25% NaOCl (Ogna Laboratori Farmaceutici, Milano, Italy) against E. faecalis, Porphyromonas gingivalis, and Prevotella intermedia. According to their results, MTAD and Tetraclean showed a high action against both strictly anaerobic and facultative anaerobic bacteria. Using the agar diffusion test, Aridizzoni et al. showed that Tetraclean eliminated 93% to 100% of E. faecalis cells.

There are few studies on the substantivity of Tetraclean. Mohammed et al. demonstrated that the substantivity of Tetraclean was significantly higher than MTAD and was retained in root canal dentin for at least 28 days. In another study, Mohammed et al. showed that Tetraclean was significantly greater than Hypoclean and 5.25% NaOCl. A direct relationship between dentine treatment time with Tetraclean and its substantivity has been shown. Pretreatment of dentine with NaOCl significantly decreases the substantivity of Tetraclean. However, it has also been shown that treatment of NaOCl-treated dentin with ascorbic acid prevents a decrease in the substantivity of Tetraclean.

Queries about this article can be sent to Dr. Mohammed at zahed_mohammed@yahoo.com.

REFERENCES

75. Giardino L, Savoldi E, Ambu E, Rimondini R, Palezona A, Debbia EA. Antimicrobial effect
71. Giardino L, Ambu E, Becce C, Rimondini L, Morra M. Surface tension comparison of
70. De-Deus G, Reis C, Fidel S, et al. Dentin demineralization when subjected to BioPure
67. Torabinejad M, Cho Y, Khademi AA, Bakland LK, Shabahang S. The effect of various concen-
65. Heard F, Walton RE. Scanning electron microscope study comparing four root canal prepa-
64. Peters OA, Barbakow F. Effect of irrigation on debris and smear layer walls prepared by two
63. Giardino L, Ambu E, Savoldi E, et al. Comparative evaluation of antimicrobial efficacy of
60. Stoodley LH, Costerton JW, Stoodley P. Bacterial biofilms: from the natural environment to
58. Mohammadi Z. Evaluation of the residual antibacterial activity of three concentrations of a
57. Mohammadi Z, Shahriari S. Residual antibacterial activity of chlorhexidine and MTAD in
54. Krause TA, Liewehr FR, Hahn CL. The antimicrobial effect of MTAD, sodium hypochlorite,
53. Viswanath D, Hegde AM, Munshi AK. The removal of the smear layer using EGTA: a scan-
52. Cruz-Filho AM, Sousa-Neto MD, Saquy PC, Picora JD. Evaluation of the effect of
51. Shabahang S, Torabinejad M. Effect of MTAD on Enterococcus faecalis-contaminated root
50. Davis JM, Maki J, Bahcall JK. An in vitro comparison of the antimicrobial effects of various
49. Torabinejad M, Shabahang S, Aprecio R, Kettering JD. The antimicrobial effect of MTAD: an
47. Tripodi D, D’Ercole S, De Fazio F, Spoto G. Demineralizing action of EGTA in endodontics.
46. Sousa SM, Silva TL. Demineralization effect of EDTA, EGTA, CDTA and citric acid on root