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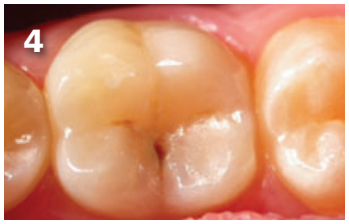

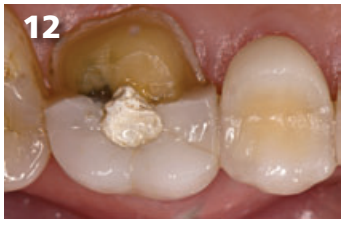

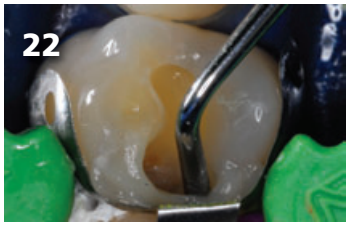

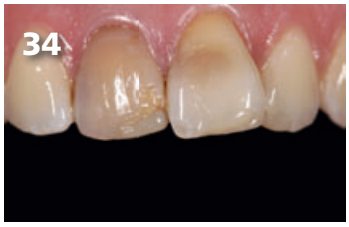

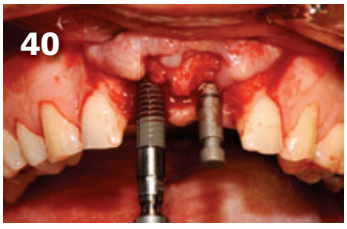

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An important aspect of the transformation of the journals was the decision to publish more original scientific material and so have a wider appeal to clinicians.The reader profile includes general dental practitioners, specialists and academics. Not only do readers have access to clinical papers, but also to significant scientific information, keeping them informed of current developments in all aspects of dentistry.

The journal is now published in three different continents, with the launch of the Australasian and Middle East Editions in 2006 and 2010 respectively. The African Edition was launched in 2011 as an adjunct to International Dentistry South Africa, which has now become a scientific/research publication.

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Flowable composites: Aesthetics for tots and teens

Fred S. Margolis[1]

Introduction

Parents are concerned about aesthetics for their children. Aesthetic dentistry can provide a beautiful smile that parents and their children desire. Self image is very important for our young patients so that they can look good and feel good about themselves. We have all experienced that wonderful spontaneous patient smile when we have turned the "ugly duckling" into a "beautiful swan." We are fortunate to have dental materials and devices that provide us the opportunity to perform aesthetic dentistry. Some of the techniques and materials we have available for our young patients' smile creations include: porcelain veneers, microabrasion, bleaching, orthodontics (including clear braces and aligners), direct and indirect composite restorations, implants, and all-ceramic crowns.

This article will describe and illustrate various uses of flowable composites that aid in providing aesthetic restorations for children and teens. The advantages of the beauty and functionality will also be elicited.

[1] *Dr. Fred S Margolis, DDS, private practice (Pediatric dentistry), Buffalo Grove, Ill., USA.*

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Table 1.
Indications for Flowable Composites

- Preventive resin restorations
- Bonding orthodontic brackets
- Minimally invasive Class I or II restorations
- Class II restorations as a base or liner under composite restorations
- Minimally invasive Class III restorations
- Class V restorations
- Splinting fractured and mobile teeth (post-trauma or periodontal involvement)
- Repairing small direct and indirect restorations
- Class VI restorations in nonstress bearing areas
- Fissure sealant

Indications for flowable composite in young patients

There are many indications for the use of flowable composites in young patients (Table 1). Some of of these are described in more detail:

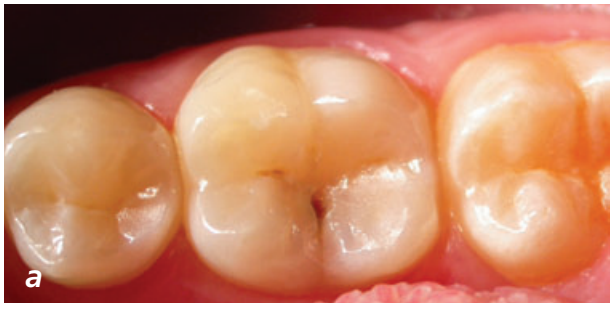

Figure 1a. Permanent molar with incipient caries. (Courtesy of Giovanni Olivi)

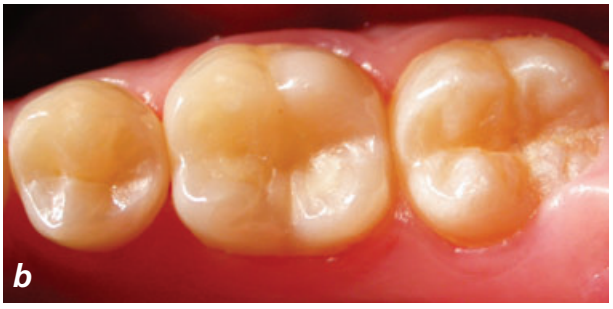

Figure 1b. Preventive resin restoration. (Courtesy of Giovanni Olivi)

Preventive Resin Restorations

Simonsen[1] has recommended that, for the type 2 preventive resin restorations (PRR) in which the preparation involves both the enamel and dentin, a flowable composite could be utilized to replace the carious tooth structure after excavation of the incipient caries. In a recent article by Savage, et al[2] it was reported that flowable composite was the most widely used restorative material for the PRR among those pediatric dentists surveyed in this study. More than 30% of the pediatric dentists always use a flowable

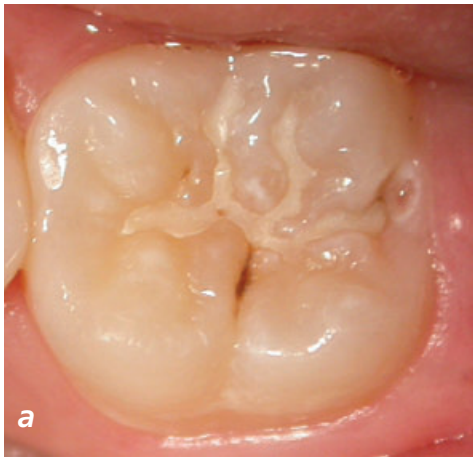

Figure 2a. Permanent molar with caries adjacent to failed sealant. (Courtesy of Giovanni Olivi)

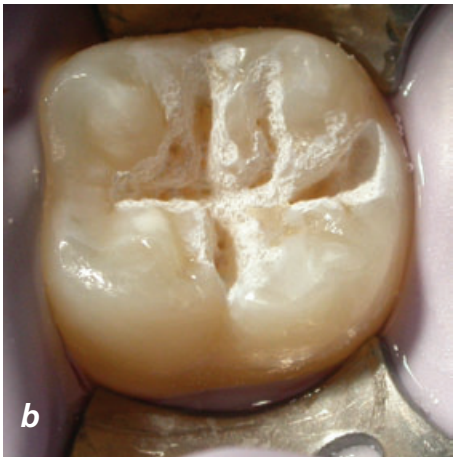

Figure 2b. Erbium laser preparation of molar for preventive resin restoration. (Courtesy of Giovanni Olivi)

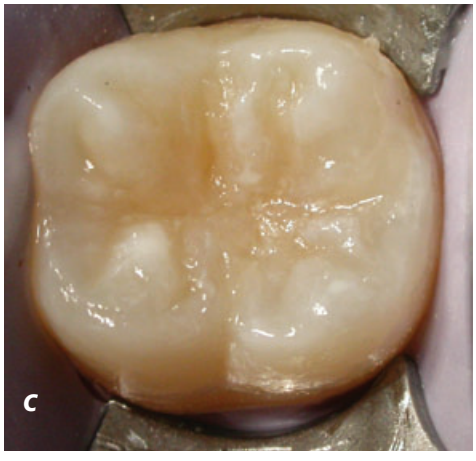

Figure 2c. Preventive resin restoration. (Courtesy of Giovanni Olivi)

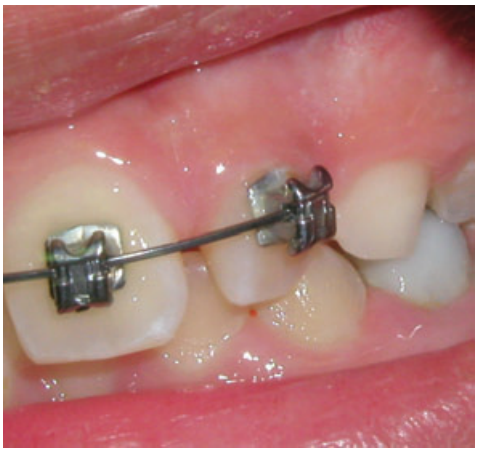

Figure 3. Bonded orthodontic brackets.

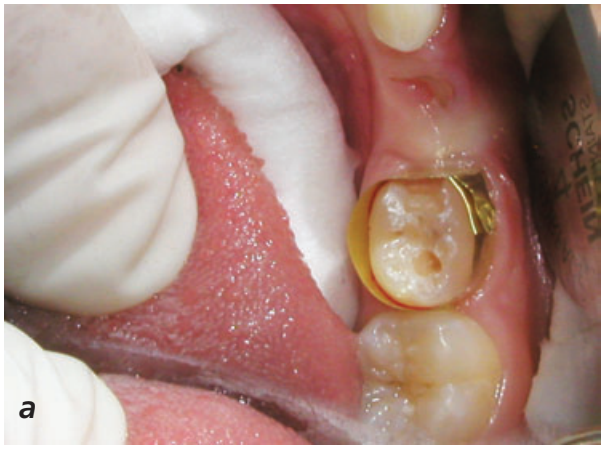

Figure 4a. Class II preparation on a primary molar.

Figure 4b. Flowable composite placed.

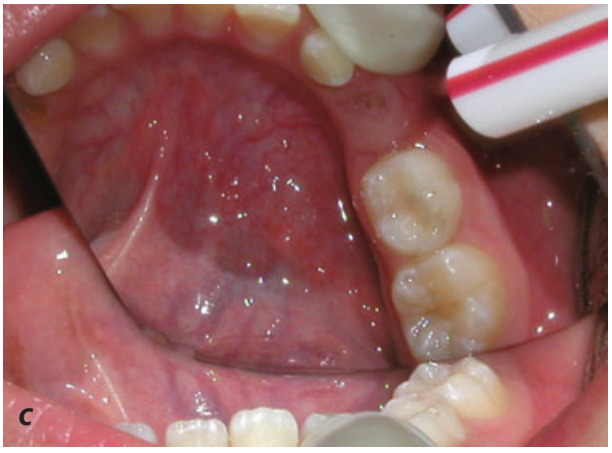

Figure 4c. Flowable composite restoration completed.

composite or a combination of flowable composite and "packable" composite/ flowable composite combination (Figures 1a and 1b).[2] The author has found flowable composite to also be useful when a sealant has failed and incipient caries has been detected at a recall visit (Figures 2a to 2c). The Venus Diamond Flow (Heraeus Kulzer) flowable composites offer low shrinkage and high flexural strength.

Bonding Orthodontic Brackets

Vicente and Bravo[3] evaluated the shear bond strength of several flowable composites after debonding of orthodontic brackets compared to a traditional orthodontic resin. The shear bond strength was measured with a universal testing machine and the adhesive remnant after debonding was quantified utilizing image analysis. The results showed that there were no significant differences between the shear bond strengths of the various groups evaluated. The orthodontic resin left significantly more adhesive on the tooth than the 3 flowable composites tested.[3] Ryou, et al[4] in a recent study concluded: "...flowable composites with no intermediate bonding resin could be conveniently applied for orthodontic bonding" (Figure 3).

Class II and V Restorations Utilizing Flowable Composite

Flowable composites are often utilized as a liner under composite restorations. The purpose is to seal the margin, which helps prevent postoperative sensitivity and secondary caries. Sadeghi and Lynch[5] investigated the effects of a layer of flowable composite and compomer on microleakage of composite restorations that extended apically to the cement-enamel junction. The results of the study showed that when flowable composites were used as a liner, both the packable and the nanofilled composite materials had significantly less microleakage than when flowable liners were not used. There was a significant reduction of the microleakage occurring under both types of composite materials at the gingival floors[5] (Figures 4a to 6b).

Illie and Hickel[6] investigated the mechanical properties of composites and concluded that flowable composites and compomers showed comparable results. Flowable composites only differed from microfilled composites in diametric tensile strength.

Some of the flowable composites the author uses routinely includes Venus Diamond Flow. The advantages to this particular flowable composite includes the increased strength (versus a sealant), low shrinkage stress, and high flexural strength. It also has the advantage of being an exact shade match with the Venus Diamond composite system. Other flowable composites that the author uses includes

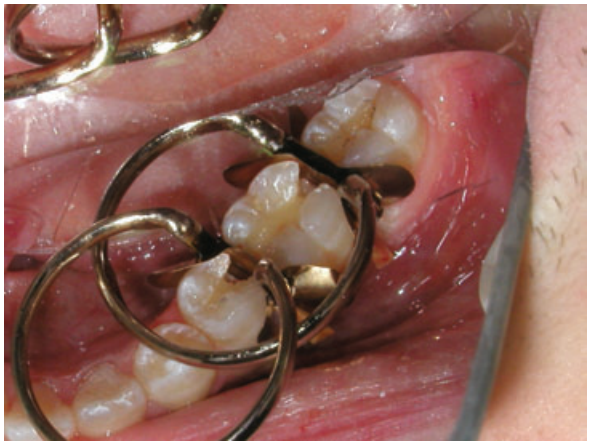

Figure 5a. Class II preparations of bicuspid and molars.

Figure 5b. Flowable composite as a liner.

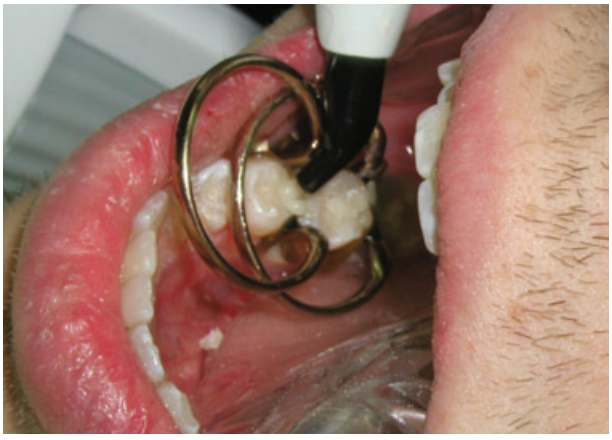

Figure 5c. Composite placed over flowable composite.

G-aenial Flo and Universal Flo (GC Corporation) and Beautifil Flow Plus (Shofu). The advantage to the later is the release of fluoride. Vertise Flow (Kerr) has the added benefit of being self-etching.

The effects of different light-curing units on the microleakage of flowable composite resins was studied by Yazici, et al.[7] They found that none of the Class V restorations restored with flowable composites exhibited marginal leakage of the enamel. Also, there was no significant difference exhibited between the flowable composites tested on the dentin margins.[7]

Splinting Fractured and Mobile Teeth and Orthodontic Retainers

Tabrizi, et al[8] found that flowable composites provided satisfactory shear bond strength comparable to a standard orthodontic resin and therefore may be used for direct bonding of lingual retainers.[8] Flowable composites may be used to splint mobile teeth utilizing orthodontic wire or nylon filament splints (Ribbond). Foek, et al[9] studied the adhesive properties of bonded orthodontic retainers to enamel, utilizing flowable composite, with both stainless steel wire versus fiber-reinforced composites. They found

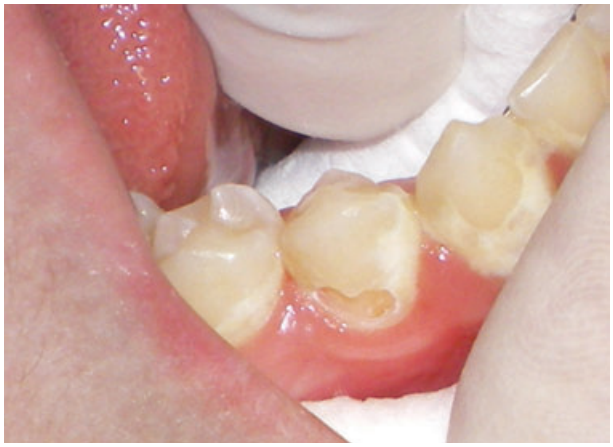

Figure 6a. Class V preparation on bicuspid.

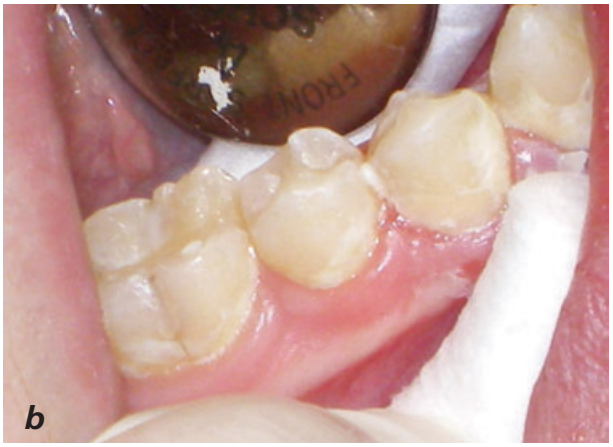

Figure 6b. Flowable composite restoration.

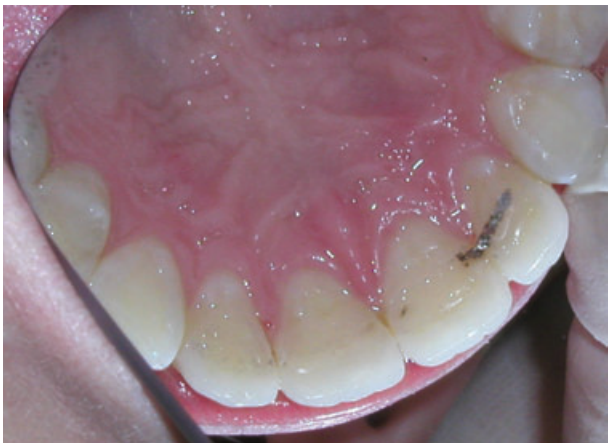

Figure 7. Splint bonded with a flowable composite.

that the bond strengths between the fiber-reinforced composites and the orthodontic wire when used as retainers did not differ significantly (Figures 7 to 9).[9]

Repairing Small, Direct, and Indirect Restorations

One of the many advantageous properties of flowable composites is their ability to repair previously placed composite restorations. Papacchini, et al[10] evaluated the effect of various intermediate resin agents on composite-to-composite bond strengths. The flowable composites showed good interfacial quality to the adhesives. Also, the application of flowable composites resulted in statistically superior tensile strength (Figure 10).[10] The author used Venus Diamond Flow in this instance due to the studies indicating its excellent bond strength, low shrinkage stress, and shade matching quality.

Table 2. The Desirable Properties of Flowable Composite are the following:

- Flowable consistency and modeling (thixotropic)
- Low shrinkage
- Radiopaque
- Shades corresponding to composites; color adaptative qualities
- Polishability and long-lasting shine
- Color stability

Important properties of flowable composites

Flowable composites exhibit many characteristics that make them an excellent choice for indications like the ones highlighted above (Table 2). The following properties are important when treating young patients with this class of composite resin restorative material.

Radiopacity of Flowable Composites

One of the qualities of a flowable composite that is very favorable is that of being radiopaque. Venus Diamond Flow has been shown to be one of the most radiopaque flowables on the market today. Murchison, et al[11] in their study, stated the following: "The level of radiopacity of the tested flowable composites was variable; those with low radiodensity should be avoided in Class II restorations, where a clear determination of recurrent caries by the examining clinician could be compromised."[11] Sabbagh, et al[12] agreed

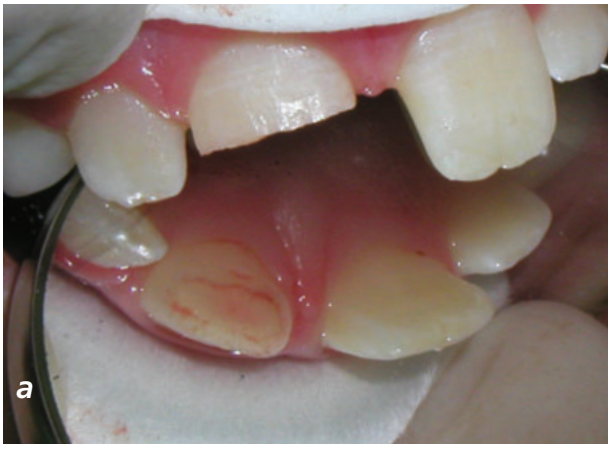

Figure 8a. Fractured permanent central incisor.

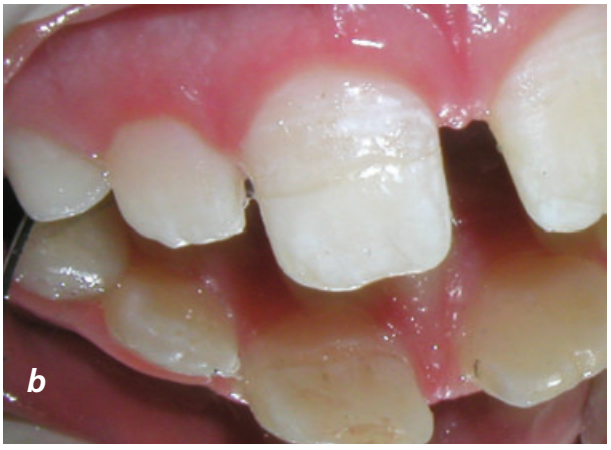

Figure 8b. Flowable composite bonded fractured segment to crown.

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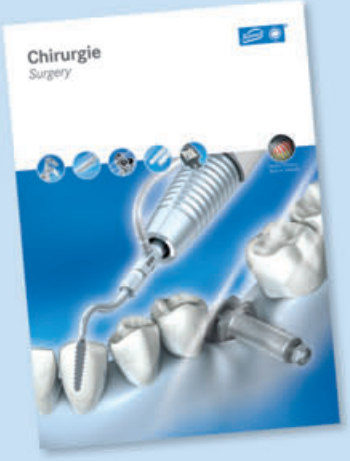

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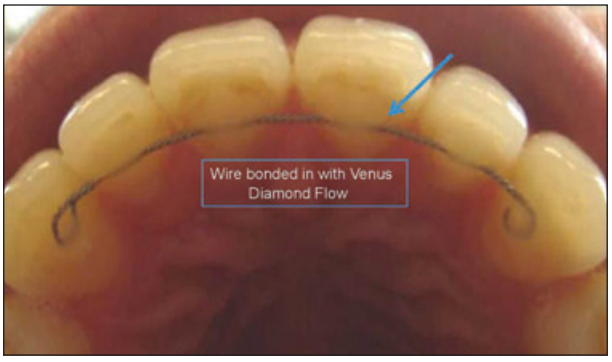

Figure 9. Orthodontic retainer bonded with flowable composite.

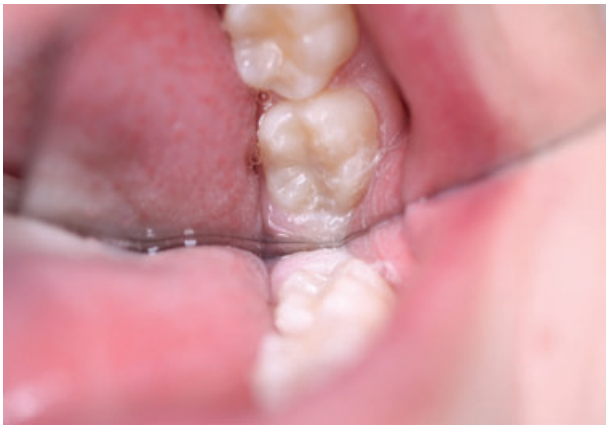

Figure 10. Occlusal restoration with Venus Bulk Flowable.

with a more recent study when they concluded that flowable composites used within intracoronal restorations, clinicians should use materials with high radiopacity (Figure 11).[12]

Polishing Flowable Composites

Polishablilty of the surface of the restoration is important for aesthetic and functional purposes. The surface should be able to have a smooth lustrous surface and be able to maintain this desired characteristic. Ozel, et al[13] studied the effect of one-step polishing systems on the surface roughness of various flowable composites. The one- or 2-step polishing systems are a good choice for the polishing of flowing composites.[13]

Conclusion

This article briefly described and demonstrated various indications for aesthetic restorations that can be used successfully for our child and adolescent patients. Modern aesthetic techniques and flowable composite resin materials, used properly for purposes such as those presented herein, will serve to broaden the scope of aesthetic dentistry delivered for children and teens.

Disclosure: Dr. Margolis receives honoraria and products from Biolase Technologies, Inc.

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Flowable Composites: Aesthetics for Tots and Teens, by Fred S. Margolis, DDS: Dentistry Today, Vol. 30, No. 4, 04/11, pp 132-137.

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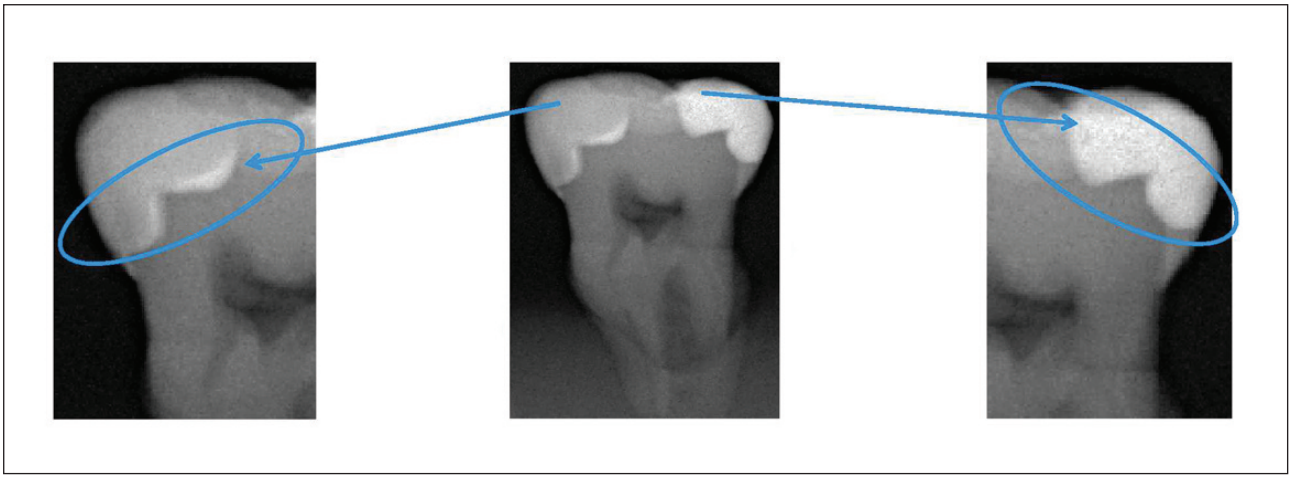

Figure 11. Radiopacity of a flowable composite material.

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Surface treatments for tooth-colored restorations: Part 2

Douglas A. Terry,[1] Markus B. Blatz[2]

Adhesive and restorative success for any indirect restoration begins and ends at the restorative-tooth interface. The bonded restorative complex includes the outer layers of the substrate, the adhesive layer, and the restorative material. Any biomaterial when properly joined to the tooth substrate is able to provide an improved marginal seal while reducing marginal contraction gaps, microleakage, nanoleakage, marginal staining, and secondary caries.[1] Also resulting from the adhesion between tooth and biomaterial is restoration retention and a reduction of stress at the tooth-restorative interface. Biomechanically, this bond reinforces tooth structure and biologically preserves tissues, seals dentin tubules, and provides long-term functional success.[2-4] In part 1 of this article, a discussion of adhesion at the restorative interface was provided to the clinician and technician to encourage more predictable methods for achieving an optimal bonded tooth-colored restoration. As part 1 described a standard surface treatment and adhesive cementation protocol for laboratory-processed composite resin restorations, this segment of the discussion will describe the surface treatment protocols for different ceramic microstructures with various clinical adhesive cementation applications.

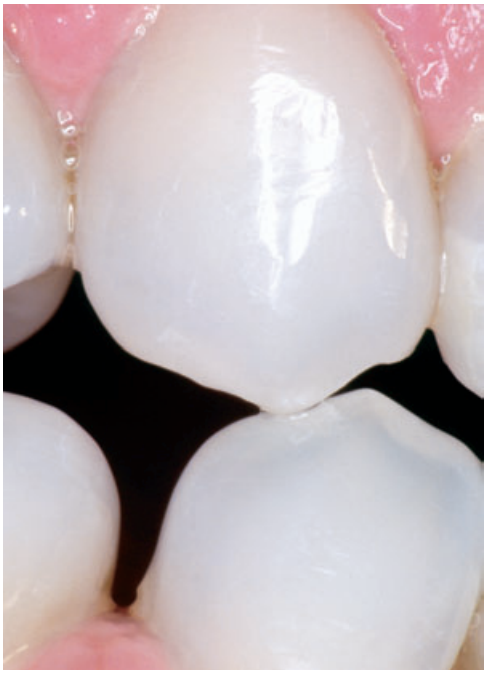

Figure 1: The patient presented with no posterior disclusion or anterior guidance after orthodontic treatment. A prepless veneer was placed (tooth No 6) to establish the proper function and to improve the aesthetics.

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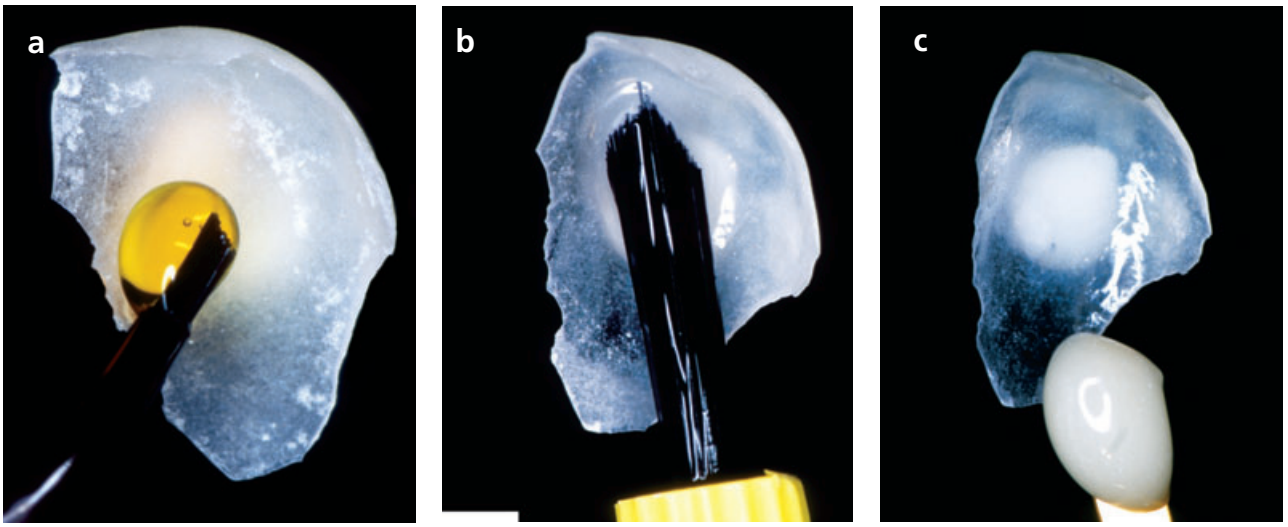

Figure 2: The internal surface of the silica-based ceramics (Willi Geller Creation, Creation International) was etched with a 9% buffered hydrofluoric acid (Porcelain Etch, Ultradent Products) for 2 minutes, rinsed, and air-dried (2a). An application of silane (Porcelain Bond Activator mixed with Clearfil SE Bond Primer, Kuraray) was applied. Some manufacturers add a silane coupler to their bonding system that is mixed with the other components (eg, bonding agent/primer) during ceramic adhesion (2b). A clear translucent light-cure resin cement (Illusion, BISCO) was applied to the internal surface of the veneer (2c).

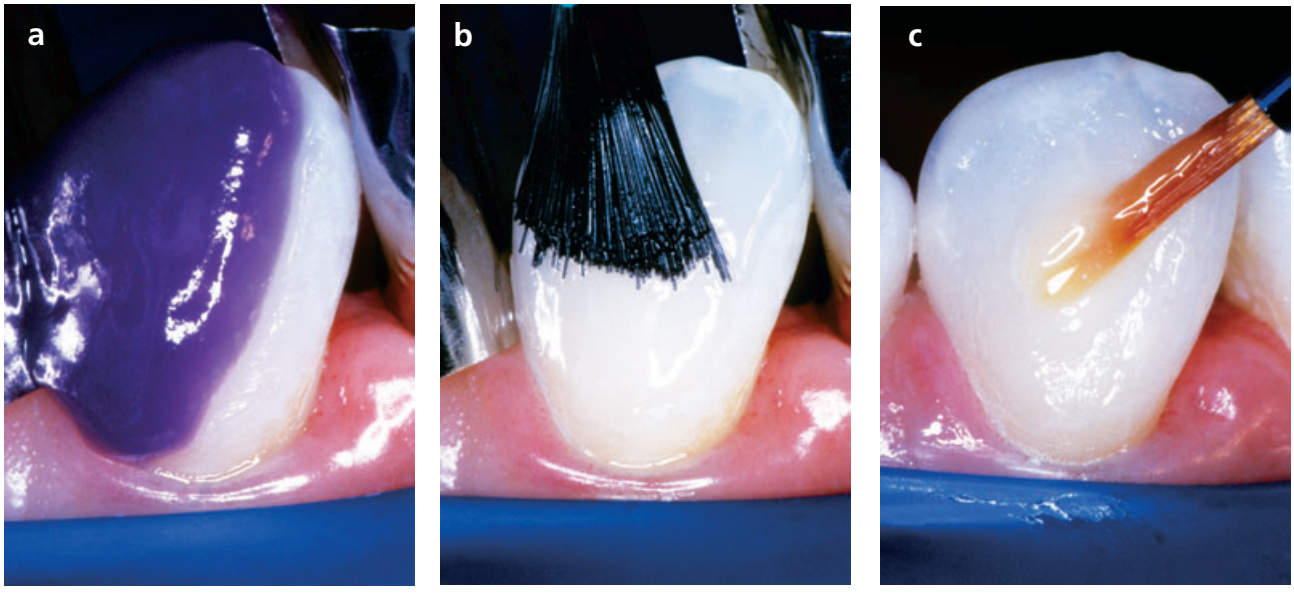

Figure 3: Once the disinfectant step was completed, the enamel was etched using a 37.5% phosphoric acid (Gel Etchant, Kerr). The gel was placed several mm beyond the anticipated restorative margin (3a). An adhesive agent (Optibond Solo Plus, Kerr) was applied to the etched enamel, air-thinned, and light-cured for 40 seconds (3b). The veneer was positioned into place and the excess resin cement was removed using the "wetbrush" technique and was light-cured for 40 seconds. It is important to leave a residual amount of resin cement at the interface to compensate for polymerization shrinkage (3c).

Surface treatment of all-ceramic restorations for adhesive resin cementation

Adhesive cementation typically involves surface treatment of the restoration and the tooth structures, application of primers and adhesives and the use of composite resin luting agents. Different ceramic surface treatments have been introduced to pretreat the intaglio ceramic surface and improve the bond at the ceramic-resin interface.[5-9] The adhesion between ceramic material and composite resins is the result of a physicochemical interaction at the ceramic-resin interface involving 2 simultaneous mechanisms – chemical bonding and micromechanical interlocking.[10] Because of the different chemical structure between silica-based and high-strength ceramics different surface treatments are required.

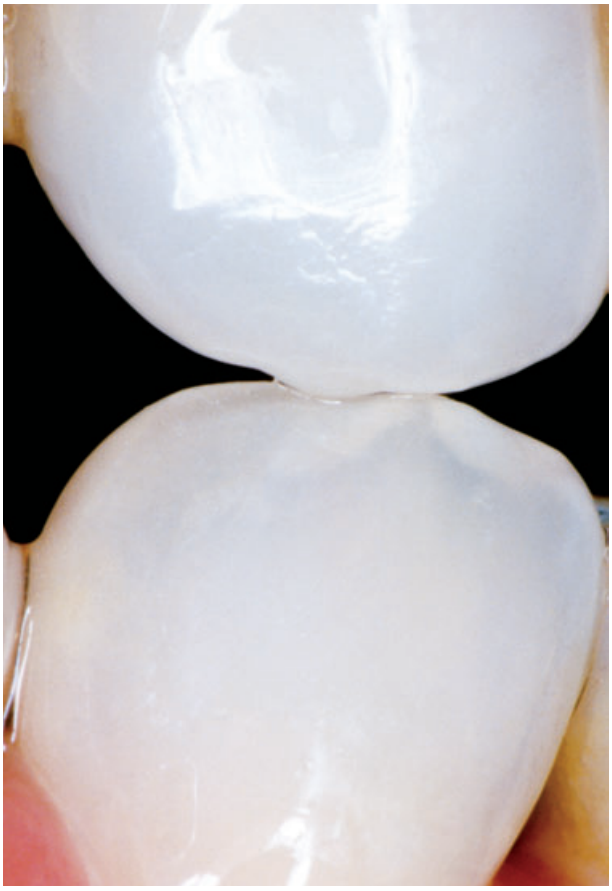

Figure 4: Function and aesthetics were improved using a noninvasive preparation-less procedure.

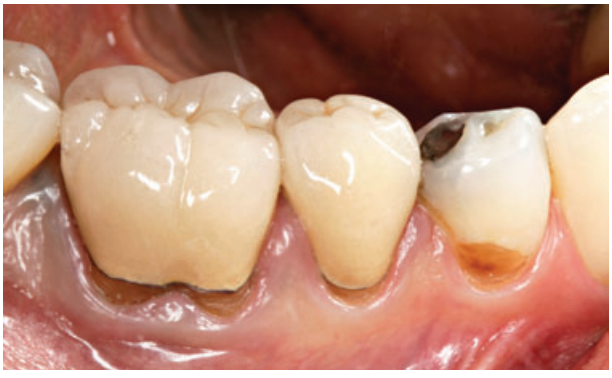

Figure 5: Preoperative facial view of existing ceramo-metal restorations with open margins, recurrent caries,and inadequate epithelial attachment. Patient presents with sensitivity and requests an aesthetic improvement. Treatment required connective tissue grafting and replacement of the existing crowns with zirconium restorations and a Class V composite restoration on the second premolar.

Silica-based ceramic restorations

Silica-based ceramic restorations, because of their optical and aesthetic properties, are used to a great extent for porcelain laminate veneers, inlays and onlays, and full-coverage crown restorations. This brittle restorative material derives its strength from the adhesive bond of the definitive restoration and the supporting tooth structure.[11,12] Proper surface treatment of the ceramic surface prior to cementation is therefore rudimentary for their long-term clinical success.[12,13] Bonding to silica-based ceramics is usually obtained by the 2 aforementioned simultaneous mechanisms.[14-25] The hydrofluoric acid (HF) attacks the glassy phase of the ceramic material,dissolving the surface and exposing the silicate crystals in the matrix, while the silane coupling agents provide a chemical covalent bonding between the silica in the ceramic matrix[20-22] and copolymerizes with the methacrylate groups through siloxane bonds.[26,27] The authors' recommend acid-etching with 4% to 9.8% HF to create surface roughness and the application time depends on the crystalline content of the specific ceramic substrate. A higher crystalline content requires less acid etching time and concentration. A silane coupling agent is then applied to the etched ceramic surface. It is important not to place an excess or thick layer of silane because additional layers of hydrolyzed silane will not bond to the porcelain surface and can result in a less than optimal porcelain bond[28,29] (Figures 1 to 4).

High strength ceramic restorations

High strength non silica-based ceramic restorations such as zirconia and alumina have increased in utilization by the clinician and technician because of the material's strength, multitude of clinical indications and applications, and its cost effectiveness compared to precious metals.[30] Of course, when preparation designs are retentive, non adhesive cements (ie, glass ionomer cements) or moderately adhesive cements (ie, self-adhesive resin cements) can be used successfully to retain these non silica-based restorations. However,when the retention/resistance form is compromised, adhesive cementation with surface treatment of the ceramic material can improve the durability and reliability of the bond for non silica-based restorations.[30] The excellent optical properties of high-strength ceramic materials are especially advantageous for indirect resin-bonded restorations such as resin-bonded fixed partial dentures. These types of restorations, however, rely on stable and long-term durable resin bonds.

Although the surface treatment for the tooth substrate remains the same (ie, self-etch or total etch), the surface treatment procedures known for silica-based ceramics cannot be utilized for high strength ceramic materials (ie, alumina, zirconia). Traditional bonding procedures (ie, acid etching and silane application) for silica-based ceramics cannot provide long-term durable bonds to the silica-free,acid resistant, high-strength ceramic materials.

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Figure 6: The internal surface of the high strength ceramic crown (Lava, 3M ESPE) was microetched using a silica coating, CoJet-Sand (Rocatec/CoJet System, 3M ESPE) (6a). A silane coupling agent (ESPE Sil) was applied onto the internal surface of the restoration (6b). Application of a methacrylate based self-etch cement (G-Cem, GC America) onto the internal aspects of the porcelain crown for final cementation (6c).

Conventional acid etchants do not sufficiently roughen the dense surface[31] of these materials and the chemical reaction from silanization of these non silica-based ceramics is not possible. However, silane application can provide increased wettability.[16-27,31,32] Silica/silane coating or application of a phosphate-monomer-containing ceramic priming agent after airborne particle abrasion increases the shear bond strength between zirconium-oxide ceramic and a resin luting agent.[33,34] In addition, several in vitro studies have indicated that air-particle abrasion and a phosphate-modified resin luting agent have the potential to provide long-term durable resin bonds.[35] Another long-term in vitro study found that silica coating and silanization increases resin bond strength to zirconia (Lava, 3M ESPE) with different resin cements.[36,37] While silica/silane coating failed to provide durable bonds to densely-sintered aluminum-oxide ceramics, it was successfully implemented for zirconia ceramics.[38,39] In an in vitro investigation on the fracture strength and marginal leakage of densely-sintered alumina crowns after aging in an artificial chewing simulator, fracture strengths were well above natural chewing forces for all cementation methods. However, adhesive bonding with a composite resin luting agent and ceramic primer containing adhesive phosphate monomers after air-particle abrasion of the crown intaglio surface significantly increased fracture strength and decreased marginal leakage as compared to conventional cementation methods. The current evidence supports the use of modified priming and/or resin composite luting agents containing special adhesive monomers (eg, MDP Kuraray) that provide chemical bonds to metal oxides and, therefore, long-term durable resin bonds to high-strength ceramic materials.[33-35,38,40-49] Airborne-particle abrasion and an MDP-containing priming agent (Porcelain Bond Activator mixed with Clearfil SE Bond Primer, Kuraray) followed by

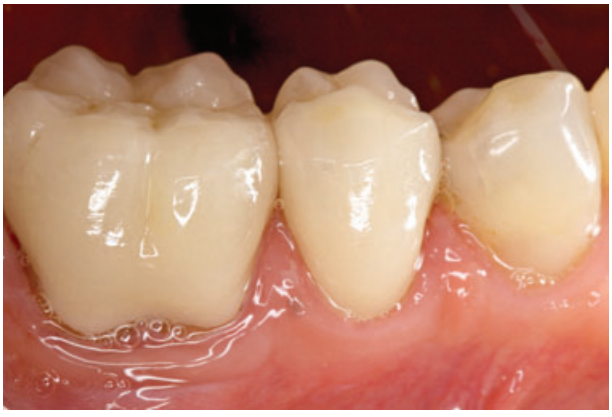

Figure 7: Postoperative facial view of the final restorations. Notice the soft tissue biocompatibility at the restorative interface.

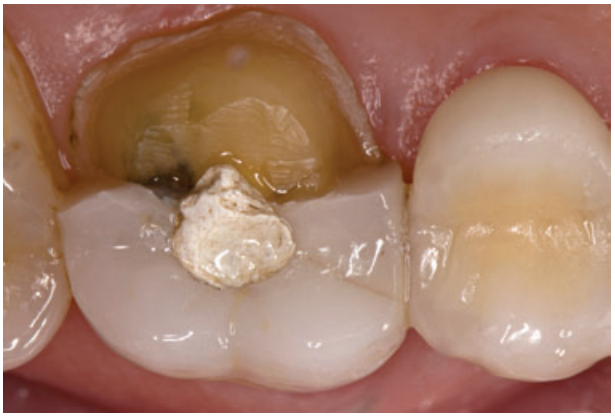

Figure 8: Patient presents with a fractured all-ceramic crown on the maxillary right first molar after endodontic treatment. Treatment involved replacement of existing crown with all-ceramic restoration fabricated with a zirconium internal substructure and Vita surface ceramics (VITA VM9, Vident).

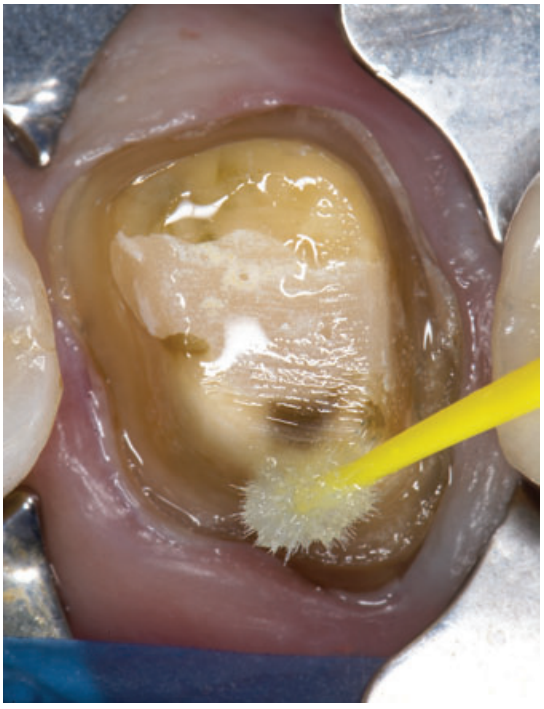

Figure 9: The prepared tooth structure was conditioned using a self-etch primer, (ED Primer, Kuraray) and air-dried using a warm air tooth dryer (A-dec).

application of an MDP-containing resin composite luting agent (Panavia F 2.0 [Kuraray]) revealed the highest shear bond strength in one study, although not significantly different from some combinations with Rocatec silica/silane coating.[50]

The authors' surface treatment protocols for high-strength ceramics (ie, aluminum and zirconium oxide) include 2 methods. One method requires silica coating of the inner surface of the restoration with CoJet-Sand (Rocatec/CoJet System, 3M ESPE) followed by an application of a silane coupling agent (ESPE Sil). The application of a silica layer to high-strength ceramics such as zirconia creates binding sites for the silane molecules while the silane provides wettability and a chemical coupling with the methacrylate based cements (Figures 5 to 7). Another user-friendly method involves an application of a commercial primer that contains phosphonate or phosphate monomers. Phosphate monomers form covalent bonds with the zirconia surface and have polymerizable resin terminal ends that copolymerize with the resin cements. The recent developments of several special ceramic primers indicate their importance. Even if a resin cement contains the same adhesive monomer as the priming agent, the primer offers a better wetting effect to the intrinsically rough intaglio surface of an all-ceramic restoration. Currently, there are several ceramic primer systems for zirconia surface preparation available such as Monobond Plus (Ivoclar Vivadent); Clearfil Ceramic Primer (Kuraray); AZ-Primer (Shofu Dental); Metal/Zirconia Primer (Ivoclar Vivadent); and Z-Prime Plus (BISCO) (Figures 8 to 12). Air-particle abrasion with small aluminum oxide particles (eg, 30 µm) before application of a ceramic primer is recommended to further increase bond strengths of composite resins to high-strength ceramic materials.

Figure 10: After air-particle abrasion of the internal surface of the restoration with aluminum oxide particles, a zirconium primer (Z-PrimePlus, BISCO) was uniformly applied to wet the internal surface and air-dried for 5 seconds (10a). A self-cure resin cement (Panavia 21TC, Kuraray) was mixed and applied to the internal surface of the crown (10b).

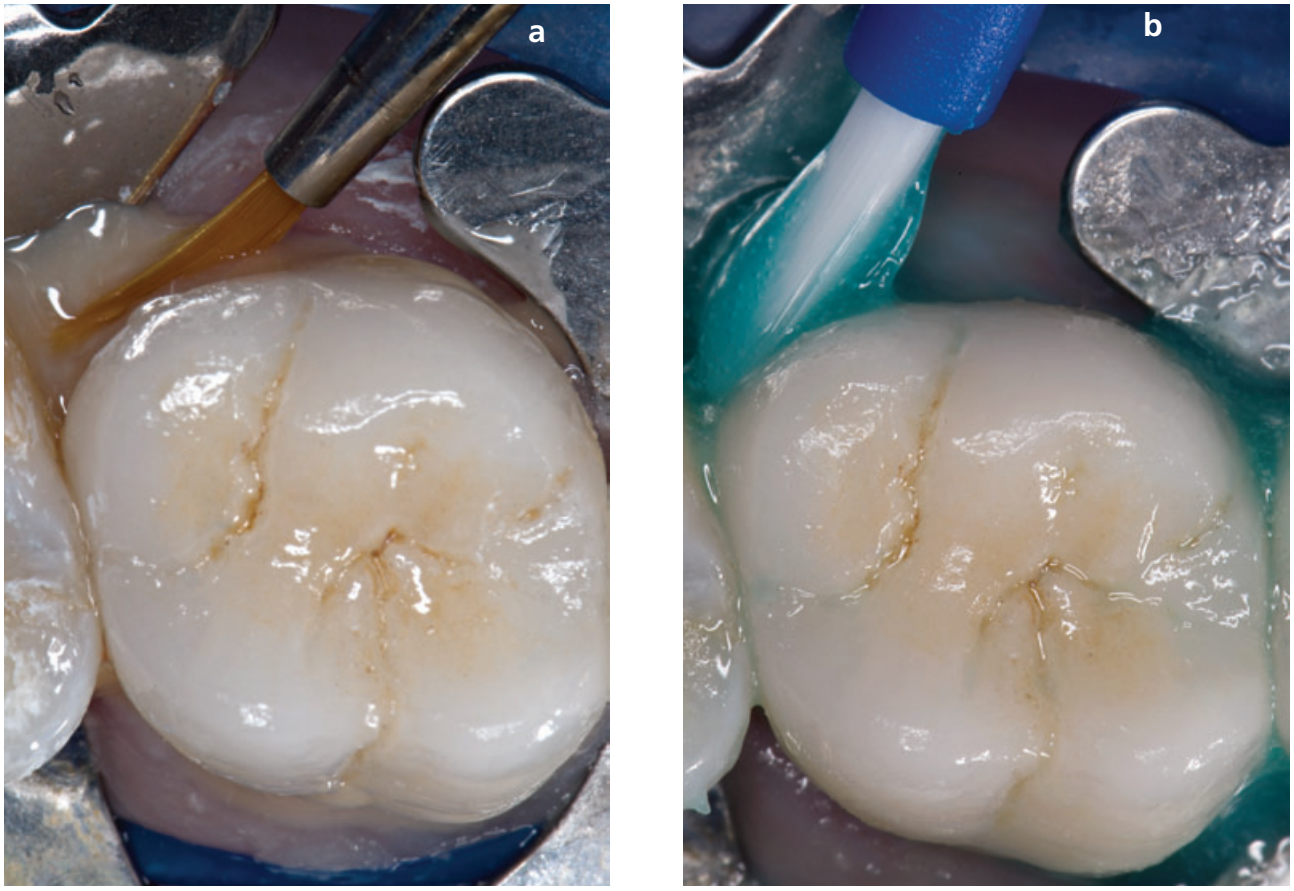

Figure 11: The excess cement was removed using a No. 000 sable brush, leaving a residual amount to compensate for polymerization shrinkage (11a). An oxygen inhibitor layer (Oxyguard II, Kuraray) was placed at the interface to accelerate the set of the resin cement (11b).

Clinical considerations for surface treatment of ceramic material

There are several consideration factors for the surface treatment of ceramic material. First, it is important to avoid contamination of pretreated ceramic surfaces, since organic contaminants such as salivary fluids or finger residue can decrease bond strengths. However, if the restoration is contaminated prior to cementation, any contaminated surface should be cleaned with a phosphoric acid solution for 15 seconds. It is important to remember that different silanes or "ceramic primers" are not the same and, for high-strength ceramics, it is imperative that the priming agent contains special monomers that bond to metal oxides. Conventional silane coupling agents and resin composite luting agents provide excellent long-term durable chemical bonds to silica-based ceramics. Such bonds,however, are not possible to high-strength ceramics that do not contain silica.[42] Also, it is important to remember, that silane coupling agents used for silica-based ceramics can have different chemical compositions. However, they must be

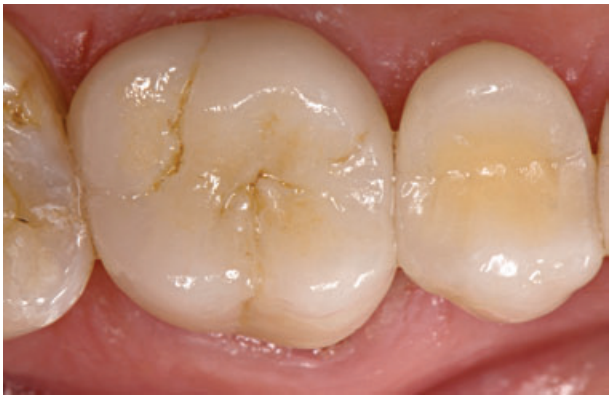

Figure 12: The completed all-ceramic restoration with a zirconium substructure and Vita surface ceramics (VITA VM9, Vident). Notice the healthy biological framework and the integration of color with the adjacent dentition.

compatible with the bonding agent and resin cement. Therefore, it is imperative to stay within one bonding system and to closely follow the manufacturer's instructions for application and timing.[12] In addition, silane coupling agents

are dispensed in single or multiple-bottle applications. Single-bottle products typically contain greater amounts of solvents and are, therefore, more susceptible to solvent evaporation,hydrolysis, and polymerization that renders the solution ineffective. Thus, it is essential to periodically review shelf life and remember to seal containers immediately after use. Also, the color of the solution can be a reliable indicator of the efficacy of the solution and if it appears milky, it should be discarded.

Conclusion

The primary objective of any cementation procedure is to achieve a durable bond and a good adaptation of the luting material to the restoration and the tooth.51 Conventional cementation techniques for indirect ceramic restorations rely on only one physico-chemical interaction – mechanical interlocking. Adhesive cementation techniques provide a combination of micromechanical interlocking and true chemical bonding. In addition, adhesive bonding of indirect restorations can increase retention, marginal adaptation, and fracture resistance of the restored tooth and the restorative material when compared to conventional luting techniques. This article has provided the clinician and technician with various alternative materials and techniques for achieving an optimal, long-term, durable adhesive bond to different ceramic microstructures.

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New clinical innovations and the benefit of magnification to ensure predictable posterior composite restorations – Part 1

Peet van der Vyver[1]

Introduction

For many years gold and amalgam have been the materials of choice for restorations in the posterior dentition due to the clinician's desire for predictable function and a lack of viable aesthetic treatment choices. Today, the benefits of posterior resin restorations extend far beyond appearance alone. Features and benefits include functional stability, conservative cavity preparation, tooth reinforcement, biocompatibility and repairability (Jackson, 1999).

Posterior composite resin restorations are generally performed as fine detail work. The restorative phase requires attention to detail while following a meticulous clinical technique. According to Liebenberg (2002), the direct Class II posterior composite resin restoration is one of the most challenging restorations due to the operative intricacy and proximal precinct. Clinical performance is affected by the degree of fine detail that can be seen by the clinician during any given dental operation. The use of magnification in dentistry is expanding rapidly. It has revolutionized endodontics and will improve many aspects of clinical dentistry. The Dental Operating Microscope (DOM) (Figure 1) improves visual acuity, provides increased precision and is also of important ergonomic benefit to the clinician.

As reported by van As (2008), 10X microscope magnification can provide the clinician with 25 times more visual information compared to that obtained from the use of entry level loupe magnification (2X) and 100 times more information compared to the naked-eye view. In a study by Leknius and Giessberger (1995) they demonstrated that dental students who performed fixed prosthodontics procedures while using magnification were found to make fifty per cent less errors than students who performed the same procedure without the aid of magnification. In 2004, Zaugg, Stassinakis and Hotz illustrated the influence of magnification on the recognition of simulated preparation and filling errors. They mounted 37 mistakes or filling errors onto a phantom head model and asked 39 dentists to examine the jaws under clinical conditions using either no visual aid (n=13), magnifying glasses (n=13) or a microscope (n=13). The group using the microscope for examination spent more time on examination and found significantly more defects than the groups using magnifying glasses or no visual aids.

The accuracy of any given procedure is increased when the stereoscopic view of the microscope is combined with the shadowless coaxial light source. Combining magnification with illumination allows the clinician to

Figure 1: Global 6-Step Dental Operating Microscope (DOM) fitted with a dual-iris, LED light source, beam splitter and HD video camera.

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visualise vital information that can influence the outcome of treatment which is not otherwise perceptible to the naked eye. In general, the benefits of microscope magnification include: magnified images, increased precision (van As, 2008), shadowless illumination, improved ergonomics and posture for the operator, digital documentation of findings by means of integrated photography or video (van As, 2008) that can be used for communication with the patient.

This article will review the benefit of magnification during the placement of direct posterior composite restorations with emphasis on how to achieve adequate interproximal contact, bonding procedures and composite insertion techniques.

Achieving Adequate Interproximal Contact and Integrity

One of the major clinical problems with direct posterior composite resin restorations is the clinician's inability to achieve an ideal interproximal contact (Burke and Shortall, 2001). The primary challenge with Class II composite restorations is to create functional, predictable proximal contact that emulates the physiological ideal (Morgan, 2004). According to Maitland (1993) some of the failures of composite restorations, which are a result of manipulative deficiencies, are open contacts which leads to continuous food impaction and periodontal disease, as well as inadequate proximal contours, faulty occlusion and excessive wear.

According to Varlan et al., (2008) you need a properly contoured matrix band that is stabilized and adequately adapted gingivally with a wedge to establish the correct interproximal contact and convex contour. If a conventional Tofflemire matrix (uncontoured or contoured) is stabilized gingivally with a wedge it will still often result in open or light contact points if the clinician does not use additional separation (Wirshing et al., 2008). One of the major problems with a circumferential band is that the matrix often flatten out interproximally due to tensioning of the band and when the interproximal box preparation is very wide (bucco-lingual direction) an open contact is the only possible outcome (Boksman, 2010). The inability to properly condense composite resin materials, the fact that they demonstrate unconstrained volumetric shrinkage of 2-5% and that the matrix band itself take up some interproximal space during the placement phase are also reasons that can contribute to open contacts with posterior composite restorations (Boksman, Margeas and Buckner, 2008).

Precontoured sectional matrices in combination with separating rings can provide the clinician routinely with predictable interproximal contacts (Van der Vyver, 2002). The precontoured metal matrices are very malleable, they can usually be sealed more completely at the gingival margin to prevent overhangs and are less likely to lose their contour if aggressively wedged (Reality, 2001). Separating rings has become indispensable when the clinicians want to achieve tight interproximal contact. These rings are placed between the teeth adjacent to the box preparation after placement of the matrix band. The engaged ring then exerts a continuous separating force on the two adjacent teeth, creating a small space that will promote adequate interproximal contact. In addition, the tines of the ring can also ensure good adaptation of the matrix band against the preparation walls of the cavity preparation to minimise or eliminate any excess of composite material at the line angles (Reality, 2001).

It is well documented in the literature that precontoured sectional matrices in combination with separating rings will result in the strongest contacts (Boksman, Margeas and Buckner 2008; Loomans et al., 2006; Saber et al., 2010) and stronger marginal ridges (Loomans et al., 2008).

There are many sectional matrix systems on the market that can help the clinician to achieve good interproximal contact and convex contour (Table 1). The author prefers to use the V3 Matrix System (Triodent) that is also marketed as the Palodent Plus System (Dentsply) in certain regions.

The curved matrix bands (available in sizes from 3.5mm up to 7.5mm) of this system are designed with a rounded gingival contour as well as with an occlusal marginal ridge

Table 1: Sectional Matrix Systems for Class II Posterior Composite Restorations

Separating Ring and Contoured Sectional Matrix System	Recommended Wedge	Manufacturer
V3 Matrix System Sectional Matrix System	Wave-Wedge	Triodent
Palodent Plus Sectional Matrix System	Palodent Plus Wedge	Dentsply
Composi-Tight Silver Plus Sectional Matrix System	Wedge Wands	Garrison Dental
Composi-Tight 3D Sectional Matrix System	Wedge Wands	Garrison Dental

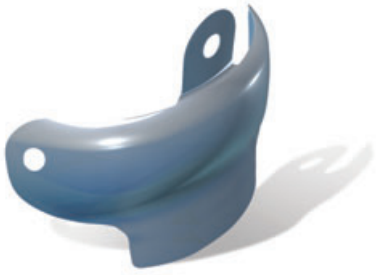


Figure 2: Curved V3 matrix band (available in sizes from 3.5mm up to 7.5mm) designed with a rounded gingival contour and with an occlusal marginal ridge contour.

Figure 3: Universal (green) and Narrow (yellow) V3 Separating Rings.

contour that routinely provide the clinician with an anatomically formed contact point, excellent marginal ridge contour and restorations that require minimal finishing (Figure 2).

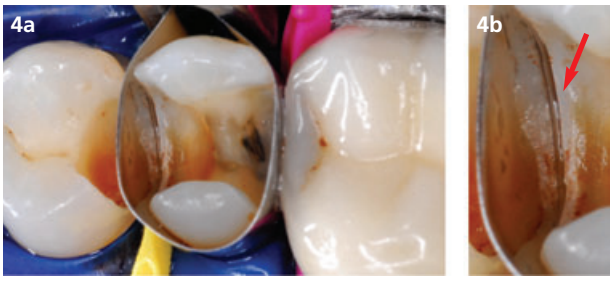
The V3 separating rings (Figure 3) are available in two different sizes, a universal (green) and a narrow ring (yellow) (for narrow embrasure spaces) fabricated from nickel titanium. The nickel titanium ring is partially covered with glass reinforced plastic tines that are V-shaped. The wide occlusal foot print of the plastic tines ensure excellent adaptation of the matrix band against the cavity margins while the V-shape tips allow for easy placement over the wedge. However, more important is the fact that these V-Shaped tines allow the operator to move, replace or add additional wedges if needed during the procedure to ensure proper adaptation of the matrix band at the gingival margin, without disassembling the matrix setup as it is the case with many other systems.

Another significant cause of failure of posterior composite resin restorations is secondary caries. Gap formation at the cavity margins can also be a result of polymerization shrinkage of the composite resin (Eick & Welch, 1986; Lutz, Krejci & Barbakow, 1991). According to Letzel (1989) marginal gaps can permit the ingress of bacteriogenic bacteria and oral fluids (Mejare, Mejare & Edwardson, 1979; Quist, 1980), resulting in the formation of secondary caries. It can also lead to post-operative sensitivity, staining at the margins (Ericksen & Pears, 1978).

The author is of the opinion that gap formation and subsequent secondary caries formation can also be a result of poor matrix management at the gingival margins of the cavity preparations. With poor matrix adaptation to the gingival margins of the preparation, crevicular fluid, blood, saliva or a combination of these fluids will contaminate the adjacent enamel, dentine or cementum. This can compromise the bonds strength of the bonding system to the remaining tooth structure in this critical area of the preparation. Figures 4a (magnification 5X) and 4b (magnification 15X) illustrate a clinical case after cavity preparation and matrix assemblage on an upper right second premolar. Note the poor matrix adaptation at the gingival cavity margin allowing crevicular fluid (arrow) to contaminate the cavity margin.

Figures 5a (magnification 5X) and 5b (magnification 15X) depict another clinical case after cavity preparation and matrix assemblage on an upper right first molar. Poor matrix adaptation at the gingival cavity margin allowed crevicular fluid and blood (arrow) from the sulcus area to contaminate the cavity margin.

It is important to note that with Class II posterior composite resin restorations the function of the wedge is not to provide tooth separation but to seal the matrix at the



Figures 4a (magnification 5X) and 4b (magnification 15X): Matrix assemblage on an upper right second premolar. Note the poor matrix adaptation at the gingival cavity margin allowing crevicular fluid (arrow) to contaminate the cavity margin.

Figure 5a (magnification 5X) and 5b (magnification 15X): Matrix assemblage on an upper right first molar. Poor matrix adaptation at the gingival cavity margin allowing crevicular fluid and blood (arrow) from the sulcus area to contaminate the cavity margin.

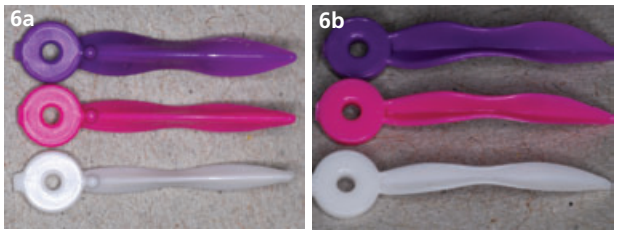


Figure 6a: Wave-Wedges (small, medium and large). Figure 6b: Inverted V-shape at the bottom to acccomodate the gingival tissue and also allow the wedges to be stacked on top of each other.

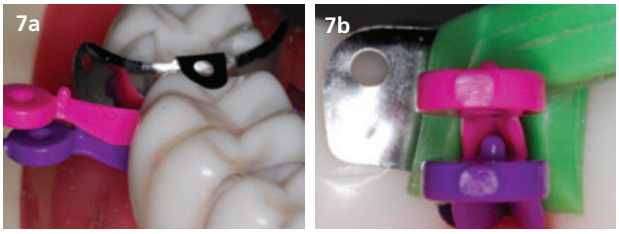


Figure 7a and b: Frontal and buccal view of Wave-Wedges stacked on top of each other.

gingival margin. The author prefers to use plastic wedges eg. Wedge Wands (Garrison Dental) or Wave-Wedges (Triodent).

The Wave-Wedges (Triodent) (Figure 6a) provide unsurpassed sealing capability at the ginigival margin. The wedges have an inverted V-shape (Figure 6b) at the bottom to acccomodate the gingival tissue and also allow the wedges to be stacked on top of each other (Figures 7a and b). It is also posiible to place one from buccal and one from palatal/ ligual aspect to increase the gingival seal. The wave shape of the wedge also allow for optimal approximation of the wedge when placed interproximally between two teeth ensuring a broad gingival seal by optimal adaptation of the interproximal space.

The interface between the gingival margin and the matrix band should be inspected under magnification (at least 10X) to ensure:

• Excellent adaptation between the gingival margin and the matrix band, ensuring the absence of any fluids penetrating between the matrix band and gingival margins. Figure 8a illustrates case where a Class II cavity preparation was done on an upper left second premolar. After matrix assemblage, and examination at 3X and 5X (Figure 8b) magnification the matrix adaptation at the gingival margin appeared to be satisfactory. However, under 15X magnification (Figure 8c), it was evident that the matrix adaptation was not as good as observed at lower magnification. Note the crevicular fluid (arrow) moving up in between the matrix band and ginigival cavity margin, that could compromise the bond strength of bonding systems to this gingival margin. After the matrix assemblage was changed Figure 8d demonstrates excellent adaptation between the gingival margin and matrix band(arrow), eliminating the presence of fluid contamination of the restorative margin and hopefully will ensure a more predictable long-term result.

• Adequate adaptation between the matrix band and the facial and lingual proximal margins. Figure 9 (magnification 8x) shows cavity preparation and matrix band assemblage on an upper first molar. Note the good matrix adaptation on the buccal proximal margin(asterisk), and very poor matrix adaptation on the palatal proximal margin (arrow). This poor matrix adaptation on the palatal proximal margin will lead to excess composite material in this area that will prolong finishing and polishing of the final restoration.

• Integrity of the gingival and proximal enamel margins.

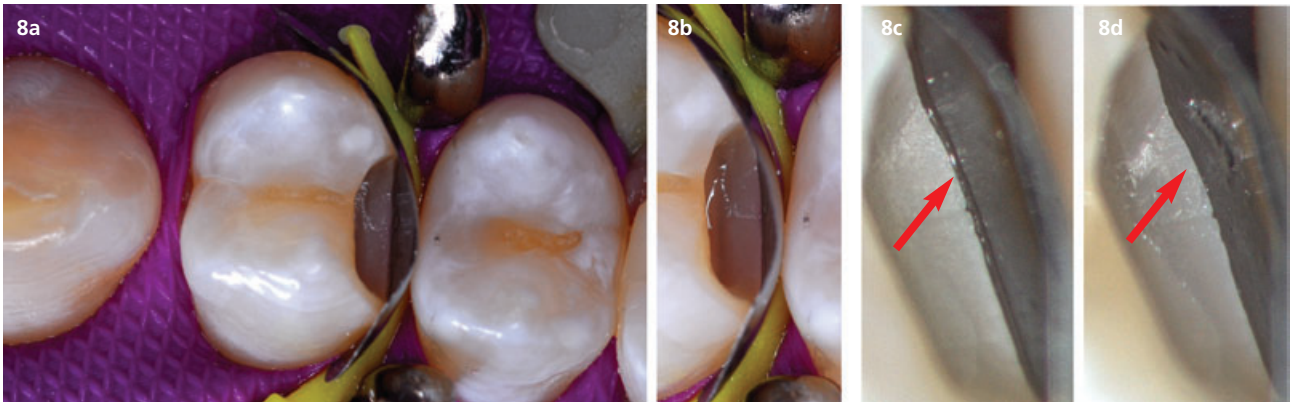


Figure 8a (magnification 5X) and 8b (magnification 5X): Class II cavity preparation on an upper left second premolar. After matrix assemblage, and examination the matrix adaptation at the gingival margin appeared to be satisfactory. Figure 8c (magnification 15X): Under high magnification it was evident that the matrix adaptation was not as good as observed at lower magnification. Note the crevicular fluid seeping in between the matrix band and gingival cavity margin(arrow). Fig 8d (magnification 15X): After the matrix assemblage was changed, excellent adaptation (arrow) between the gingival margin and matrix band was achieved.

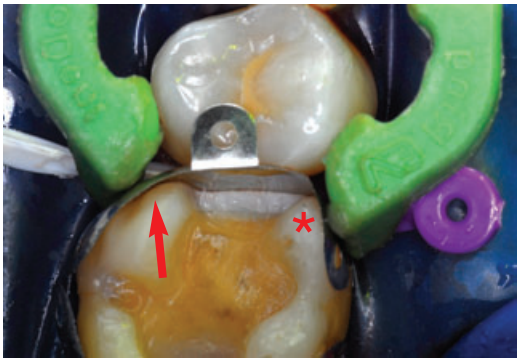


Figure 9 (magnification 8X): Matrix band assemblage on an upper first molar. Note the good matrix adaptation on the buccal proximal margin (asterisk), and very poor matrix adaptation on the palatal proximal margin (arrow).

Unsupported enamel often chips off when the clinician exerts force on the margins during placement of the wedge (gingival margin) or the separating rings (proximal margins).

Etching of Enamel and Dentine

Enamel bonding plays an important adjunctive role in the long-term retention of adhesive restorations, and recent work confirms the strength and stability of the etched enamel bond (Van Meerbeek et. al., 1994). Traditionally, etching enamel with approximately 30 - 60% phosphoric acid solution for 30 - 60 seconds and appropriate washing and drying give reasonable good enamel bond strength.

Dentine bonding systems can consist of a conditioner/ etchant, primer and adhesive. Acids or conditioners are applied to the dentine surface in order to remove the smear layer (amorphous layer of cutting debris and bacteria that is left on the dentine after cavity preparation according to Eick et. al.,1970) and concurrently decalcify the underlying intertubular dentine.

The extent of the dissolution depends on the type and concentration of the acid, as well as the viscosity and the exposure time of the etchant (Van Meerbeek et. al., 1992). The dentine may be extensively demineralised and weakened if the concentration of the acid is too high or if the exposure time is too long (Wang and Nakabayashi, 1991). The depth of dentine demineralisation has become an important issue in dentine bonding (Perdigão and Lopes, 2001). The incomplete penetration of bonding resin into the demineralised microporous collagen network could result in a delicate zone inside the hybrid layer and the unaltered dentine that could be susceptible to continuous degradation (Sano et. al., 1994) and microleakage (Walshaw and McComb, 1998). Therefore, it is recommended that dentine should not be conditioned/ etched for longer than 15 seconds (Walshaw and McComb, 1998).

When a dentinal surface is etched with an acid and copiously washed with water, the surface is demineralised for about 3-5 microns (Perdigão, 1995), leaving a collagen network behind. To allow effective penetration of the primer and adhesive into this collagen network the dentinal surface must not be overly dried - if this happens the collagen network will collapse, resulting in low bond strengths (Gwinnett, 1992).

Magnification during the etching of enamel and dentine can benefit the clinician in following ways:

- It was observed under magnification that there is often incomplete removal of acid etchants at this margin. It is very common in mesial interproximal box preparations of premolar and molar teeth due to the limited perpendicular access of the three-one syringe to this part of the preparation. Leaving phosphoric acid and its by-products on the gingival margin prior to the application of the bonding resin system might influence the bond strength. It can lead to over-etching of the dentine in this area or to dilution and contamination of the bonding system components. Figure 10 demonstrates a case after cavity preparation, matrix assemblage and etching with 35% phosphoric acid. Figure 10a (magnification 3x) shows the result after rinsing of the phosphoric acid with water for 10 seconds. Under higher

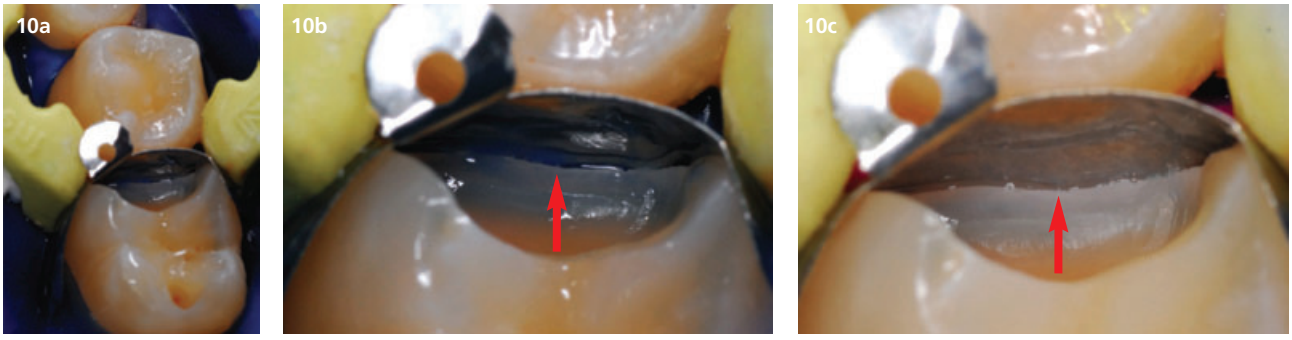


Figure 10a (magnification 3X): Clinical view after matrix assemblage and etching with 35% phosphoric acid on a lower right first molar. Figure 10b (magnification 10X): Higher magnification showed that not all the phosphoric acid (arrow) was rinsed away with water. Figure 10c (magnification 10X): Visible moisture (arrow) at the gingival margin due to poor matrix band adaptation at the gingival margin after removal of the phosphoric acid.

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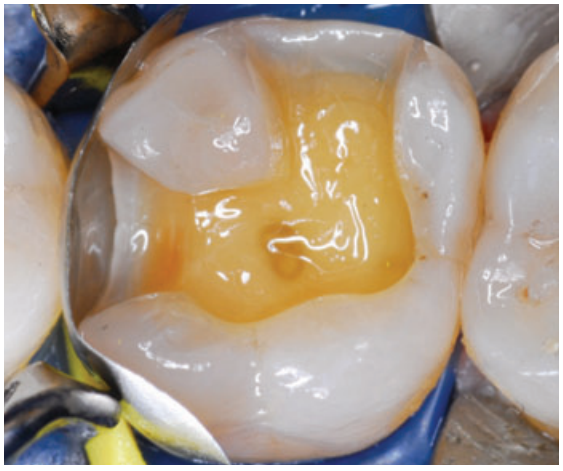

Figure 11 (magnification 10X): Magnified view of a cavity preparation and matrix assemblage on an upper right first molar. Note the shiny appearance of the dentine after several applications of primer and evaporation of the solvent.

magnification (10x) (Figure 10b) it was evident that not all the phosphoric acid was rinsed away with water. Failure to remove this acid properly before application of a dentine bonding system can severely compromise the bond strength in the proximal box preparation. In the author's experience it is more prevalent in cases where there is poor matrix adaptation between the matrix band and the gingival margin. Figure 10c (magnification 10x) also illustrates visible moisture at the gingival margin due to poor matrix band adaptation at the gingival margin after removal of the phosphoric acid.

• Regulating the amount of water evaporation after etching to create a dry, moist or wet dentine surface (according to the bonding system used) and a dry, frosty white etched enamel surface.

Application of the Primer or Primer/Resin Combinations

The modern trend is to saturate the exposed dentine and enamel with primer (multi-component systems) or primer/resin (single component systems) for approximately 15-20 seconds. After the recommended waiting time, the surface is lightly air-dried to volatilise the solvent of the primer/resin. According to Walshaw and McComb (1998), any solvent remaining on a primed dentine surface will prevent complete adaptation of bonding resin.

The primed surface should appear shiny. If it has a matt finish it probably indicates that the dentinal tubules are not properly sealed and the application of a second coat is advisable. Figure 11 (magnification 10x) shows a magnified view of a cavity preparation and matrix assemblage on an upper right first molar. Note the shiny appearance of the dentine after several applications of primer and evaporation of the solvent, prior to light-curing.

Application of the Bonding Resin (Multi-component systems only)

The adhesive resin must be placed in an even, thin layer without the need to air-thin. Air thinning of the bonding resin can lower the bond strength and cause surface defects (Hilton and Schwartz, 1995). The optimal thickness for adhesive resin layers is about 100µm (Moon and Chang, 1992) and when placed in such thick layer, the resin may act as a stress-relaxation buffer due to its high elasticity (Van Meerbeek et. al., 2001). After application the adhesive must be light-cured for 10 - 15 seconds for direct restorative techniques.

The benefits of magnification during primer/resin application include:

• Ensuring that all the etched dentine surfaces are adequately covered with the primer or primer/resin solutions. Assessing the quality of the primed or primer/resin surface - magnification allows the clinician to identify areas that does not appear shiny. Primer or primer/resin solutions can then be reapplied to these areas before application of the bonding resin or composite resin material. Figure 12 illustrates a clinical case of a MOD preparation on an upper left second premolar. Examination under magnification (10X) revealed failure to coat the dentine in the mesial proximal box (arrow) adequately with primer/resin.

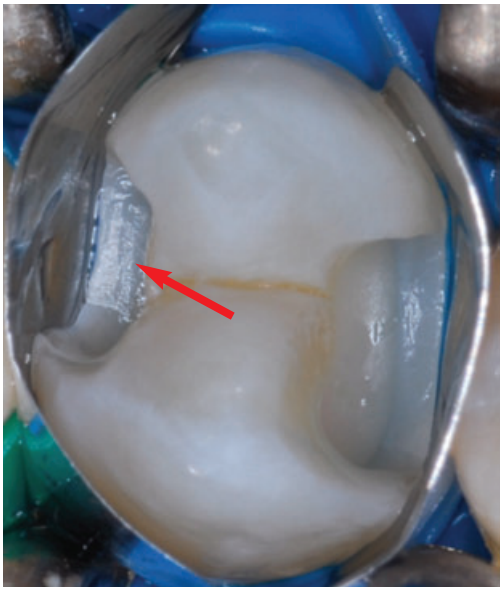

Figure 12 (magnification 10X): MOD cavity preparation with matrix band assemblage on an upper left second premolar. This magnified view revealed failure to coat the dentine in the mesial proximal box (arrow) adequately with primer / resin.

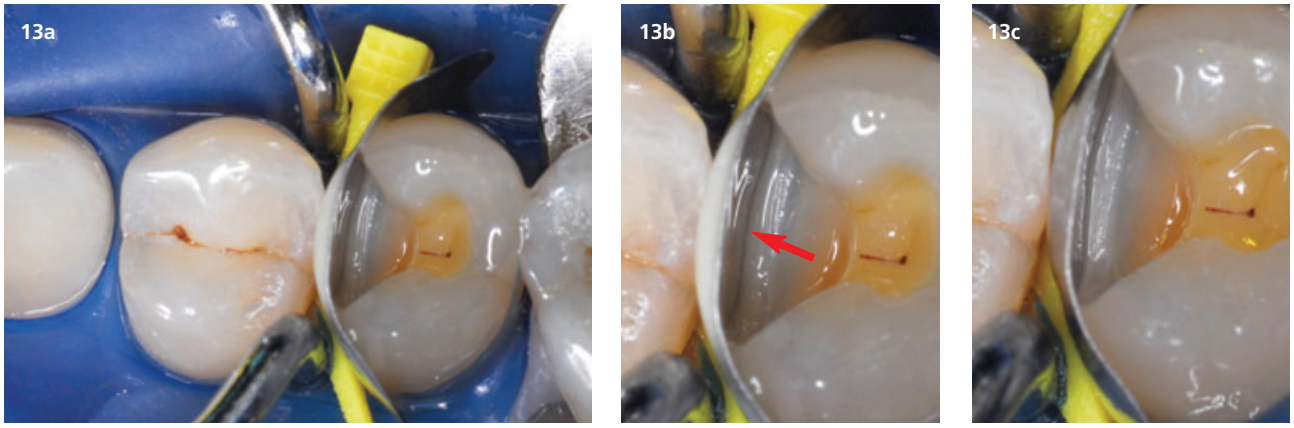

Figure 13a (magnification 3X): Clinical case where bonding agent was applied and air-thinned to a Class II cavity preparation on an upper right second premolar. Figure 13b (magnification 10X): Evidence of pooling of an excessive amount of bonding resin (arrow) at the junction between the gingival margin and matrix band. Figure 13c (magnification 10X): Final result after careful removal of the excessive amount of resin.

• Ensuring that most of the solvent in the bonding system is evaporated and eliminating excessive amounts of primer solution pooling up in areas that were not reached during the evaporation phase. Leaving excessive amounts of solvent in the mixture can also lead to incomplete polymerization of the bonding resin. Figure 13a (magnification 3x) demonstrates a clinical case where bonding agent was applied and air-thinned to a Class II cavity preparation on an upper right second premolar. On 10X magnification (Figure 13b), there was clear evidence of pooling of an excessive amount of bonding resin at the junction between the gingival margin and matrix band. Figure 13c (magnification 10x) shows the final result after careful removal of the excessive amount of resin.

Composite Insertion Techniques

The author prefers to use a modified centripetal build-up technique for Class II restorations as proposed by Bichacho (1994). With this technique the lost tooth structure is replaced from the periphery towards the center of the cavity, ensuring excellent marginal adaptation at the gingival margin. Effectively, a Class II preparation is transformed into a Class I preparation.

The first step is to re-establish the proximal wall. A small drop of flowable composite is dispensed under magnification on the interface between the matrix band and gingival margin (Figure 14a). A regular viscosity composite resin (Enamel shade) is then dispensed onto the uncured flowable material (Figure 14b). The material is condensed towards the gingival margin and towards the matrix band with a composite instrument (Sculp Condensor, Coltène Whaledent). This layer of composite material is manipulated until it forms a thin rim of material (1-1.5mm) extending from the buccal to the lingual proximal margin (Figure 14c).

Excess composite material at the occlusal surface is removed with a sharp probe or composite instrument (Sculp Carver, Coltène Whaledent) (Figure 14d) - ensuring the formation of an anatomically contoured marginal ridge. The height of the marginal ridge should correspond with the marginal ridge height of the adjacent tooth, unless otherwise observed during the initial inspection of the tooth prior to the restorative phase. Overcontouring is one of the most common placement errors with direct posterior composite restorations (Morgan, 2004). Overcontouring of the marginal ridge often leads to subsequent overcontouring of the entire restoration, resulting in excessive finishing and polishing procedures. This envelope of composite material is light-cured for 40 seconds.

At this stage, it is advisable to remove the separating ring and check if a tight contact was established (Figure 15a) (magnification 5x). This is done with an attempt to pull on the sectional matrix band. If the band is firmly wedged between the composite resin and the adjacent tooth, it generally confirms the establishment of an adequate contact. However, if the band can be removed with light force, the contact is inadequate, and the proximal wall should be removed and replaced before proceeding to the next step. The ends of the sectional matrix band are reflected back towards the adjacent tooth (Figure 15a) (magnification 5x) to protect the adjacent tooth and the newly established proximal contact against possible iatrogenic damage that might occur during finishing procedures at a later stage. In addition, it also allows the clinician full view and access to the occlusal surface during placement of composite resin

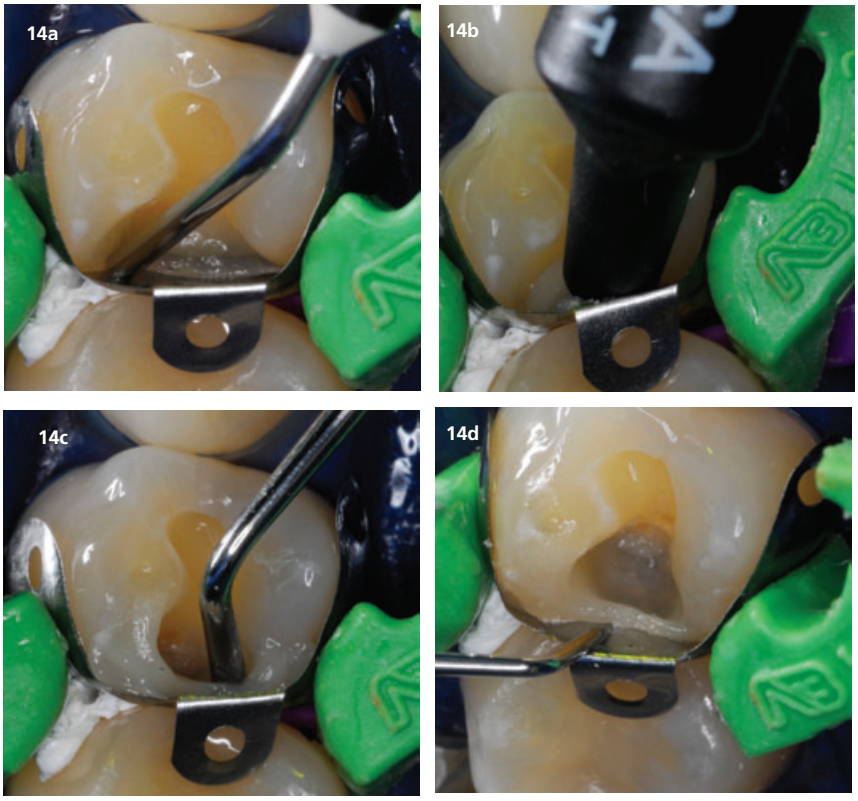

Figure 14 a. Small drop of flowable composite is dispensed under magnification on the interface between the matrix band and gingival margin. Figure 14b. Regular viscosity composite resin (transparent or translucent shade) is then dispensed onto the uncured flowable material. Figure 14c. Composite material is condensed towards the gingival margin and towards the matrix band with a composite condenser (Sculp Condensor, Coltène Whaledent) until it forms a thin rim of material (1-1.5mm) extending from the buccal to the lingual proximal margin. Figure 14d. Excess composite material at the occlusal surface is removed with a sharp probe or composite instrument – (Sculp Carver, Coltène Whaledent) ensuring the formation of an anatomically contoured marginal ridge.

into the remaining Class I restoration.

After successful creation of the translucent envelope, a horizontal layer of dentine shade composite material (1.5-2mm) is placed into the remaining Class I cavity outline (Figure 15b) (magnification 5x), to within 1-1.5mm of the cavosurface margin. This layer is light-cured for 20 seconds. An oblique layer of enamel shade material is packed from the surface of the horizontal layer of dentine material up to the external buccal cavity margin. A composite instrument (Sculp Condensor, Coltène Whaledent) is used to shape the resin and to define anatomy using the remaining cuspal inclines as an indicator. After light-curing this layer for 10 seconds, a second oblique layer, extending from the margin formed between the horizontal dentine and oblique enamel material is packed towards the external lingual cavity margin, using the same method. Before this layer is light-cured for 20 seconds, occlusal characterization is done with a sharp composite instrument (Figure 15c) (magnification 5x). The tooth is covered with a thin layer of glycerine gel and light-cured for 20 seconds. This step ensures the transformation of the oxygen inhibit layer to a smooth, completely cured surface that will eliminate clogging of uncured resin into the finishing instruments. The restoration is then fully cured from different angles (buccal, lingual and occlusal) for a total of 60 seconds.

If any excess composite material is visible at the margins of the buccal and lingual proximal margins, it can be removed under magnification with a thin carbide bur. A series of finishing disks (OptiDisc, Kerr) (Figure 15d) (magnification 5x) can be used to contour the marginal ridge and polish the proximal areas. The sectional matrix band is still protecting the interproximal contact against iatrogenic damage during this finishing step and should only be removed once the operator is satisfied with the final contour of the proximal wall.

Rubber dam is removed and occlusal adjustments are made where necessary. It is recommended that accessible margins must be sealed with a surface sealant to reseal any

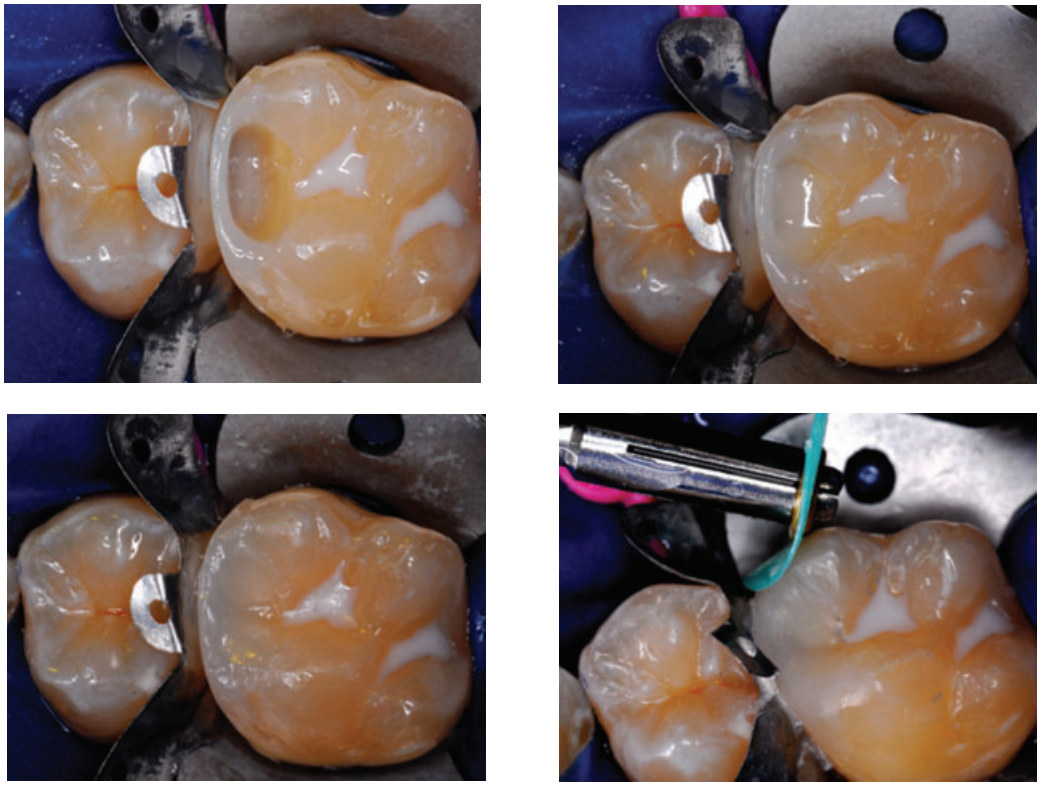

Figure 15a (magnification 5X): Ends of the sectional matrix band is reflected back towards the adjacent tooth. The band will still protect the newly established contact point against possible iatrogenic damage that might occur during finishing and polishing. Figure 15b (magnification 5X): Horizontal layer of dentine shade composite material (1.5 - 2mm) is placed into the remaining Class I cavity outline. Figure 15c (magnification 5X): Oblique layer of translucent enamel material is packed from the surface of the horizontal layer of dentine material up to the external buccal cavity margin and light-cured for 10 seconds. A second oblique layer, extending from the margin formed between the horizontal dentine and oblique enamel material is packed towards the external lingual cavity margin. Figure 15d (magnification 5X): Excess composite material at the cavity margins is removed under magnification with a small medium grit polishing disc (OptiDisc, Kerr). Note that the sectional matrix band is protecting the interproximal contact during this finishing step.

microcracks that might have been caused by trauma of finishing procedures. Application of a surface sealant can reduce the wear rate of posterior composite restorations (Dickenson & Leinfelder, 1993). Clinically, the restoration margins are etched with phosphoric acid, rinsed and dried before a surface sealant (Fortify, Bisco Dental Products or Permaseal, Ultradent) is applied and adequately light-cured. These products also produce an oxygen inhibited layer and should be cured through a glycerine gel. Alternatively, BisCover (Bisco Dental Products), an acrylate based light-cured surface resin that does not produce a oxygen-inhibited layer, can be used. According to Morgan (2004) it can either be placed as a surface sealant after acid etching to fill any micro-cracks or it can even be placed on the enamel layer of partially cured composite resin (instead of glycerine gel) to interact with the oxygen-inhibited layer and prevent its formation.

The advantages of packing the composite material into the cavity preparation under magnification include:

- It is easier to pack a thin even layer of material against the matrix band and to ensure good adaptation of the composite material to the cavity walls
- Packing of the oblique layers of composite right up to the cavity margins without any excess material. This will minimize the finishing procedure and provide the patient with a restoration with improved physical and mechanical characteristics (Terry, 2005). Duke (1993) demonstrated that a reduction in finishing results in less damage to the composite material, In addition, the restoration will demonstrate less micro-fracture, improved wear and clinical performance.
- Improved precision when any excess of material is removed with rotary instruments.
- Identification of any cracks or microscopic porosities that might have formed during the polymerization or finishing procedures. It is recommended that accessible margins be etched with phosphoric acid, rinsed and dried, before a surface sealant (Fortify, Bisco Dental Products or Permaseal,

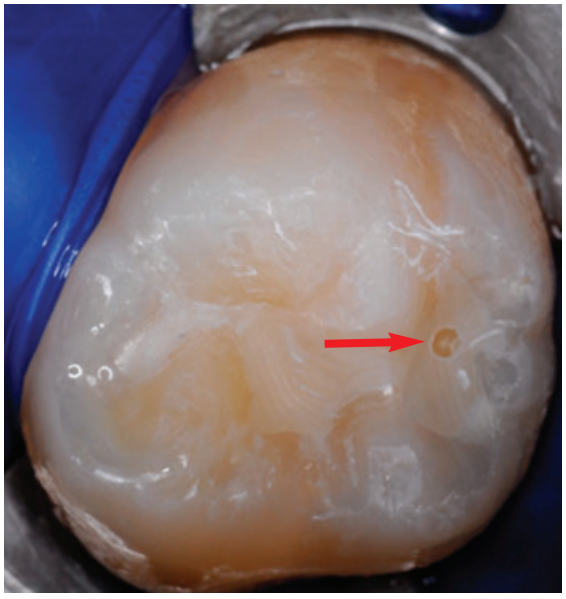

Figure 16 (magnification 10X): Class I composite restoration on an upper right first molar. Note the porosity (arrow) in the composite material that was evident after examination under magnification.

Ultradent) is applied into the defective areas and adequately light-cured. These products also produce an oxygen inhibited layer and should be cured through a glycerine gel. Application of a surface sealant can reduce the wear rate of posterior composite restorations (Dickenson & Leinfelder, 1993). Figure 16 (magnification 10x) illustrates the final result after placement of a Class I composite restoration on an upper right first molar. Note the porosity (arrow) in the composite that was evident after finishing of the restoration with a carbide bur.

Conclusion

This paper has described innovative materials and techniques that can be used clinically to improve the long-term success of direct posterior composite restorations. The use of magnification is highly beneficial in eliminating many of the procedural errors that can occur during the restorative phase, thereby improving the overall quality of the bonded restoration. Part 2 of this paper will discuss the pre-operative examination, isolation of the working field, protection of the adjacent tooth as well as the benefit of magnification during cavity preparation.

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Restoring severely discoloured anterior teeth using minimally invasive procedures

Daniel Edelhoff[1] and Oliver Brix[2]

Introduction

Endodontically treated incisors may entail serious esthetic deficiencies as a result of severe discolouration and present a challenge to the restorative team. The objective of the treatment is to reconstruct the biomechanical and optical properties of the affected teeth, at the expense of as little natural dental tissue as possible. By following a clearly coordinated procedure, the treatment team may achieve satisfactory results with an internal bleaching method, an adhesive post build-up and a preparation technique that suits the requirements of the restorative material. The invasiveness of this approach is considerably reduced as compared with conventional restorative techniques.

This article discusses the rehabilitation of two upper central incisors by placing fibre-reinforced composite posts, using build-up materials and subsequently restoring the teeth with 360° veneers made from lithium disilicate ceramic (LS_2).

Initial situation

A 28-year-old male patient came to the practice and expressed the wish to have his endodontically treated and severely discoloured upper central incisors restored. He said that he had not experienced any problems since the resection of the root some years previously; however, he was dissatisfied with the impaired esthetic appearance caused by the affected teeth (Figures 1 to 3).

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Figure 1: The pronounced discolouration and the inadequate tooth position of the upper central incisors impaired the esthetic appearance.

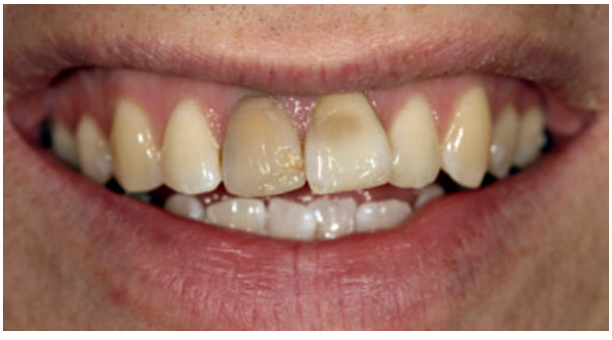

Figure 2: The severe discolouration of tooth 11 also caused a discolouration of the marginal gingival area.

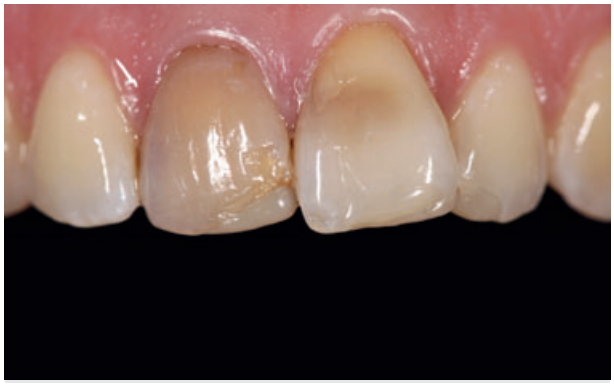

Figure 3: The asymmetrical tooth axes of the central incisors are clearly visible.

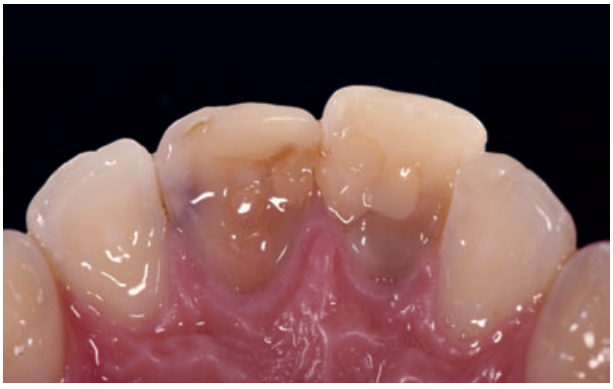

Figure 4: Leaking composite restorations and secondary caries in the endodontically treated teeth 11 and 21.

The clinical and radiological evaluations revealed tight and properly executed root canal obturations in teeth 11 and 21. There were no signs indicating the presence of root canal posts, but the extensive composite restorations in both teeth were leaking and showed secondary caries (Figure 4). At the time of the clinical evaluation, the restorations were already five years old. The specific challenges facing the treatment team was the patient's wish to have the esthetic appearance of his teeth restored in a timely fashion. The patient required that his natural tooth shade and position be restored and, to the extent possible, that the remaining tooth structure be stabilized in the long term.

Treatment planning

Before we proceeded to planning the permanent restoration, the inadequate fillings of the anterior teeth as well as the secondary caries were removed. This allowed us to assess the extent to which the teeth had been damaged. In addition, a possible contamination of the two root canals with microorganisms – resulting from the inadequate fillings which had been in place for years – had to be ruled out.

Both root canal fillings had been tightly sealed at the cemento-enamel junction with separate fillings. The canals therefore did not have to be re-opened. Internal bleaching of the crown portions of both teeth using the walking bleach technique was planned.

After an initial technical and clinical evaluation, the following treatment plan was determined: First, the tooth position and proportions should be corrected by means of an analytic wax-up. The brightness of the affected teeth was then to be adjusted by internal bleaching to match the brightness of the neighbouring teeth during a preliminary

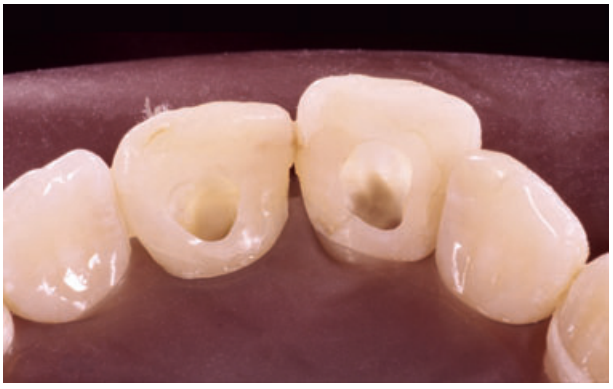

Figure 5: The root canal fillings were checked prior to the internal bleaching procedure, and the cemento-enamel junction was additionally sealed. The cavities were now ready for the application of the bleaching agent.

treatment phase. Given the extensive lesion, we opted for a direct adhesive build-up after endodontic treatment with cemented fibre-reinforced composite posts. For the final restoration of the severely destroyed anterior teeth, we decided to use 360° veneers based on a lithium disilicate material. In order to achieve an optimum esthetic outcome, the veneers were to be fabricated in the cut-back technique.

Preliminary treatment and preparation

After the coronal pulp chamber of the two incisors had been cleaned, an additional seal was placed at the cemento-enamel junction using a small amount of phosphate cement. This measure ensured that the bleaching agent which would be applied later did not diffuse into these sensitive areas (Figure 5). For the internal bleaching, a mixture of sodium perborate powder and distilled water was applied using the walking bleach method. The palatal access to the coronal

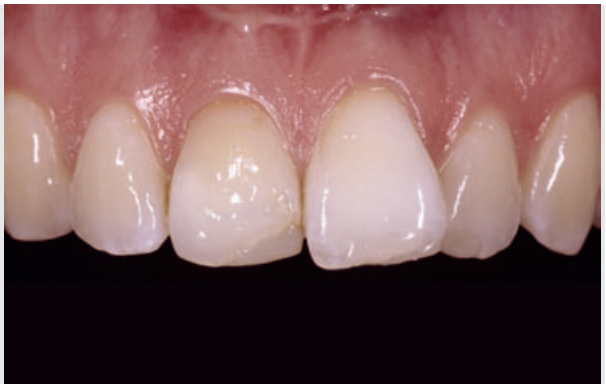

Figure 6: Two weeks later: The severe discolourations were almost entirely removed by the internal bleaching treatment.

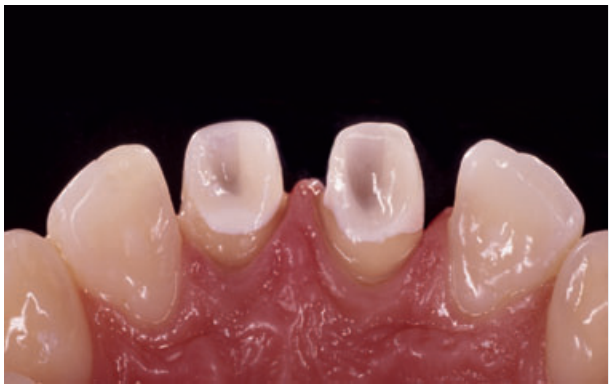

Figure 7: The built-up and prepared incisors. Given the severe degree of destruction, adhesively cemented fibre-reinforced composite posts combined with mouldable composite materials were used.

pulp chamber was sealed with cotton pellets soaked in bonding agent (Heliobond) and a low-viscosity composite (Tetric EvoFlow®). The next appointment was scheduled one week later. The desired tooth shade had not yet been achieved, and therefore fresh bleaching agent was applied. After another week with the bleaching agent in place, a satisfactory brightness value was observed on both abutment teeth (Figure 6). A calcium hydroxide preparation (CalciPure®) was inserted into the pulp chamber and left in place for a week in order to neutralize the bleaching agent.

After the neutralization phase, we proceeded to the post-endodontic build-up of the abutment teeth. For this purpose, the coronal sealing of the root canal fillings was removed and standardized holes for the fibre-reinforced composite posts (FRC posts) were drilled. The posts were luted with Variolink® II (dual-curing, low viscosity, shade: white-opaque) and a multi-step adhesive (Syntac®). After the posts had been covered with a low-viscosity composite (Tetric EvoFlow), a bright, highly filled viscous composite (Tetric EvoCeram®, Bleach XL) was applied to create the direct build-up (Figure 7). A high-power curing light (bluephase® G2 with > 1,000 mW/cm2) was used for the final polymerization of the cementation and buildup materials. A diagnostic pattern was employed for the minimally invasive preparation. This template was fabricated on the basis of the wax-up and contained all information relating to the correction of the tooth position and the outer contour of the final restoration.

Temporization and fabrication of the final veneers

The diagnostic template was also used for creating the direct veneer temporaries. The temporary restorations could thus be fabricated in a fairly straightforward manner using a Bis-GMA-based temporary material (Telio® C&B, A2). A bonding agent (Heliobond) was applied to the finished, non-etched preparation surfaces and to the inner side of the temporaries and light-cured after removal of excess material.

After a four-week evaluation phase of the tooth shape and position, which both were determined by the wax-up and transferred to the temporaries, a precision impression of the prepared teeth and an impression of the antagonist jaw were taken. This information was sent to the laboratory together with the facebow, the registration of the jaw relation and an image of the prepared abutment teeth. The image showing the preparations helped the laboratory to assess the required degree of opacity for the framework structure. Given the different levels of translucency, the different buildups of the abutment teeth and to ensure an improved masking capability in case of a relapse of the discolouration, the treatment team chose to use press

Figure 8: Lithium disilicate-based 360° veneers made of IPS e.max Press. In order to better mask the dental structure with a minimum layer thickness, an MO ingot was selected.

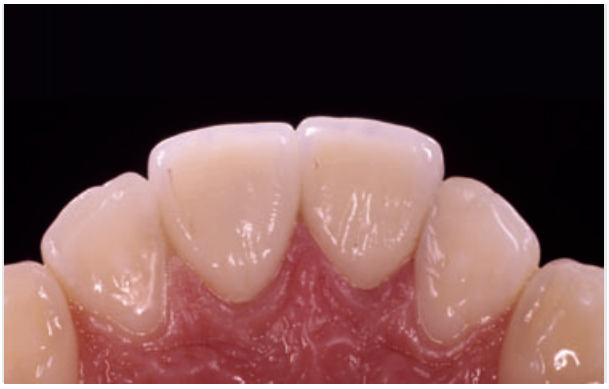

Figure 9: The optimum masking of the extensively built-up abutment teeth achieved by an MO ingot coping and a try-in paste in the shade white-opaque became evident already during the try-in of the veneers.

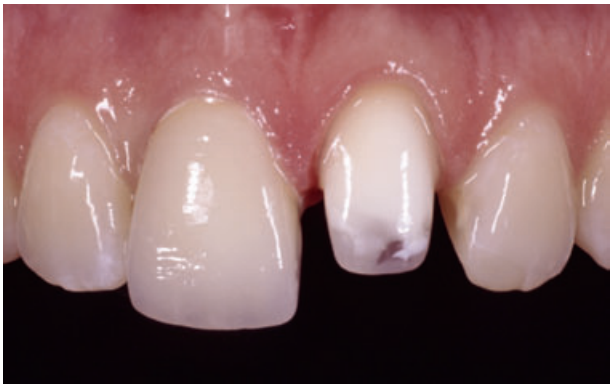

Figure 10: Frontal view of the veneers during try-in. The use of lithium disilicate as the basis of the restoration ensured a homogeneous appearance regardless of the substructure.

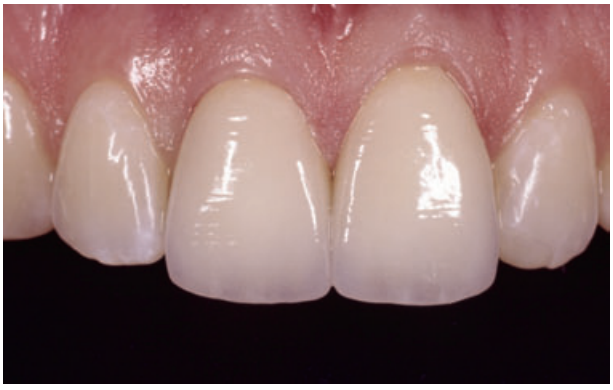

Figure 11: The 360° veneers were seated with the luting cement that corresponded to the try-in paste used; a multi-step dentin adhesive system was used. Thus, an excellent esthetic outcome could be achieved reliably and predictably.

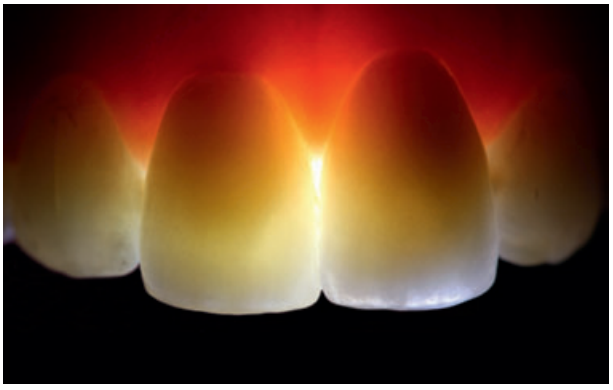

Figure 12: The restorations in transmitted light. By combining translucent build-up materials and glass-ceramic veneers, a light transmission that matches the properties of natural teeth was achieved.

ceramic ingots with a medium opacity level in shade 0 (MO 0). The IPS e.max® Press frameworks were veneered with the IPS e.max® Ceram veneering ceramic in the shade A2 (Figure 8).

Try-in and seating

After removal of the temporary restorations, residues of the bonding agent were removed with cleaning brushes and a fluoride-free cleaning paste. In order to check the shape and shade of the veneers in the patient's mouth, the restorations were tried in with a shaded glycerine gel (Try-in Paste, Variolink II, white-opaque). A perfect masking of the abutment teeth was already achieved at this stage and the resulting situation showed a harmonious appearance regardless of the substructure (Figures 9 and 10).

The inner aspects of the glass-ceramic veneers were etched with a hydrofluoric acid gel (< 5% IPS® Ceramic Etching Gel) for 20 seconds. Subsequently, a bonding agent (Monobond Plus) was applied. Only the multi-step dentin adhesive system Syntac was applied to the tooth. The restorations were luted into place with the Variolink II system (white-opaque) (Figure 11).

Conclusion

A light transmission which corresponds to that displayed by natural teeth was achieved by using translucent build-up materials in conjunction with glass-ceramic lithium disilicate veneers (Figure 12). The final outcome with regard to

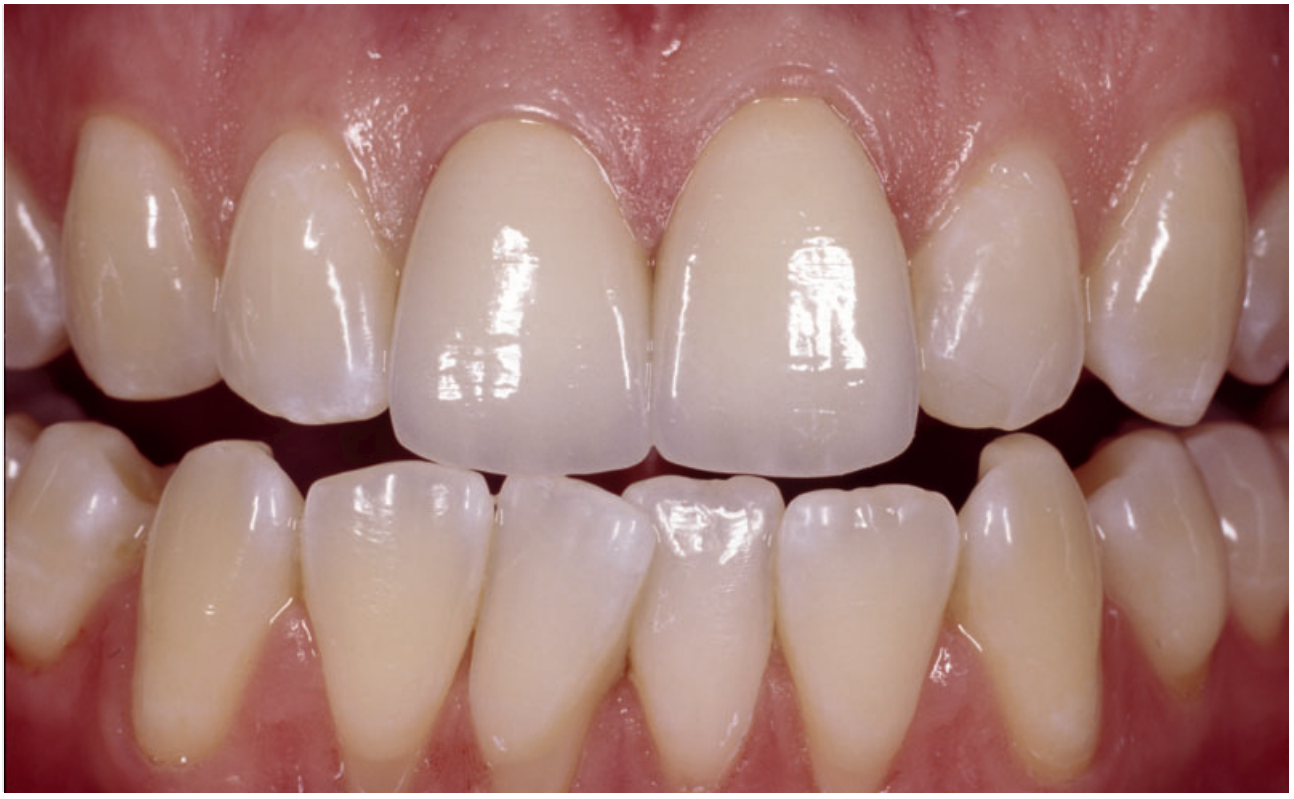

Figure 13: Postoperative view with mandible in protrusion. The final check of the functional and esthetic parameters was satisfactory. The tooth shade excellently matched the adjacent teeth.

Figure 14: Portrait image of the final outcome: The discolourations were removed, the tooth position corrected and the tooth proportions adjusted (for comparison, see Figures 1 and 2).

functional and esthetic parameters was found to be very satisfactory at the final evaluation. The tooth shade was in perfect harmony with the surrounding dentition. In addition to removing the severe discolouration of the hard and soft tissues, we were able to correct the tooth position and adjust the tooth proportions (Figure 13). The patient was fully satisfied with the esthetically pleasing outcome and did not experience any phonetic problems resulting from the correction of the tooth position (Figure 14).

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Case Report on the use of bone level implants in an esthetically demanding case

Paul van Zyl and Gerrit Wyma

Introduction

Since the introduction of Straumann® Bone Level implants to the market, esthetically challenging cases can now be managed where Straumann® Tissue Level implants were previously contra-indicated. The importance of the correct three dimensional surgical placement of implants to achieve acceptable clinical and esthetic results is well documented.[1] Limited interdental space and loss of buccal bone volume, especially where two or more teeth have been lost, have proven to be challenging esthetic cases. The bone volume can be preserved after extraction, or deficient areas can be predictably augmented by means of procedures using autogenous bone, with or without synthetic bone graft substitutes such as Straumann® BoneCeramic.[2, 3] While limited interdental space cannot be changed, the use of narrower platform implants emerging from the level of the bone has proved to produce predictable esthetic results.

Case Presentation

In the following case, a 30 year old male lost his two central incisors as a result of an traumatic incident. He presented with a removable plastic partial denture in position, replacing these two teeth. (Figures 1,2,3). His lower right central incisor was also devitalized during this incident, with subsequent discoloration and the development of a

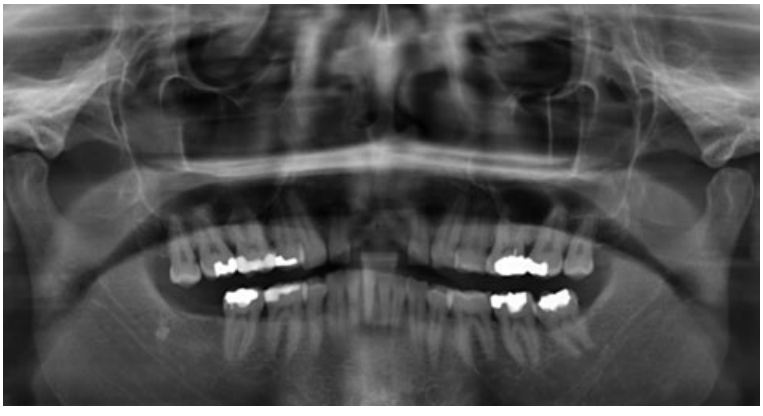

Figure 1: Pre operative panoramic xray.

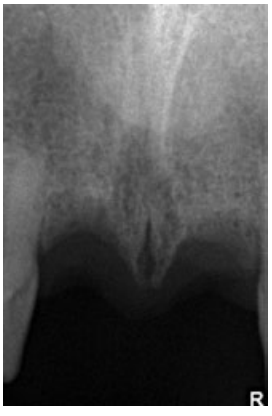

Figure 2: Intra-oral radiogragh, note the preservation of the inter dental bone spike 11/21.

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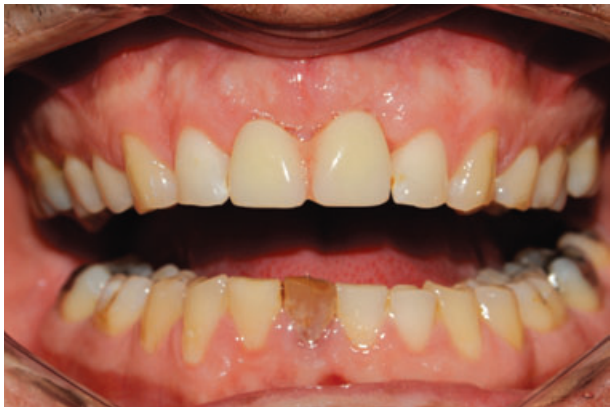


Figure 3: Pre operative presentation with the socket fit plastic partial denture in position.

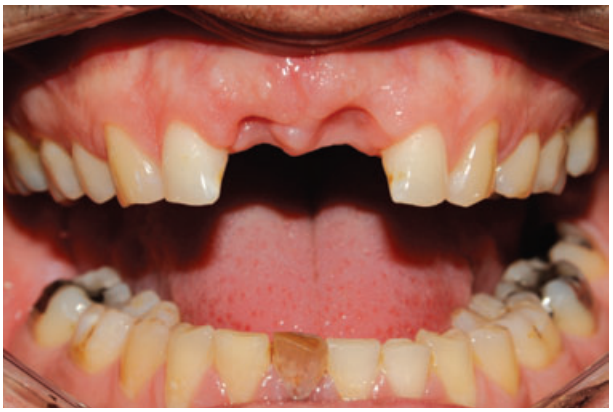


Figure 4: Pre operative situation, note the preservation of the papillae between 11/21.

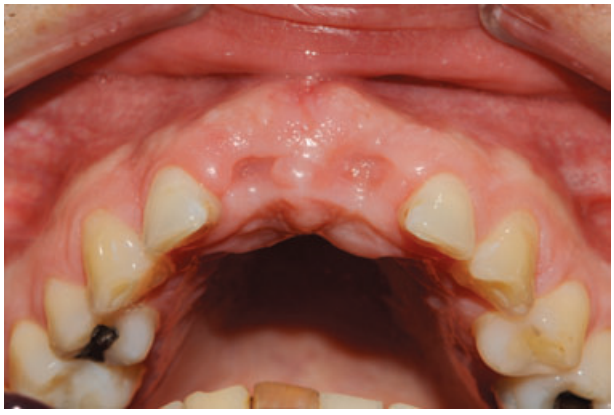


Figure 5: Inter dental space measured 14,6 mm, note the deficient buccal bone volume.

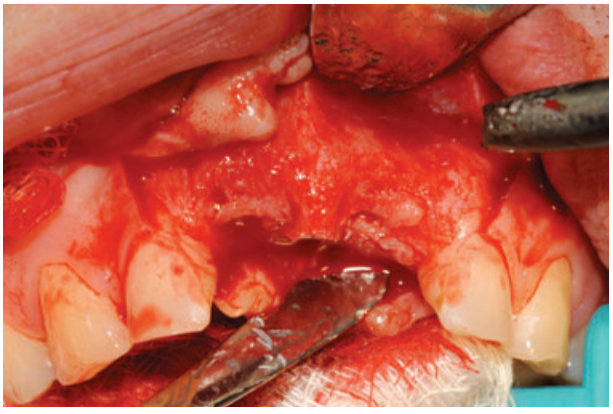


Figure 6: Full thickness flap with vertical relief incisions from the center of the adjacent lateral incisors.

periapical radiolucent lesion. The ridge contour seemed to be well preserved and the interdental space measured 14.6.mm. The previous interdental papilla was also well preserved. (Figures 4, 5) A decision was made to place two adjacent 12 mm, 4.1mm Regular Crossfit™ (RC) Straumann® Bone Level Implants. (SLActive).

Surgery

A full thickness, with two vertical incisions flap, with a broad base was made (Figure 6) and the pilot drill osteotomies were done to determine parallelism (Figure 7). The implants were planned in a palatal position (Figure 8) to preserve the buccal bone plate and allow screw retained

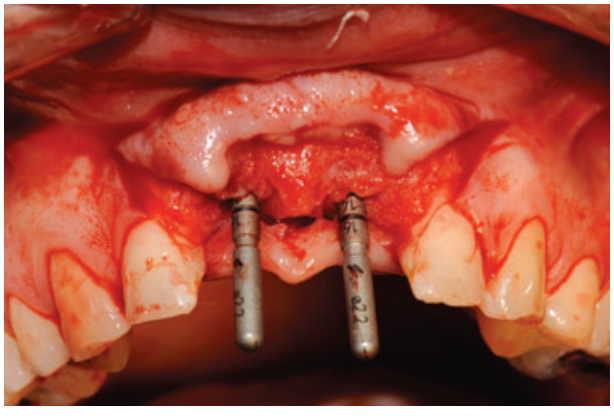


Figure 7: Pilot drills showing parallelism and distance between implants, as well as adjacent teeth.

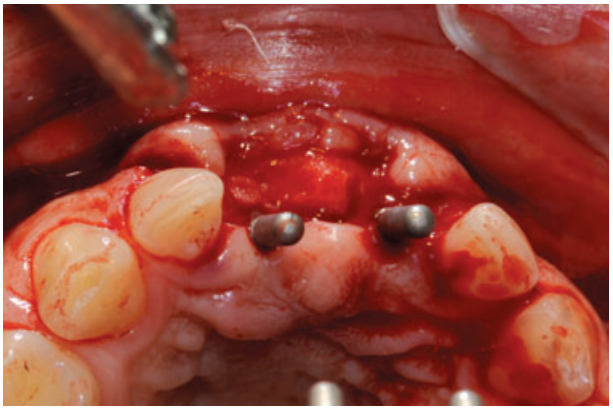


Figure 8: Palatal positioning of the implants.

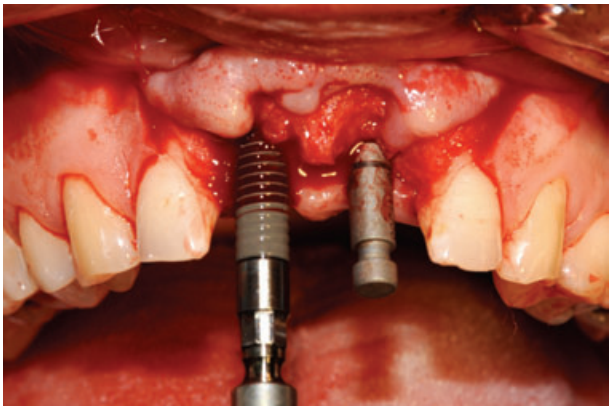


Figure 9: 12mm length, 4.1mm diameter Straumann® BoneLevel™ with SLActive surface implants were inserted. Note the shiny wet surface of the implant.

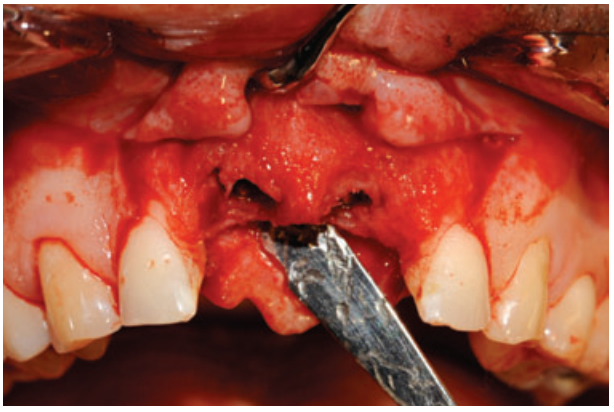


Figure 10: Note the depth of implant placement, subcrestal, 3,5mm below adjacent CEJ's.

restorations with a predictable esthetic outcome. After continuing through the drill sequence the implants were inserted (Figure 9). Note the depth of placement of the implants, 3,5mm below the adjacent cemento-enamel junctions (Figure 10).

With the 3 mm healing caps in position (Figure 11), autogenous bone collected in a bone trap was used to additionally augment the buccal bone volume and contour. The bone trap was connected to a separate suction, used only during the drilling of the osteotomies (Figures 12a and b). This was covered with a collagen membrane (Figure 13) before wound closure with polylactic acid sutures

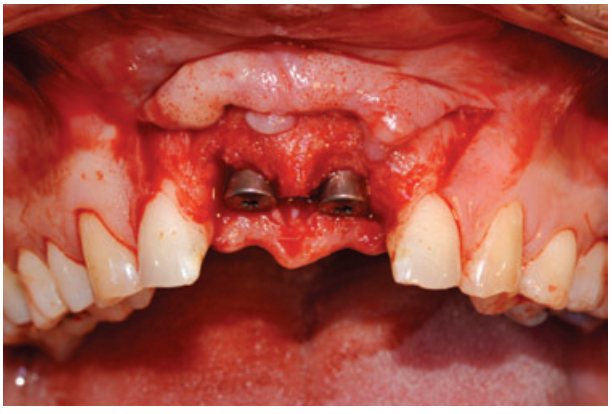


Figure 11: 3mm healing caps in position.

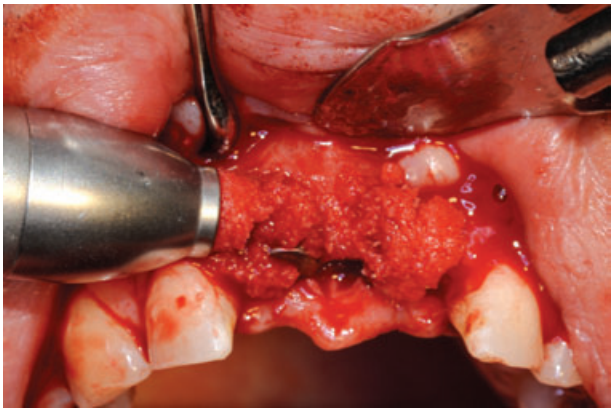


Figure 12a and b: Autogenous bone harvested with bone trap placed bucally to enhance buccal volume.

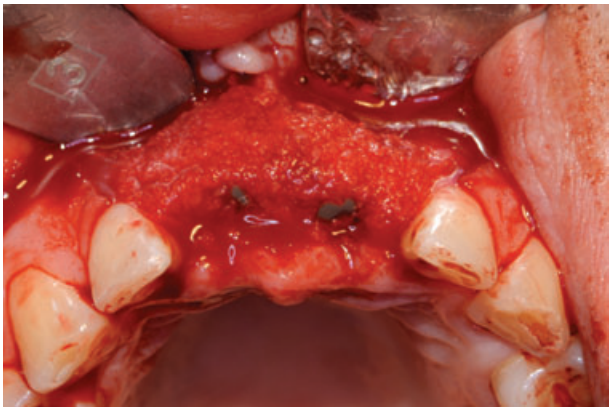


Figure 12b

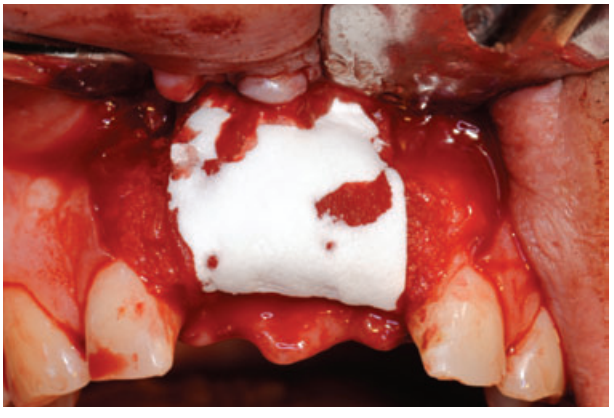
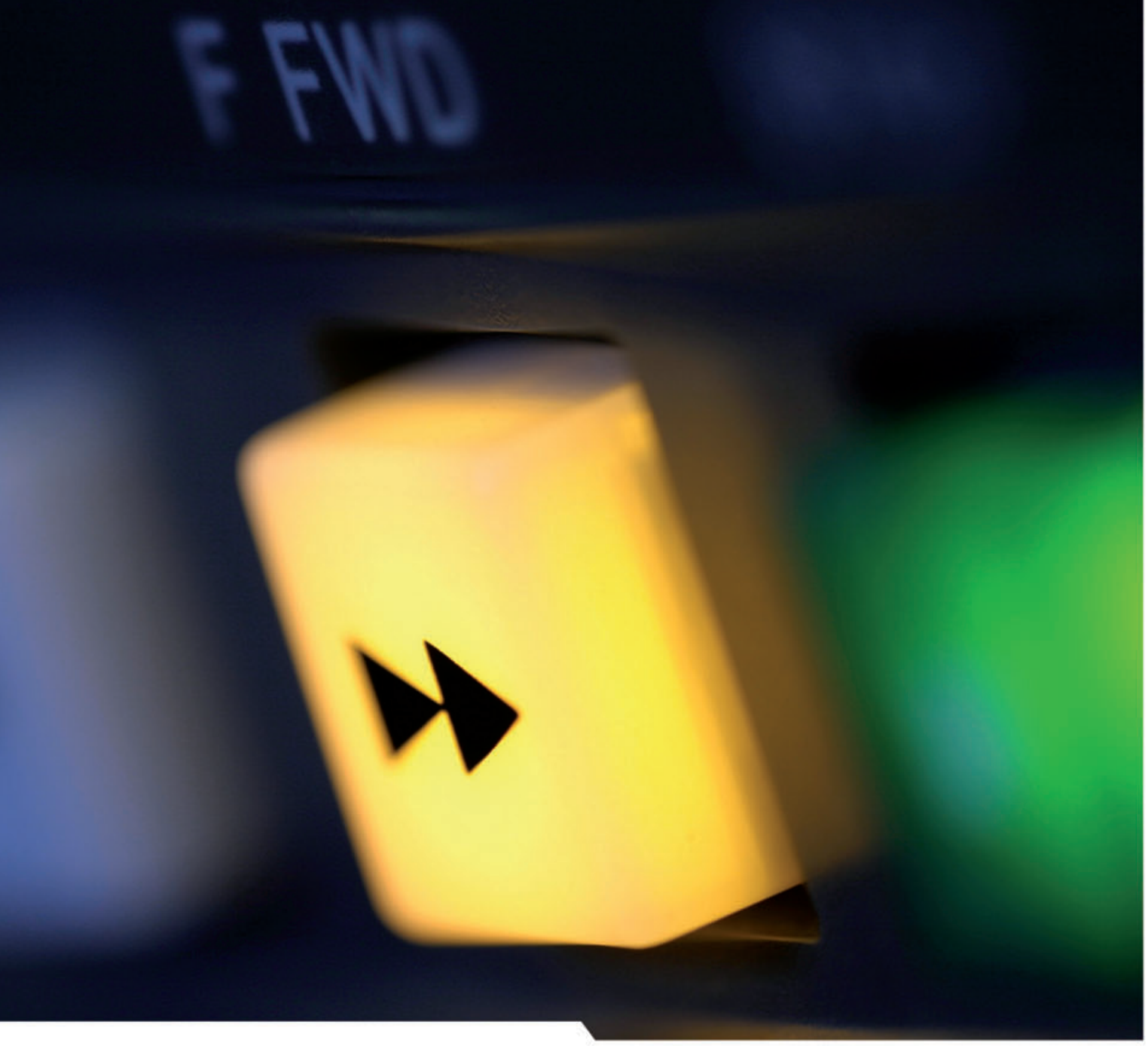


Figure 13: Collatape collagen membrane placed over autogenous bone.



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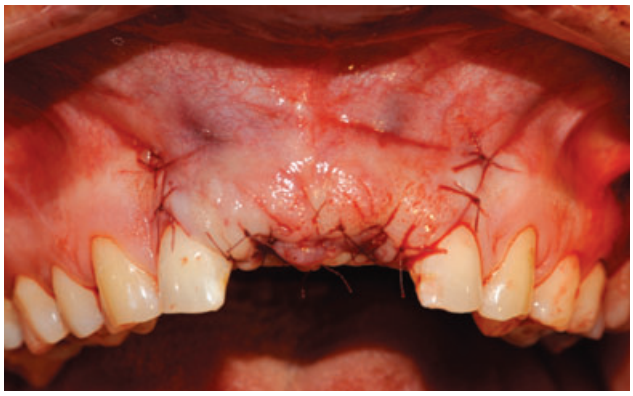

Figure 14: Wound closure with coronally repositioned flap.

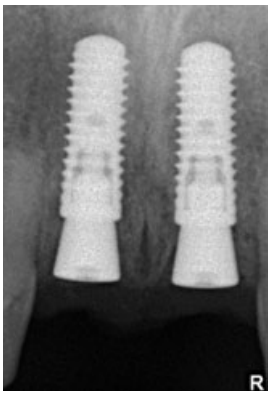

Figure 15: Six weeks submerged healing with 3mm healing caps in position.

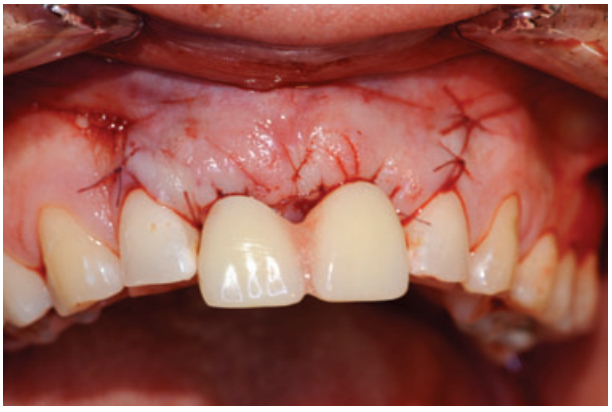

Figure 16a and 16b: Adaptation of excisting partial denture to accommodate extra bulk of tissue.

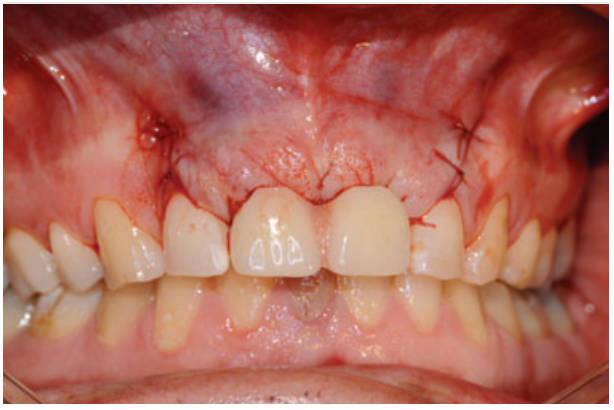

Figure 16b

(Figure14). The flap was coronally repositioned after relieving the periostium. The implants were left to heal submerged for six weeks (Figure 15).

The existing partial denture was adapted to accommodate the extra bulk of tissue. (Figures 16a and b).

After six weeks healing was allowed (Figure 17), the implants were exposed by means of a tissue punch and 5mm healing caps (Figures 18, 19).

Restoration

After initial healing the patient was referred for the

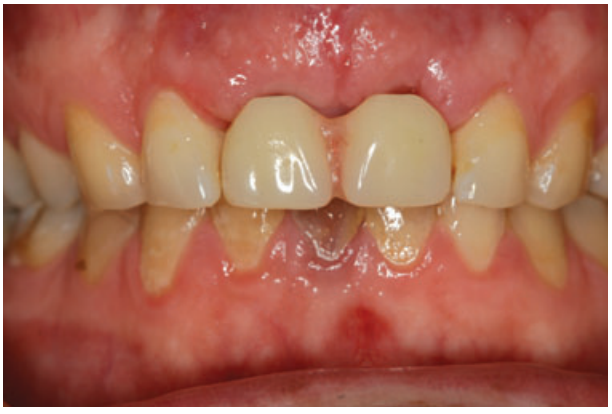

Figure 17: Situation after six week healing period.

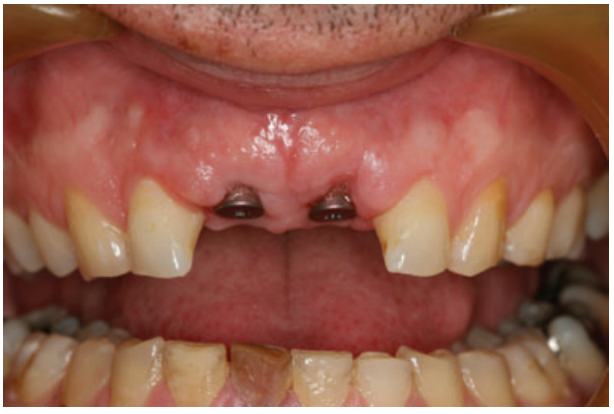

Figure 18: Punch exposure and connection of 5mm healing caps.

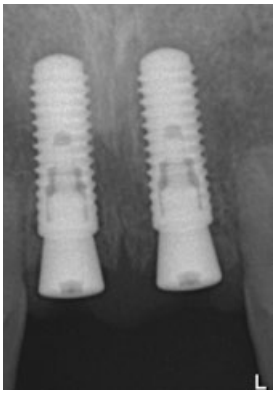

Figure 19: Radiograph after exposure.

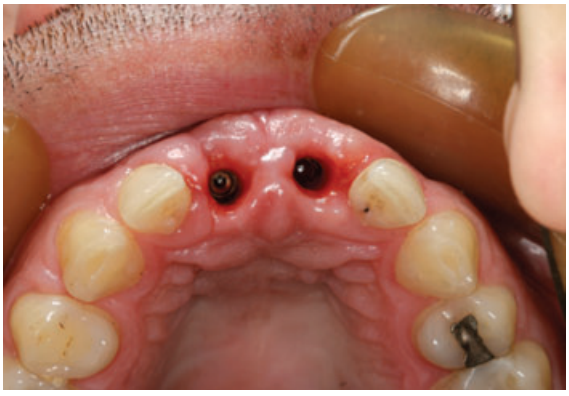

Figure 20: Presentation of soft tissue prior to impressions for restoration.

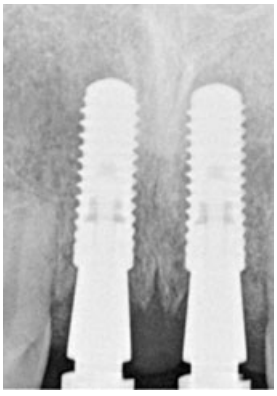

Figure 21: Verification of impression copings on radiogragh.

restorative phase (Figures 19, 20). Open tray impression copings were connected and the positive positioning verified with an digital x-ray (Figures 21, 22). A stock tray and polivynalsiloxane two phase impression material were used to record the position of the implants (Figures 22, 23) No soft tissue contouring has been done at this stage, mainly due to the unavailability and financial restrictions of the patient.

Gold abutments fitting the CrossFit™ connection were used to wax up and cast on the ideal envisaged emergence profile of the two individual incisors. Porcelain was fused to these abutments to produce screw retained individual crowns (Figures 24, 25, 26). Due to the depth of the implants and narrow profile of the soft tissue, screw retained crowns are required to be able to produce enough pressure to be able to seat the restorations. Note the blanching of the soft tissue immediately after the seating of the restorations (Figures 27, 28, 29). As no soft tissue profile was generated before the final crowns were connected, these crowns should be connected with caution to prevent over "stretching" of the soft tissue.

The precise and snug connection of the CrossFit™ connection can be seen on the post operative radiograph (Figure 30). Also note the level of the bone in relation to the implant level and horizontal offset. This will nourish and support the soft tissue volume and profile as seen 12 days post insertion (Figure 31,32).

After 12 months the soft tissue profile and bone around the implants are stable and healthy with an overall very pleasing esthetic result (Figures 33, 34).

Conclusion

With the correct three dimensional placement of implants, even in limited space and esthetically

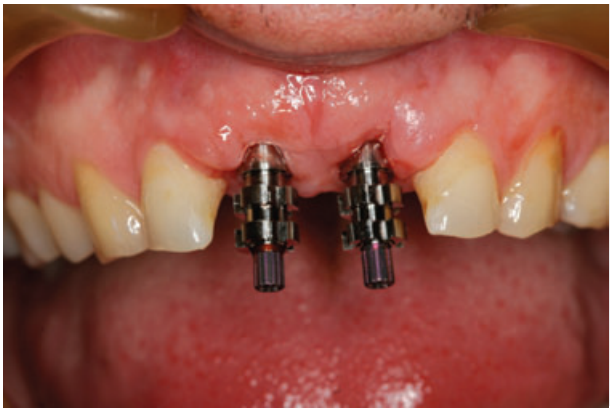

Figure 22: Impression copings connected.

Figure 23: View of impression with impression copings picked up with two phase putty wash poly vinyl silocsane impression material. (Aquasyl from Dentsply).

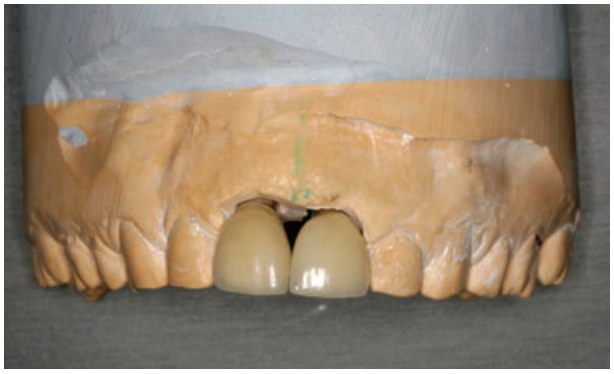

Figure 24: Laboratory model with completed restorations. Note the space left for the soft tissue remodeling.

Figure 25: Note the shape of the restorations to be connected to allow soft tissue regeneration and anatomic profile.

challenging areas, two adjacent implants can be inserted and restored with a long term predictable outcome. The esthetic outcome of these cases are totally dependent on the perfect positioning of the implants. It is imperative that the clinician and dental technician have the appropriate knowledge and experience in such challenging cases to achieve predictable results, both for function and esthetics. With Implants in the correct position, with sufficient surrounding tissues, and knowledge of the prosthetic shapes and space, final restoration can be finalized with great predictability.

Acknowledgement

For 20 years of excellent ceramics and support
Mr Ian Robertson
Designer Dental Laboratories

Figure 26: Note the buccal concavity to predict the gingival margin height.

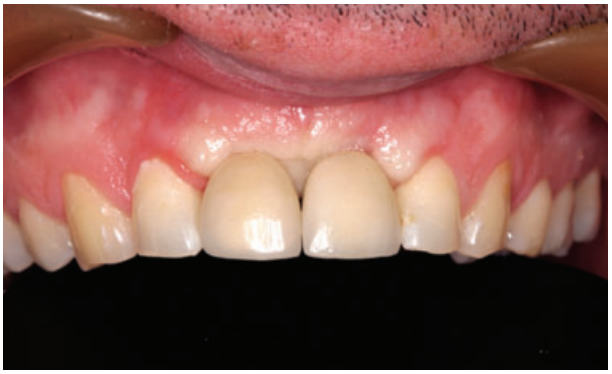

Figure 27: Connection of the crowns, to the implants. Note the blanching of the soft tissue to adapt to the shape of the restorations.

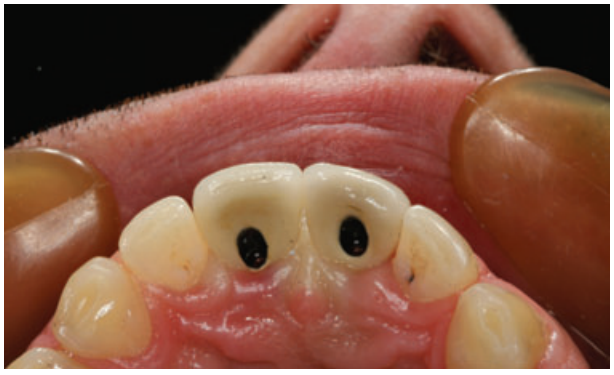

Figure 28: Screw access holes in singulum positions, perfectly positioned implants.

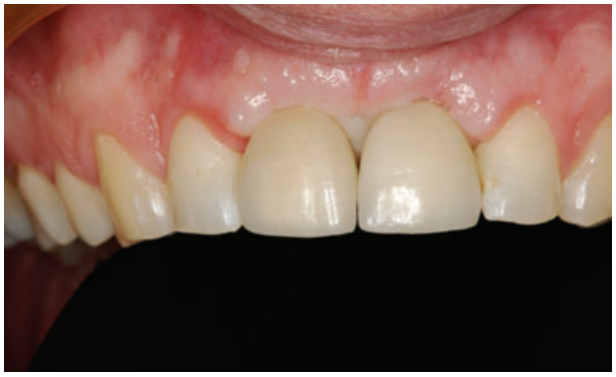

Figure 29: Closer view of soft tissue blanching immediately after connection of the restorations. This should disappear within 10 minutes after connection.

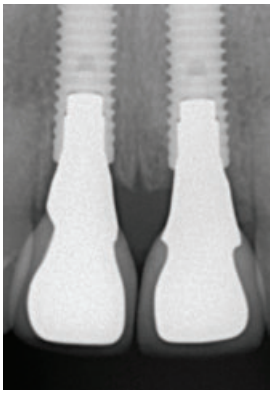

Figure 30: Radiogragh of the connected crowns to verify the positive seat of the crossfit connection.

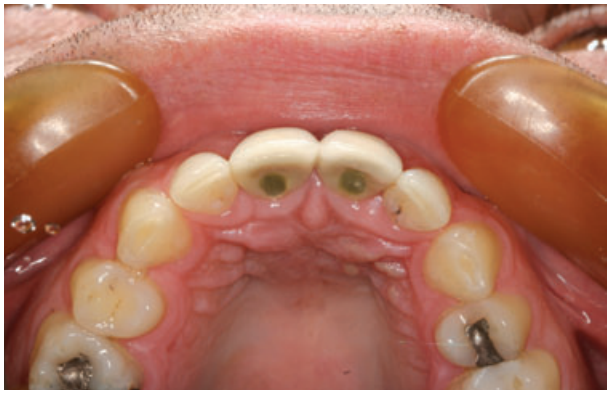

Figure 31: Palatal view 12 days post insertion of the restorations.

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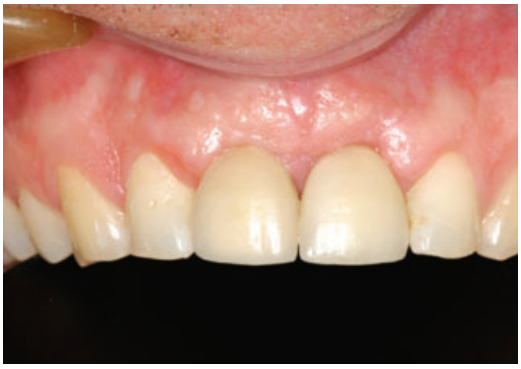

Figure 32: Frontal view 12 days post insertion of the restorations, note the natural colour and shape of the soft tissue.

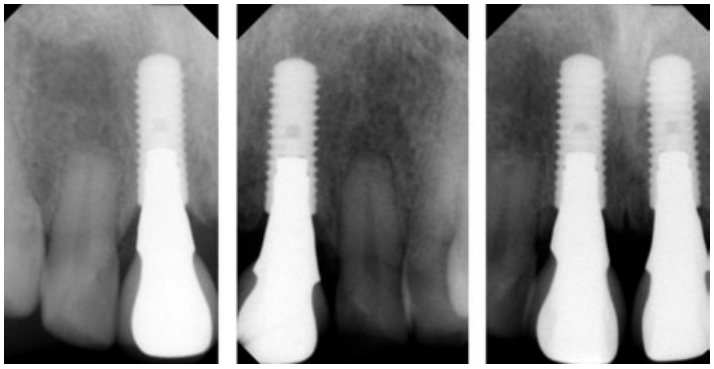

Figure 33: Radiogragh 1 year post insertion of the restorations, note the preservation of the marginal bone level.

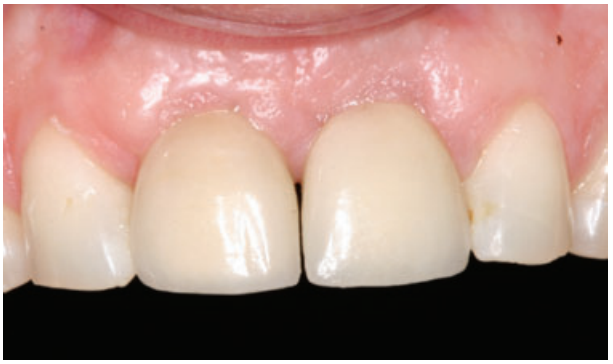

Figure 34: Frontal view 1 year post insertion of the restorations. Note the natural soft tissue profile and volume.

Contemporary technologies for remineralization therapies: A review

Laurence J. Walsh

Introduction

In the last decade there has been a veritable explosion of interest in technologies which may have value for remineralization of enamel and dentine, or for desensitization of exposed dentine affected by dental erosion.[1] The characteristics of an ideal remineralizing agent are summarized in Table 1, which provides a backdrop against which to contrast the available materials and technologies.

Enamel minerals

The mineral in dentine and enamel is not pure hydroxyapatite, but rather a mixture of compounds including a number of carbonated apatites, with greater diversity of composition in dentine than in enamel.[2] Fluorapatite is less acid soluble than hydroxyapatite, which in turn is less soluble than carbonated apatites.[3,4] Because of this chemical inhomogeneity of enamel, the process of enamel remineralization is rather complex. While a ratio of 10 calcium ions to 6 phosphate ions to 2 fluoride or hydroxyl ions (or one carbonate ion) appears suitable, there is evidence which supports other ratios for calcium to other components. Nevertheless, calcium availability remains the singular limiting factor in enamel remineralization.

One of the most important properties of calcium phosphate/calcium fluoride materials is their solubility behavior, bearing in mind that the majority of calcium compounds are very insoluble.[5]

Remineralization

Remineralization is the natural repair process for non-cavitated lesions, and relies on calcium and phosphate ions assisted by fluoride to rebuild a new surface on existing crystal remnants in subsurface lesions remaining after demineralization. These remineralized crystals are less acid soluble than the original mineral.[6] The composition and the concentration of inorganic ions in saliva and in dental plaque significantly influence the degree of saturation of the water-rich fluid which is in immediate contact with enamel.[7]

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Brisbane QLD 4000, Australia

The role of saliva

The critical role played by salivary components in controlling the equilibrium between de- and remineralization is ably demonstrated when salivary output is compromised and patients suffer dramatic increases in risk for dental caries and/or dental erosion. Enhanced remineralization of white spot lesions by stimulated salivary flow (e.g. from chewing a sugar-free gum) illustrates dynamic protective effects of saliva. Protective properties of saliva which increase on stimulation include salivary clearance, buffering power, and degree of saturation with respect to tooth mineral.[8]

It has been noted in the dental literature that the design of experiments using dental caries or dental erosion models must take into account the static and dynamic effects of saliva.[9] In the context of remineralization, an important component of saliva are its proteins, such as the glycoproteins which adsorb onto tooth structure to form the protective pellicle layer, and the phosphoproteins which regulate calcium saturation of the saliva. Pellicle is known to reduce mineral loss from enamel under conditions of acid challenge, more so for enamel than for dentine.[10,11]

Moreover, the early pellicle glycoproteins, acidic proline-rich proteins and statherin, are known to promote remineralization of the enamel by attracting calcium ions. (Table 2) Acidic proline-rich proteins bind strongly to hydroxyapatite, inhibit crystal growth of calcium phosphate salts from solutions supersaturated with respect to hydroxyapatite, bind calcium ions, and interact with several oral bacteria on adsorption to hydroxyapatite. Statherins, as well as histatins, and cystatins also exhibit affinities to mineral surfaces, and inhibit calcium phosphate precipitation.[12-14]

Some experimental systems such as in situ studies which use enamel slabs embedded into appliances allow full expression of the impacts of saliva, whilst some laboratory bench models exclude the involvement of saliva, and create nonsensical interpretations from the standpoint of clinical practice. Laboratory testing protocols using ionic solutions have significant limitations, most particularly related to their inability to simulate the complex biological processes involved.[15,16]

It appears that protective effects of salivary components and

Table 1
Requirements of an ideal remineralization material

Diffuses into the subsurface, or delivers calcium and phosphate into the subsurface
Does not deliver an excess of calcium
Does not favour calculus formation
Works at an acidic pH
Works in xerostomic patients
Boosts the remineralizing properties of saliva
For novel materials, shows a benefit over fluoride

Based on Zero, 2006.[88]

therapeutic agents act in a cooperative manner. An example would be the similar role played by salivary statherins and by the casein phosphopeptides in Recaldent™, both of which regulate the behaviour of calcium and phosphate, and stabilize calcium phosphate compounds.

For Recaldent™ and other agents which interact extensively with saliva, it is essential that they are tested in models where human saliva is used, rather than with artificial saliva solutions which lack a complete repertoire of proteins, since studies which exclude salivary proteins will underestimate the true remineralizing actions of this agent.[17-19] It is preferable that *in situ* models are used, with enamel or dentine slabs carried in the mouth and exposed to the normal oral environment. Such models explore the demin-remin balance in human subjects without actually causing caries in the natural dentition of those subjects.[20]

A key salivary parameter to consider in terms of remineralization is the extent of variations in calcium concentration between resting saliva (where it is low) and stimulated saliva (where it is higher). While phosphate levels in resting saliva do not vary markedly, large fluctuations in calcium concentrations occur in the one individual.[21,22]

Differences in calcium concentration have important implications for the critical pH and for the possibility of remineralization, since the latter will not occur when the degree of saturation of saliva with respect to tooth mineral is low.[23] In other words, remineralization may be enhanced by providing low levels of bio-available calcium and phosphate ions, in conjunction with minimal amounts of fluoride (<1 ppm).[24] Conversely, under low calcium concentrations, remineralization is a chemical impossibility.[25] There are significant inter-individual and time-related variations in pH, buffer capacity, and salivary concentrations of calcium and phosphate.[26] These changes impact directly on the likelihood of mineral loss and gain, in terms of both dental erosion and dental caries.[27]

Saliva, enamel, bone, cementum, dentine and milk contain closely related phosphoproteins which bind and stabilize calcium and phosphate, orchestrating the behaviour of these ions in a pH dependant fashion. In fact, statherins in saliva, casein phosphoproteins in Recaldent products, and phosphoproteins in tooth structure share remarkable similarity. When hard tissues are demineralized, the phosphoproteins which remain influence the ability of this tissue to remineralize.[28]

Mineral or ionic technologies: Fluoride

Fluoride works primarily via topical mechanisms which include (1) inhibition of demineralization at the crystal surfaces inside the tooth, (2) enhancement of remineralization at the crystal surfaces (giving an acid resistant surface to the reformed crystals), and, at high concentrations, (3) inhibition of bacterial enzymes. Low levels of fluoride in saliva and plaque help prevent and reverse caries by inhibiting demineralization and enhancing remineralization. On the other hand, high levels of surface fluoride can increase resistance to carious lesion formation and to dental erosion.[29] Numerous laboratory studies have shown that low levels of fluoride, typical of those found after many hours in resting plaque and saliva, and resulting from the regular use of fluoride dentifrices, can have a profound effect on enamel demineralization and remineralization.[30]

Fluoride present in the oral fluids alters the continuously occurring dissolution and reprecipitation processes at the tooth-oral fluid interface. Remineralization of incipient caries lesions is accelerated by trace amounts of fluoride.[31,32] High concentration fluoride therapies lead to deposition of aggregates of calcium fluoride on the surface, which then acts as a reservoir of fluoride. The rate of fluoride release is enhanced at lower pH levels.[33] A pH less than 5 causes loss of adsorbed phosphate, and triggers a slow dissolution of the calcium fluoride.[34,36] To increase its surface area, nano-sized particles of calcium fluoride have been prepared, with a diameter of some 41nm.[35] Such particles are many times larger than those in Recaldent™ (CPP-ACP or CPP-ACFP), where the nanoclusters are only 2 nm in diameter.

In laboratory studies where there is no saliva or plaque present and prolonged contact with remineralizing agents is assured, artificial solutions containing calcium and phosphate,

Table 2
Some key proteins which stabilize calcium and phosphate

Saliva	
	statherin
	acidic proline-rich proteins
	histatins
Milk	
	Alpha and beta caseins
Hard tissues	
	Ameloblastin
	Enamelin
	Osteopontin
	Bone sialoprotein
	Dentine sialoprotein

Based on Huq et al. 2005[89]

and fluoride (at levels of 1 ppm) can result in mineral gain in natural and laboratory-created white spot carious lesions over a 4 week period.[37] This, however, is not a realistic manner in which to test for the true remineralizing capabilities of a particular agent or formulation.

Beta Tricalcium phosphate (TCP)

Tricalcium phosphate has the chemical formula $Ca3(PO_4)_2$, and exists in two forms, alpha and beta. Alpha TCP is formed when human enamel is heated to high temperatures. It is a relatively insoluble material in aqueous environments (2mg/100 mL in water).[38,39] Crystalline beta TCP can be formed by combining calcium carbonate and calcium hydrogen phosphate, and heating the mixture to over 1000 degrees Celsius for 1 day, to give a flaky, stiff powder. The average size of the TCP particles can then be adjusted by milling them. Typically, particles range from 0.01 to 5 microns in size. Beta TCP is less soluble than alpha TCP, and thus in an unmodified form is less likely to provide bio-available calcium. It is used in products such Cerasorb®, Bio-Resorb® and Biovision®.[40]

TCP has also been considered as one possible means for enhancing levels of calcium in plaque and saliva. Some small effects on free calcium and phosphate levels in plaque fluid and in saliva have been found when an experimental gum with 2.5% alpha TCP by weight was chewed, when compared to a control gum without added TCP.[41]

A major problem with such uses of TCP is the formation of calcium-phosphate complexes, or if fluorides are present, formation of calcium fluoride, which would inhibit remineralization by lowering the levels of bioavailable calcium and fluoride. For this reason, TCP levels have to be kept very low, in the order of less than 1%. Alternatively, TCP can be combined with a ceramic such as titanium dioxide, or other metal oxides, to limit the interaction between calcium and phosphate, and make the material more stable in solution or suspension.[42,43]

Particles of TCP or TCP alloys can be coated with sodium lauryl sulphate (SLS) or other surfactants, or with carboxylic acids (such as fumaric acid), polymers and copolymers, by pulverizing the TCP or TCP alloy together with the coating material a planetary ball mill for several days.[43] It has been suggested that the organic coating prevents undesirable interactions with fluoride, but may dissolves away when particles contact saliva. This is the basis for the 3M Espe ClinPro™ fluoride dentifrices. According to the manufacturer, this organically modified TCP technology should operate best as a remineralizing agent at neutral or slightly alkaline pH. There is some laboratory evidence using bovine enamel models which show increased surface microhardness, and fluoride incorporation into the outer layers of the enamel.[44] It is not yet known what effects are achieved in the enamel subsurface, or whether any subsurface remineralization occurs. The manufacturer has provided some data on fluoride release, using the FDA method designed to assess fluoride dentifrices. The assay is however inappropriate for making any comparisons with topically applied protein-based systems such as GC MI Paste Plus™ (Tooth Mousse Plus). An independent assessment of the soluble fluoride, phosphate and calcium release properties of ClinPro Tooth Crème, GC MI Paste Plus/Tooth Mousse Plus, and 19 other commercially available topically delivered dental products with added calcium was presented at the September 2009 IADR Pan Asian Pacific Federation meeting.[45] Calcium in all 21 the products was found to have low water solubility except for MI Paste Plus, which contained 321.8 ± 2.6 µmol water soluble calcium per gram of crème, a level which was 14 times greater than that of ClinPro Tooth Crème and other products. MI Paste Plus also contained the highest amount of water soluble phosphate (245.7 ± 2.7 µmol/g). The high water solubility of the calcium, phosphate and fluoride in MI Paste Plus was attributed to the presence of the casein phosphopeptides.

This recent work reinforces the point that bioavailable calcium is the key limiting factor in remineralization, not fluoride. This is logical given the molecular and atomic ratios within various apatities. For example, with fluorapatite, the ratio is 10 calcium, 6 phosphate and 2 fluoride ions, of the 42 atoms in the molecule. Large fluoride uptakes by tooth enamel are not required for remineralization or for reductions in caries incidence.[46]

Pronamel

Despite its name, Pronamel™ is not considered a remineralizing agent per se, and it does not contain any calcium compounds. It is a relatively new addition to the Sensodyne™ family of fluoride dentifrices, and is targeted to help with the problem of dental erosion. It contains 5% potassium nitrate to help relieve tooth sensitivity, has a neutral pH and a low abrasivity, and lacks the detergent sodium lauryl sulfate formally found in

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We are proud and excited to announce the second GCO Congress (Supported by the EAO) taking place for the first time in South Africa. This distinctive event is an international meeting of world class standard with highly respected speakers who mix clinical knowledge and ground-breaking new techniques with solid scientific background. The congress theme is 'Implant Complications – From Treatment Planning to Solutions', with the aim of fostering safe clinical practice by promoting the understanding of the cause and effect of complications in implantology.

The congress has drawn together a group of highly acclaimed specialists from **Switzerland, Germany, France, Italy, South Africa, Brazil** and **Denmark** - providing an authoritative and reliable scientific and clinical basis for the treatment of patients, as well as addressing exciting new innovations and research.

Osseointegration 2012 will address the most relevant issue in implantology today. Diagnosing, classifying and treating complications. You would be able to leave this congress with the knowledge of how complications can be treated and avoided.

The congress incorporates an exhibition and networking parties in the exhibition area at the end of Days 1 & 2.

The congress coincides with the Cape Argus Cycle Tour, thus it is possible to combine these two exciting events in Cape Town. This is one of the largest and most prestigious cycle tours in the world, attracting over 40,000 competitors and takes place on the Sunday 11 March 2012. For details go to: www.cycletour.co.za

PROGRAMME OUTLINE

Thursday, 8 March 2012
Session 1: Welcome Address
Session 2: Treatment Planning - Anatomy to Radiology
Session3: Guided Surgery & Evaluation of Integration
Session 4: Surgical aspects of treatment planning - Immediate placements or staged placements

Friday, 9 March 2012
Session 5: Implant Types
Session 6: Posterior implant reconstructions
Session 7: Prosthetic complications from start to finish
Session 8: Long term maintenance, peri-implantitis

Saturday, 10 March 2012
Session 9: The Human Factor in Implantology
Session 10: Peri-implantitis and choice of prosthetic materials
Session 11: Traditional Dentist Treatment versus Implant Option

TARGET AUDIENCE

- Implantology Specialists
- Dentists
- Dental Technicians
- Dental Hygienists
- Academics & Trainers
- Researchers
- Dental Equipment Specialists

CONFIRMED SPEAKERS INCLUDE

Prof Sergio Bernardes, Brazil
Prof Else M Pinholt, Denmark
Dr Franck Renouard, France
Prof Friedrich Neukam, Germany
Prof Christoph Hämmerle, Switzerland
Prof Andrea Mombelli, Switzerland
Dr Vincent J Morgan, USA
Dr John Bronner, South Africa
Dr Howard Gluckman, South Africa
Dr Rabia Goolam, South Africa
Dr Niel Grundling, South Africa
Dr Dale Howes, South Africa
Dr Werner Joubert, South Africa
Dr Johann Lochner, South Africa
Dr Jacques Malan, South Africa
Dr Johan Marnewick, South Africa
Dr Thabit Peck, South Africa
Dr Louwrens Swart, South Africa
Dr Wynand van der Linden, South Africa
Dr Peter van der Meulen, South Africa
Dr Hans van Heerden, South Africa
Prof Andre van Zyl, South Africa
Dr Paul van Zyl, South Africa
Dr Christiaan Vorster, South Africa
Dr Rone Walters, South Africa
Dr Gerrit Wyma, South Africa

For the full programme go to: www.sbs.co.za/oc2012

CONGRESS VENUE

The congress will be held in the Cape Town International Convention Centre (CTICC), opened in 2004, which offers superb facilities and state of the art technologies, comparable to the best in the world. The CTICC is located between the city centre and the Victoria and Alfred Waterfront, right in the midst of hotels, restaurants, entertainment, and shopping.

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Table 3
Summary of current technology as at February 2009

Material	Publication	Level of evidence
ClinPro Tooth Crème™	1	Preliminary
Novamin™	1	Preliminary
DCPD	2	Preliminary
Pronamel™	2	Preliminary
Enamelon™	3	Preliminary
ACP	4	Preliminary
Various Ca compounds	10	Preliminary
CPP-ACP/ACFP	45	Systematic reviews
Fluoride	>5000	Systematic reviews

The publications column refers to the number of relevant MEDLINE listed refereed journal papers relating to the technology. The highest levels of evidence are randomized controlled clinical trials (RCTs) and systematic reviews of such clinical trials. See reference 90 for a discussion of levels of evidence.

dentifrices. The fluoride component is sodium fluoride, giving 0.15% w/v fluoride ion, or 1500 ppm, an increase of 50% above conventional dentifrices.

There are two published studies on this product, both of which are studies of dental erosion conducted in the laboratory setting. In the first, the protective effect of incubation in a toothpaste slurry before acid challenge of human enamel slabs was examined. While pre-incubation did have a protective effect, this did not differ amongst the five brands tested.[47]

The second laboratory study also focussed on dental erosion and compared Proenamel™ and GC MI Paste/Tooth Mousse™. Both were applied for 15 minutes before enamel specimens were exposed to an erosive challenge of 0.2% citric acid for 1 hour. The lack of saliva and moisture in the experimental protocol renders the latter product at a distinct disadvantage and favours a high fluoride toothpaste because of its deposition of calcium fluoride, as discussed previously. Nevertheless, both agents reduced enamel loss and offered a degree of protection from erosion.[48]

NovaMin™

NovMin™ is a bioactive glass containing calcium sodium phosphosilicate, and comprises 45% SiO_2, 24.5% Na_2O, 24.5% CaO and 6% P_2O_5. There is some evidence of desensitizing actions of NovaMin™, as seen in a 6 week clinical trial,[49] and some evidence regarding reductions in plaque index and gingival index,[50] however at the time of writing there is no other published information from refereed journals regarding this material, although a number of unpublished reports are provided by the manufacturer on its web site,[51] which are focussed on its effects as a desensitizing agent.

One of these unpublished studies describes a laboratory study employing enamel slabs and pH cycling which compared two dentifrices, both containing 1100 ppm fluoride, but with the NovaMin test product containing 5% by weight NovaMin bioactive glass particles, in place of an equivalent amount of silica abrasive in the control. There was improved performance of the NovaMin product in mineral gain compared with the control.

NovaMin has been incorporated into a number of products, including dentifrices and gels. One of these, Oravive Tooth Revitalizing Paste™, is a dentifrice which is explicitly free of fluoride.[52] Recent data for bioavailable calcium and phosphate suggest only a low bioavailability from NovaMin.[45]

Enamelon™

Enamelon consists of unstabilized calcium and phosphate salts with sodium fluoride. The calcium salts are separated from the phosphate salts and sodium fluoride by a plastic divider in the centre of the toothpaste tube. There is a modest evidence base for Enamelon™, with five laboratory studies, three rat caries trials, and four clinical trials. There is evidence of a caries inhibitory action of Enamelon™ dentifrice in a rat dental caries model.[53]

Clinical studies have indicated that incidence of root surface caries in radiotherapy patients using Enamelon ™ dentifrice over 12 months was superior to a conventional fluoride dentifrice and was comparable to that of daily use of stannous fluoride gel in trays.[54,55] Some clinical benefits on desensitization of sensitive cervical dentine over an 8 week have also been reported, compared to a conventional dentifrice containing sodium fluoride without calcium and phosphate.

An inherent technical issue with Enamelon™ is that calcium and phosphate are not stabilized, allowing the two ions to combine into insoluble precipitates before they come into contact with saliva or enamel. This is unlike Recaldent™, which has the casein phosphoproteins to stabilize calcium and phosphate.

The manufacturer of this product claims that its "Liquid Calcium" formula delivers fluoride along with soluble calcium and phosphate. A simple assessment of the fluoride level of Enamelon (and other products) may correlate with their remineralizing actions because of the limiting factor of calcium.[56]

Amorphous calcium phosphate (ACP)

This macromolecule was developed by the American Dental Association Health Foundation. It is prepared using low temperature methods, and can be modified to create hybrids which contain silica or zirconia.[57]

When applied topically, it is thought that ACP hydrolyzes under physiological temperatures at a pH of 7.4 to form octacalcium phosphate and an intermediate, and then surface apatite. If this did occur, it would not constitute remineralization of enamel subsurface (white spot) lesions, since these require penetration of calcium and other ions into the subsurface. The surface actions of ACP would, paradoxically, reduce surface porosity and thus render such sites less likely to undergo subsurface reminerlization.

The predominantly surface action of ACP does however explain its desensitizing effects,[58,59] and how it can fill in surface defects in tooth enamel, and cause cosmetic improvements in dimpled, abraded or etched tooth enamel.[60,61] For these reasons, ACP has been included in prophylaxis pastes and in bleaching gels. It would however be incorrect to attribute remineralizing claims to this material. One ACP-containing material, Discus Dental NiteWhite ™ claims to "rebuild tooth enamel, making teeth stronger and less susceptible to caries."[62] There is no published evidence in the current dental literature to support claims of subsurface remineralization or reversal of white spot lesions.

The stability of ACP in dental products is an issue. Single phase ACP systems are formulated without water, to keep the ACP from reacting to form apatite. An alternative approach is to separate the calcium and phosphate components, and mix these during dispensing immediately prior to use, using a dual dispensing system, similar to that described for Enamelon™.[63]

Dicalcium phosphate dehydrate (DCPD)

This material has been used in some fluoride dentifrices to attempt to enhance on the remineralizing effects of the fluoride component. Inclusion of DCPD in a dentifrice increases the levels of free calcium ions in plaque fluid, and these remain elevated for up to 12 hours after brushing, when compared to conventional silica dentifrices.[64]

Other calcium compounds

Because an inverse relationship exists between plaque calcium concentrations and dental caries risk, a range of other calcium compounds have been added to oral care products in an attempt to promote remineralization.[65] Unfortunately, with the exception of Recaldent™ technology, other approaches have not been particularly successful at delivering water-soluble bio-available calcium.[1, 45] A further problem is that adding calcium compounds directly into gels, dentifrices, and chewing gums causes unfavorable interactions with fluoride compounds in the same products, and reduces the palatability of these dental products because inorganic calcium salts taste chalky or astringent.

Similar comments apply to the incorporation of calcium compounds into drinks to reduce their erosive potential. Some calcium salts have been added to erosive drinks to increase calcium levels and reduce surface softening caused by these beverages, but other than by adding Recaldent,[1] it is not readily possible to gain dramatic increases in calcium levels in the most erosive foods and beverages.

Recaldent (CPP-ACP nanocomplexes): a protein technology

Other than fluoride, this is the most extensively researched remineralization technology, with more than 50 published studies in the dental literature, including 20 on the widely known topical tooth crème GC Tooth Mousse™/MI Paste™, with a number of large scale randomized controlled clinical trials and several systematic reviews published over the past 2 years.

This technology was developed by Eric Reynolds and co-workers at the University of Melbourne, and has since been incorporated into chewing gums (such as Recaldent gum™ and Trident White™) and tooth crèmes (GC Tooth Mousse™ and MI Paste™). A formulation with incorporated fluoride to a level of 900 ppm (GC Tooth Mousse Plus™, MI Paste Plus™).

This protein nanotechnology combines specific phosphoproteins from bovine milk with forming nanoparticles of amorphous calcium phosphate (ACP). The precise ratio is 144 calcium ions plus 96 phosphate ions and 6 peptides of CPP.

The casein phosphopeptides (CPP) are produced from a tryptic digest of the milk protein casein, then aggregated with calcium phosphate and purified by ultrafiltration. Under alkaline conditions the calcium phosphate is present as an alkaline amorphous phase complexed by the CPP. The nano-complexes form over a pH range from 5.0 to 9.0. Under neutral and alkaline conditions, the casein phosphopeptides stabilize calcium and phosphate ions, forming metastable solutions that are supersaturated with respect to the basic calcium phosphate phases. The amount of calcium and phosphate bound by CPP increases as pH rises, reaching the point where the CPP have bound their equivalent weights of calcium and phosphate.

Recaldent works effectively as a remineralizing agent at acidic pH levels (down to 4.0) as well as in the neutral and alkaline range.[1,66] The present author was involved in developing a number of the clinical protocols for using these tooth crèmes in clinical dental practice, for treating white spot lesions, fluorosis, orthodontic decalcification, enamel dysmineralization, and sensitive dentine.[67] Current work is exploring how Recaldent can be used to modify dental plaque ecology, given that CPP bind to certain plaque bacteria and

also localize ACP within dental plaque biofilms.[68]

There is extensive clinical as well as laboratory evidence for the effects of Recaldent as a remineralizing agent, as well as a truly anti-cariogenic agent, with the latter being demonstrated in both animal and in situ human caries models. The material is pH responsive, with increasing pH increasing the level of bound ACP and stabilizing free calcium and phosphate, so that spontaneous precipitation of calcium phosphate does not occur. This provides an anti-calculus action.[69]

CPP-ACP provides a highly effective means for elevating calcium levels in dental plaque fluid, something which is desirable for enhancing remineralization, but is difficult to achieve by using calcium in other forms.[70] In fact, in a mouthrinse study which compared CPP-ACP and solutions of calcium phosphate, only the CPP-ACP-containing mouthrinse significantly increased plaque calcium and inorganic phosphate levels.[71]

The delivery of simultaneous calcium, fluoride and phosphate using Recaldent products which include fluoride provides an effective means of controlling the process of fluoride levels in dental plaque. These levels influence the behaviour of bacteria as well as contributing to remineralization.

The anti-caries action of Recaldent involves actions other than suppressing demineralization and enhancing remineralization. There is increasing evidence that Recaldent may influence the properties and behaviour of dental plaque through (1) binding to adhesin molecules on mutans streptococci and thus impairing their incorporation into dental plaque, (2) elevating plaque calcium ion levels to inhibit plaque fermentation; and (3) providing protein and phosphate buffering of plaque fluid pH, to suppresses overgrowth of aciduric species under conditions where fermentable carbohydrate is in excess.

The extent of remineralization seen with Recaldent does not significantly correlate with levels of CPP-bound ACP or the degrees of saturation for hydroxyapatite, octacalcium phosphate, or ACP. Rather, there is a strong correlation between remineralization and the concentration of the neutral ion pair $CaHPO_4$. By stabilizing calcium phosphate in solution, the CPP maintain high-concentration gradients of calcium and phosphate ions and ion pairs into subsurface lesions, an effect which explains the high rates of enamel subsurface remineralization which can be achieved when these products are used in solutions, gums, lozenges and crèmes.[72]

CPP-ACP incorporated into chewing gum, lozenges and mouthrinses has been shown to re-mineralize enamel subsurface lesions in numerous human in situ studies.[73] Enhanced remineralization of enamel subsurface lesions has also been shown when CPP-ACP is added to bovine milk at levels of 2.0 or 5.0 g/liter. At an intake level 200 mL of milk once daily for each weekday over three consecutive weeks, gains in mineral content of 70 and 148%, respectively occurred, relative to the normal milk control.[74]

Current treatment protocols using Recaldent tooth crèmes such as MI Paste and Tooth Mousse[67] recognize the importance of the neutral ion species gaining access to the subsurface lesion through a porous enamel surface. This is the reason why arrested white spot lesions should have a surface etching treatment before remineralization with Recaldent products. Such a treatment, either alone or combined with gentle pumicing, will remove approximately 30 microns of surface enamel, but will not cause further mineral loss from the subsurface zone of the white spot lesion.[75]

Unlike fluoride treatments with conventional dentifrices (1,000 ppm) which deposit surface mineral but do not eliminate a white spot lesion,[76] Recaldent has been shown to cause regression of lesions, with a large scale 2 year clinical trial with 2720 adolescent subjects demonstrating regression of proximal carious lesions on sequential standardized digital bitewing radiographs. Those chewing the CPP-ACP gum were also less likely to show caries progression of approximal caries relative to a control sugar-free gum.[77]

CPP-ACFP nanocomplexes

Casein phosphopeptides containing the cluster sequence-Ser(P)-Ser(P)-Ser(P)-Glu-Glu- bind fluoride as well as calcium and phosphate, and thus can also stabilize calcium fluoride phosphate as soluble complexes. These complexes are designated CPP-ACFP. Studies of such nano-complexes based on the casein alpha-S1 peptide fragment 59-79 have revealed a particle size of some 2 nm and stoichiometry of one peptide to 15 calcium, 9 phosphate and 3 fluoride ions.[78]

Clinical studies of mouthrinses and dentifrices containing CPP-ACP and fluoride have provided interesting insights into the synergy between these. For example, addition of CPP-ACP to a fluoride mouthrinse increases the incorporation of fluoride into dental plaque biofilm. A dentifrice containing CPP-ACP with fluoride provides remineralization which is superior to both CPP-ACP alone and to conventional and high fluoride dentifrices.[79] This synergy between CPP-ACP and fluoride had been identified in laboratory studies using GC MI paste/Tooth Mousse, which showed that Tooth Mousse (without fluoride) remineralized initial enamel lesions better when applied as a topical coating after the use of a fluoride dentifrice.[80] In the absence of such "environmental" fluoride, the predominant mineral that will be formed in enamel subsurface lesions during remineralization with CPP-ACP will be hydroxyapatite.

It is now known that CPP can stabilize high concentrations of calcium, phosphate and fluoride ions at all pH values from 4.5 up to 7.0, and is able to remineralize enamel subsurface lesions was observed at all pH values in this range, with a maximal effect at pH 5.5.[81] In fact, at pH values below 5.5, CPP-ACFP produces greater remineralization than CPP-ACP, and the major product formed when remineralization is undertaken with CPP-ACFP is fluorapatite, which is highly resistant to acid dissolution. In either event it appears that mineral formation is optimized, since acid challenge of lesions

after remineralization with CPP-ACP or CPP-ACFP gives demineralization underneath the remineralized zone, indicating that the remineralized mineral was more resistant to subsequent acid challenge.[82]

Remineralization of dentine

While this paper has focussed on remineralization of enamel, it is noteworthy that interest is increasing in treatments which can remineralize carious or eroded dentine. The presence of phosphoproteins in the normal protein composition of dentine, its more complex structure and greater water content make dentine a rather more challenging substrate to control for systematic scientific study. A particular problem is that some laboratory studies omit saliva and thus remove the important contributions of pellicle and of salivary phosphoproteins such as statherin to the process. [83] This makes data gained by studying the application of simple solutions of calcium and phosphate compounds onto dentine slabs impossible to apply into the clinical setting.

Recent work has shown that fluorapatite, rather than calcium fluoride, is formed within dentine by application of neutral sodium fluoride gels followed immediately by laser treatment, a process now termed "photonic conversion".[84-86] It has also been shown that CPP-ACP (GC MI Paste/Tooth Mousse) can arrest incipient root surface caries lesions and can have a hardening effect, illustrating once again the value of such approaches in patient care.[87]

Conclusions

Looking at the evidence base, it is clear that, other than for fluoride, the strongest level of clinical evidence for remineralization is for the casein phosphopeptide-based Recaldent technology, with both long term large scale clinical trials and randomized controlled clinical trials to support its efficacy. This technology fulfils the characteristics of an ideal novel remineralizing agent identified by Zero in 2006.[88] This is perhaps not surprising given its ontogeny, particularly its similarity to other proteins which stabilize calcium and phosphate in body fluids (Table 2).[89]

The evidence base for other novel methods (summarized in Table 3) can perhaps best be summarized as "preliminary", since at this time they are interesting from the scientific standpoint but have little in the way of laboratory, human in situ, or clinical trial data to support their use, and certainly cannot be promoted as being equal or superior to either fluoride or Recaldent. It is important for dental professionals to be aware that it takes significant time to establish the bona fides of a new technology,[90] and that a "watching brief" is necessary in this rapidly professing area of dental science.

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Comparison of smear layer removal using four final-rinse protocols

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Abstract

Objectives: This study aimed to compare the efficacy of Tetraclean and 17% EDTA as final irrigants in the removal of the smear layer in the coronal, middle and apical thirds of the instrumented root canal. **Methods and Materials:** Forty extracted human permanent teeth (n=10) were randomly assigned to 4 groups: no smear layer removal (group 1); EDTA rinse (group 2); liquid component of Tetraclean only (group 3); Tetraclean (group 4). The specimens were analyzed using scanning electron microscopy analysis at 500X and 1000X magnification and cleaning was evaluated at the apical, middle, and cervical levels using a three-point scoring system. Data were statistically analyzed using Kruskal-Wallis analysis of variance test (5% significance level). **Results:** When the entire canal was considered, groups were ranked in the following order: 1>2≥3=4 ($p<0.05$). For different sections of the canal space, distance from the apex (2, 6 and 10 mm) influenced smear layer removal within each group ($p<0.05$). **Discussion:** Differences between EDTA and Tetraclean were only evident at 6 mm from the apex, whereas at 2 mm both protocols had similar performances in smear layer removal from the root canal system of single-rooted permanent teeth. **Conclusions:** the use of a chelating agent leads to a higher removal of smear layer from the root canal walls.

Key words

EDTA, Endodontic treatment, irrigation, smear layer, sodium hypochlorite.

Introduction

The main purpose of root canal therapy in infected teeth is the elimination of debris, toxins and microorganisms by chemomechanical preparation. However, even after cleaning and shaping, total sterilization of the root canal system remains difficult to achieve.[1]

Studies have shown that mechanical instrumentation of root canals implies the formation of a smear layer covering the dentinal walls[2] and containing both inorganic and organic materials.[2] The presence of the smear layer may considerably delay or prevent the penetration of antimicrobial agents, such as endodontic irrigants and

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intracanal medications, into the dentinal tubules,[3] as well as interfere with the adhesion of root canal sealers to the root canal walls, thus compromising the quality of the root canal filling.[4]

Keeping or removing the smear layer is a highly controversial subject. Nevertheless, it seems that the smear layer itself may be infected and may harbor bacteria within the dentinal tubules.[5] This is significant in teeth with infected root canal system where the outcome of the endodontic treatment depends on the elimination of bacteria and their byproducts from the root canal system. In these cases at least, removing the smear layer appears to be of importance.[6]

For effective removal of both organic and inorganic components of the smear layer, combined application of sodium hypochlorite (NaOCl) and a chelating agent, such as ethylenediaminetetraacetic acid (EDTA), is recommended.[7] The combination of these substances is capable of removing the smear layer, mainly from the middle and cervical thirds.[8] However, the application of EDTA for more than 1 minute[9,10] and in volume more than 1 ml[9,10,11] has been reported to be associated with dentinal erosion. It is also noteworthy that chemical interactions between NaOCl and EDTA should be taken into account. Mixing them caused a complete loss of free available chlorine from NaOCl in less than one minute.[7] This suggests that in an alternating irrigating regimen, copious amounts of hypochlorite should be administered to rinse out chelator remnants and allow the NaOCl to develop its antimicrobial and tissue dissolving potential. However, the interaction between NaOCl and EDTA makes usage of this two component difficult.[12]

In 2003, Torabinejad[9] proposed the use of an irrigant to be used in association with 1.3% NaOCl to remove smear layer from canal walls and facilitate the elimination microorganism from infected dentin.[13] This irrigant (MTAD, Dentsply Tulsa Dental, Johnson City, TN USA) is a solution containing a mixture of an antibiotic (doxycycline), an acid (citric acid), and a detergent (Tween-80). Citric acid works as a chelating agent in association with the lower chelating action of the antibiotic, while surfactant is able to facilitate the penetration of the solution into the root canal system. While Shabahang and Torabinejad[13] demonstrated the efficacy of this solution, other studies have shown several important limits. Tay et al.[14] demonstrated that the solution was more aggressive against intertubular dentin, leading to a reduction of collagenic matrix exposed. A new irrigant, Tetraclean (Ogna Laboratori Farmaceutici, Milano, Italy), has been developed containing a mixture of a tetracycline isomer, an acid and 2 detergents. It is recommended to be used as a final rinse after root canal preparation.[15] It is similar to MTAD but with a reduced amount of doxicycline (50mg/5ml instead of 150mg/5ml for MTAD), with polypropylene glycol (a surfactant), citric acid, and cetrimide. This substance is supposedly capable of eliminating all bacteria and smear

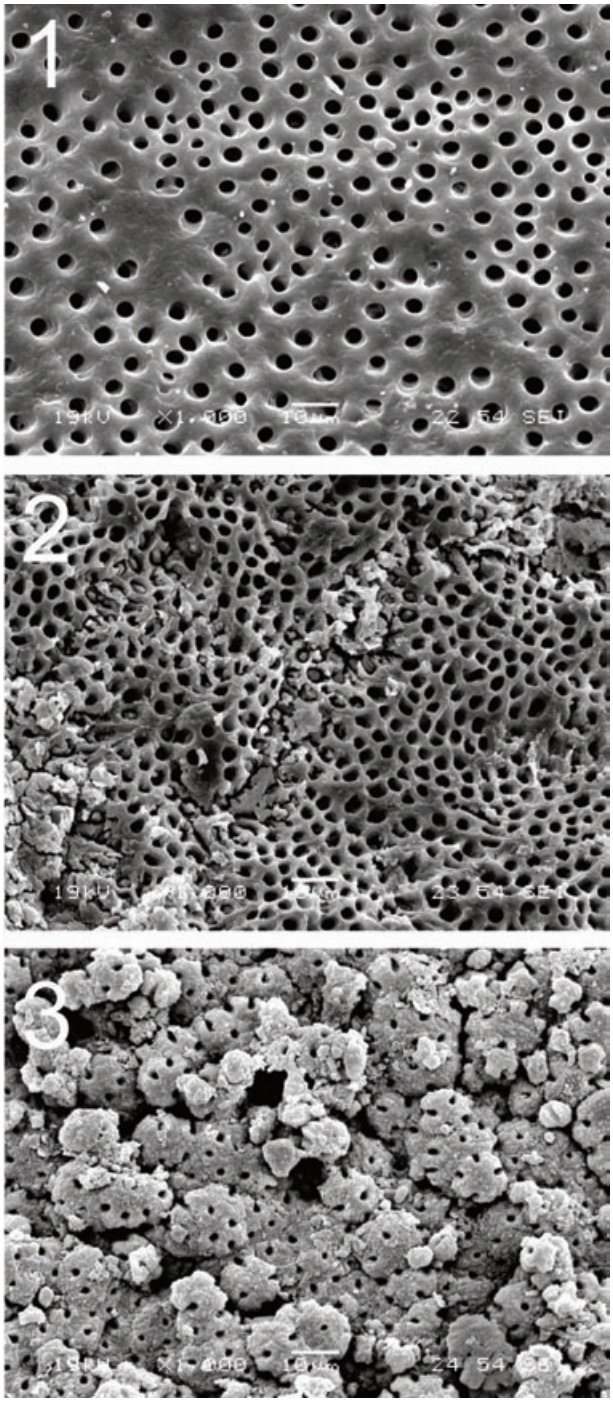

Figure 1: SEM MICROGRAPHS SCORE 1 = No smear layer. No smear layer on the surface of the root canals; all tubules were clean and open; 2 = Moderate smear layer. No smear layer was observed on the surface of root canal, but tubules contained debris; and 3 = Heavy smear layer. Smear layer covered the root canal surface and the tubules.

Table 1

Group	Coronal third scores			Median	Middle third scores			Median	Apical third scores			Median	P value
	1	2	3		1	2	3		1	2	3		
Control (n=9)	0	1	8	3.000	0	0	9	3.000	0	0	9	3.000	<0.05
EDTA (n=10)	3	6	1	2.000	0	6	4	2.000	0	7	3	2.000	<0.05
Tetraclean Liquid (n=9)	7	2	0	1.000	3	6	0	2.000	0	7	2	2.000	<0.05
Tetraclean Liquid+Powder (n=10)	9	1	0	1.000	7	3	0	1.000	0	8	2	2.000	<0.05

Group	Whole root Canal scores			Median	P value
	1	2	3	3.000	
Control (n=29)	0	2	27	2.000	<0.05
EDTA (n=30)	3	19	8	2.000	<0.05
Tetraclean Liquid (n=29)	11	15	3	1.000	<0.05
Tetraclean Liquid+Powder (n=30)	16	12	2		<0.05

layer from the root canal system when used as a final irrigation.

This study aimed to compare the efficacy of Tetraclean and 17% EDTA in the removal of smear layer from the coronal, middle and apical thirds of instrumented root canals. The null-hypothesis tested was that there are no statistically significant differences between different protocols for smear layer removal.

Materials and Methods

Sample preparation

Forty human single-rooted teeth with a straight single canal recently extracted for periodontal reasons were selected for the study under a protocol approved by the local ethical committee. Exclusion criteria were: teeth shorter than 20 mm, apex larger than #25 before instrumentation, presence of caries, root fissures or fractures. All teeth were stored in saline at 4°C and used within one month after extraction.

To standardize canal instrumentation, crowns were removed by cutting the teeth 12 mm above the apex, using a water-cooled slow-speed Isomet saw (Buehler, Lake Bluff, IL). Size 10 K-file was inserted into each canal until it was seen through the apical foramen. The working length was established by reducing this length by 0.5 mm. The canals were shaped with nickel-titanium rotary instruments (FlexMaster, VDW, Munich, Germany). Size 30/.06 taper was the last file used at the working length. Irrigation with 5% NaOCl (Niclor 5 Dentale, Ogna, Muggio', MI) was performed during instrumentation using a syringe with a 30-gauge needle (Perio/Endo Irrigation Needle, Biaggio, Switzerland), and the teeth were then randomly divided into four groups (N=10). The exterior part of the apical third of each root was covered with sticky wax to prevent irrigants from dripping through the apical foramen. This was done after placing a calibrated Fine-Medium gutta-percha cone (Mynol Curaden Healthcare SRL, Saronno, VA) at the working length in order to avoid wax intrusion into the apex and the cone was removed after the wax had set.

After instrumentation, each group of teeth underwent a specific final irrigation protocol. For group 1 (control), 5% NaOCl was used (3ml); for group 2 (EDTA), 17% \EDTA (3ml, Ogna, Muggio', Milano, Italy) was used for 1 minute

followed by 5% NaOCl (3ml); for group 3 (Tetraclean liquid, polypropylene glycol and citric acid), the liquid component of Tetraclean was used for 1 minute (3ml), followed by 5% NaOCl (3ml); and for group 4 (Tetraclean), Tetraclean (powder+liquid, 3ml, polypropylene glycol, citric acid and Doxycycline 50 mg/5 ml) was used for 1 minute followed by 5% NaOCl (3ml). The solutions were introduced into the root canals using a 30-gauge needle (Miraject, Hager Werken, Duisburg, Germany), which penetrated to 1-2 mm of the working length. The root canals were then irrigated with 5ml of distilled water and dried with paper points.

SEM observations

Two longitudinal grooves confined to dentin were prepared on the buccal and lingual surfaces of each root using a diamond disc. The roots were then immersed for 30 seconds in a bowl containing liquid nitrogen, which was sufficient for most of them to generate a separation of the two root halves, otherwise a chisel was introduced into the grooves to separate the two root halves. For each root, the half containing the most visible part of the apex was conserved and coded. The coded specimens were then mounted on metallic stubs, gold sputtered, and examined using a scanning electron microscope (SEM JSM-6060LV, JEOL, Tokyo, Japan). Pictures taken at 500X and 1000X were used to evaluate the coronal (10 mm from apex), middle (6 mm from apex), and apical (2 mm from apex) levels of each specimen. The amount of smear layer remaining on the surface of the root canal or in the dentinal tubules was scored according to the following criteria:[7] no smear layer on the surface of the root canals, all tubules were clean and open (score 1); no smear layer was observed on the surface of root canal, but tubules contained debris (score 2); and smear layer covering the entrances of the tubules (score 3) (figure 1). Approximately 250 scanning electron microscopy photomicrographs were scored by two expert endodontists who were unaware of the coding system in order to exclude observer bias. In the case of disagreement between the operators, the higher score was assigned.

Statistical analysis was performed using Kruskal-Wallis analysis of variance followed by Dunn's multiple comparison tests to reveal differences among the groups at $p<0.05$.

Results

One specimen in the control group and one in group 3 were excluded from the study because the canals had been perforated by the disc during the preparation for SEM evaluation. The results obtained in terms of smear layer scores are shown in Table 1. Statistically significant differences were found among the groups in relation to the irrigant used. When the levels were compounded, groups were ranked in the following order: $1>2\geq3=4$ ($p<0.05$). For different sections of the canal space, the distance from the apex (2, 6 and 10 mm) influenced the smear layer removal within each group ($p<0.05$).

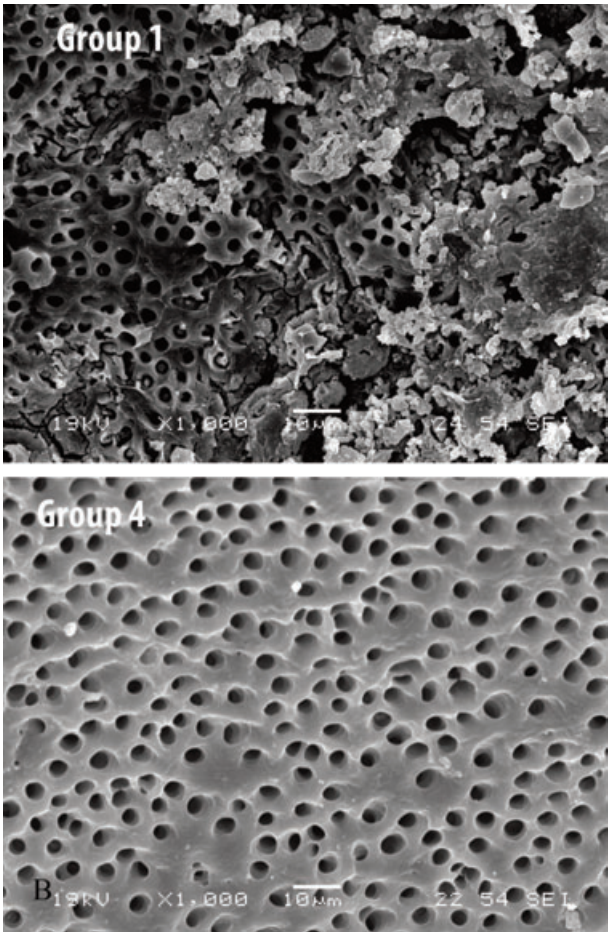

Figure 2: SEM micrographs representing different smear layer removal ability at 6 mm from the apex between group 1 and 4.

Analysis of the smear layer removal at different locations revealed that at 10 mm from the apex, the control group showed the highest score without significant differences with group 2. Groups 3 and 4 revealed the lowest scores ($p<0.05$). At 6 mm the result obtained were similar to those at 10 mm but group 4 performed significantly better than group 2 (fig.2) ($p<0.05$). At 2 mm from the apex the control group showed the highest score with a statistical significant difference with all the other groups ($p<0.05$).

Discussion

The null-hypothesis tested in the study had to be rejected since there were statistical differences between the smear

layer removal ability of the different irrigation protocols.

In the present study, 3ml of chelating solutions were used. There is no agreement in the literature concerning the volume of chelating agent or the contact time required in final rinse protocols.[7,9,11] EDTA and Tetraclean were not used according to usually recommended durations but according to experimental ones. As it has been shown that EDTA is effective in removing smear layer without affecting intra and peritubular dentin,[11] 1min application of EDTA was chosen as protocol, and tetraclean application time was mirrored to that of EDTA. It is noteworthy that different application times might yield different results.

The results of the present study are in accordance with other studies showing that NaOCl is not effective in removing the smear layer[7,9,11] when used without a chelatant. When considering the whole root canal it was evident that the use of a chelatant was imperative for removing the smear layer. Tetraclean is a helpful solution for the removal of the smear layer when used as a final rinse ex vivo: it promotes clean canal walls, with absence of smear layer and opened dentinal tubules, without changing the structure of dentine.[16] In this study, a final rinse of each canal was performed by using 3 ml of 5% NaOCl for all the experimental groups to standardize final irrigation protocols. Because this study examined only the efficacy of different protocols for smear layer removal, further studies should be conducted to examine the effect of 5% NaOCl final rinse on antimicrobial effectiveness of doxycycline component in Tetraclean and its substantivity. The liquid component of Tetraclean has been proposed for the final rinsing step, followed by 5%NaOCl (group 3), for understanding the chelating action when citric acid works with surfactants, estimating an optimal time-effect relationship for the clinical application. De Deus et al.[17] reported that demineralization kinetics promoted by 10% citric acid is faster than for 17% EDTA as demineralizing substance: real-time observation of the demineralization process in radicular dentine 17% EDTA promoted much weaker demineralization and caused less peritubular and intertubular dentine erosion when compared with 10% citric acid. The association of a powder and a liquid (group 4) is even more effective in cleaning the root canal walls. This is possibly due to the presence of an antibiotic with chelating action in the powder. Doxycycline has been used in periodontal treatments because of its antibacterial and chelating ability as well as its substantivity.[18] Barkhordar et al[19] and Haznedaeroglu and Ersev[20] recommended the use of tetracycline hydrochloride to remove the smear layer from the surface of instrumented canals and root-end cavity preparations.

At 6 mm from the apex, groups 2 and 3 gave better results than control group, and group 4 revealed statistically significant differences with all the other groups: this can be explained by the addition of a powder containing a tetracycline isomer which has a chelating action and improves the penetration ability of the solution into this narrow region of the root canal. However at 2 mm from the apex, groups 2, 3 and 4 were not statistically different, and gave lower scores when compared to the control group. At this level, the presence of the surfactant agent should have improved the penetration of the solution into dentinal tubules however, no significant differences were detected. Although images from groups 4 revealed better smear layer removal than group 2, the sample size was probably too small to allow detection of differences between these groups. The current study showed that the process of smear layer removal was more efficient in the coronal and middle thirds than in the apical third of the canals. This finding is in agreement with the results of various studies that have shown an effective cleaning action in the coronal and middle thirds of the canals even when different irrigation times and volumes of solutions were investigated.[7] A larger canal diameter in the coronal and middle thirds exposes the dentin to a higher volume of irrigants, allowing a better flow of the solution and, hence, further improving the efficiency of smear layer removal.[7] Consequently, it is important to use other methods, such as ultrasonic devices, for improving the efficiency of low-volume chelating agents used for a short application time[22] From another standpoint, Mancini et al[21] showed that the apical third is always the least cleaned as it is likely to receive less volume of irrigant when compared to the more coronal portion of the canal. In a recent study Poggio et al[16] investigating by SEM image analysis the endodontic dentinal surfaces after canal shaping with Ni-Ti instruments and irrigating with 5.25% NaOCl + different irrigating solutions as final rinse showed that NaOCl+Tetraclean group had significantly lower scores than other groups were in accordance with present study.

It is evident that increasing the instrument taper will allow a deeper penetration of the irrigation needle and improve the flushing of debris.[23] Shuping et al[24] found a better antibacterial effect using nickel-titanium (NiTi) instrumentation when NaOCl was used, but only after instrumentation exceeded ISO size #30 to #35. To overcome the potential limited irrigation in the apical area, enlargement of this area has been advocated for better cleansing.[25] For this reason it was decided to prepare the apical foramen of the samples to #30 in order to be able to compare the outcome of the present study with other

studies in literature.

It is noteworthy that when an antibiotic is included in the formulation of the irrigant, the possibility of increasing the microbial resistance to that antibiotic should be taken into account. Several mechanisms including oxygen limitation, antibiotic penetration, and the presence of a small subpopulation of 'persister' cells, could be responsible of antiobiotic susceptibilities.[26]

Therefore it can be concluded, within the limitation of this ex-vivo study, that the use of a chelating agent leads to a higher removal of smear layer from the root canal walls. Differences between EDTA and Tetraclean were only evident at 6 mm from the apex, whereas at 2 mm both protocols had similar performances in smear layer removal from the root canal system of single-rooted permanent teeth.

Acknowledgments

The authors deny any conflict of interest.

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Title: Fiber Posts and Endodontically Treated Teeth: A Compendium of Scientific and Clinical Perspectives. Authors: Marco Ferrari with Lorenzo Breschi and Simone Grandini

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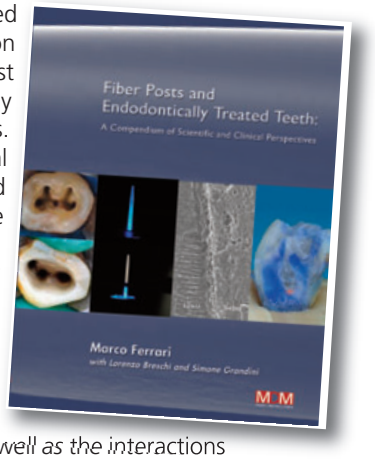

Fiber-reinforced composite posts represent a paradigm shift in restorative dentistry that emerged almost two decades ago. In combination with filled resins and adhesive technology, this addition to our therapeutic armamentarium has managed to slowly enclose on the quasi-monopoly of cast post and cores in restoring endodontically treated teeth. In his foreword, Carel Davidson justifiably underlines the need for continuous information regarding emerging and developing materials. Marco Ferrari goes further in the introduction by stating that in rapidly developing technological sectors, information may be obsolete by the time it is published. This clearly prompts the need for comprehensive publications that bridge the gap between the clinical aspect of the restorative treatment and the technological properties of materials.

Restoration of endodontically treated teeth using fiber-reinforced posts involves many materials, concepts, and procedures that belong to different medical and technological niches. The authors judiciously addressed the difficulty by dividing the topics in the different chapters of the book.

After chapter one in which the author introduces the book, chapter two reviews current knowledge on adhesion to intraradicular dentin. Differences between this substrate and coronal dentin and modifications that affect the dentin during post space preparation are highlighted as well as the interactions with the various adhesive systems. The clinical factors that influence the quality of the dentin/adhesive interface are also reviewed. A particular feature of his book is that it is intended as a sequel to "Fiber Post" published in 2002 by the same author. In that aspect, the authors chose not to replicate already published material but rather update existing data and add new trends and alternative therapeutic solutions such as polyethylene fiber post-core material.

Clinically, fiber-reinforced composite post restorations have to obey the same imperatives as their metallic counterparts. This book provides a very pertinent overview of the prerequisites for post placement namely endodontic treatment, retreatment, and post space preparation: it is an area where shear clinical practice has outstripped theoretical knowledge and the clear guidelines provided in chapters four through six are both updated and useful. From another standpoint, it has been well established that the seal provided by permanent restorations is directly responsible for long-term success of endodontic treatments and chapter seven goes over procedures and techniques susceptible of improving interfacial properties of metal-free, resin-based, fiber-reinforced composite restorations.

An interesting addition to the book is the next chapter, inasmuch as it explores laboratory procedures, and how data might be interpreted and extrapolated to clinical situations. Such details are usually not present in textbooks as they are more relevant to researchers and less to clinicians. The authors take here the time to explain to the reader how to take better advantage of the results published in research papers by understanding the actual research protocols and their limitations.

Self-adhesive technology gained in importance in the past few years and offers promising new horizons in restorative dentistry, especially when used as a complement to fiber posts. In that aspect, chapter nine reviews the current state of the art in matters in self-adhesion from basic materials science to clinical application, describing in detail how this new trend may fit into the metal-free restoration philosophy.

The next 2 chapters encompass fracture of endodontically treated teeth restored using fiber-reinforced resin posts with or without crown coverage. The authors review the current literature regarding the mechanical resistance of such restorations and discloses the amazing properties of fiber posts in improving the resistance of endodontically treated teeth. They then explain how theoretical mathematical models of these restorations are used to confirm the experimental findings through finite element analyses.

A legitimate question would be to know how do these theoretical considerations translate clinically. Chapter twelve presents a rather pertinent overview of clinical trials conducted on fiber posts and adhesive restorations moving the reader from the in vitro laboratory tests environment to chairside clinical tests. It is interesting to notice that going beyond the rigidity of theoretical testing, the inherent flexibility of clinical work displays an even more attractive image of fiber posts.

In the last chapter, Franklin Tay reflects on the changes in clinical practice that have been achieved with fiber posts and adhesive technology. He goes one step further by imagining what could be the future of fiber-reinforced restorations based on the breakthroughs and new perspectives investigated in other high-tech fields such as nanocomposites, nanotubes, variable fiber geometry, and self-repairing materials. However, he emphasizes on the necessity of scientists and clinicians working together to answer the need for realistic appraisal of new techniques in a general practice setting and the changing emphasis of consumer demand with aesthetics becoming a prime concern, almost equaling restoration longevity as the main criteria for materials choice.

This book is rigorous in its form and methodical in its approach. High-quality graphics illustrate appropriately the different chapters and help in visualizing several concepts or clinical situations as they favorably complete the text. The book displays an excellent balance between basic research and clinical practice and helps improving patient care by unraveling the secrets of state of the art composite and adhesive materials. It should prove a valuable reference for those dentists who are always on the lookout to improve their clinical practice as it helps bridge the gap between the technology of modern materials and the appropriate clinical application protocols.

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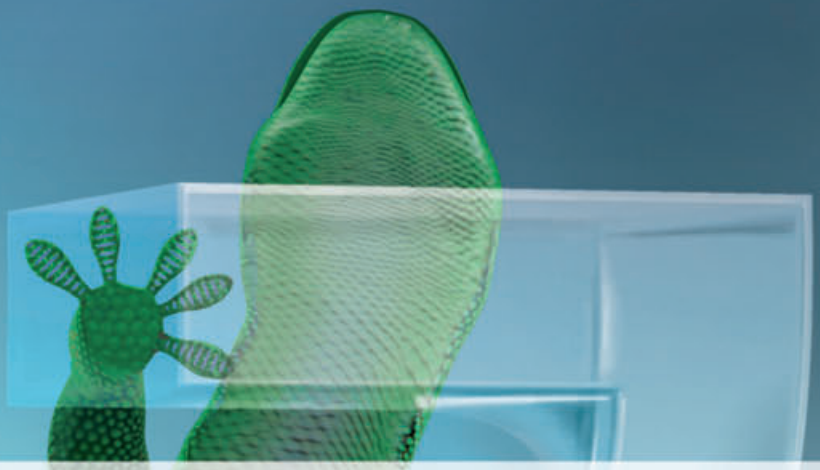

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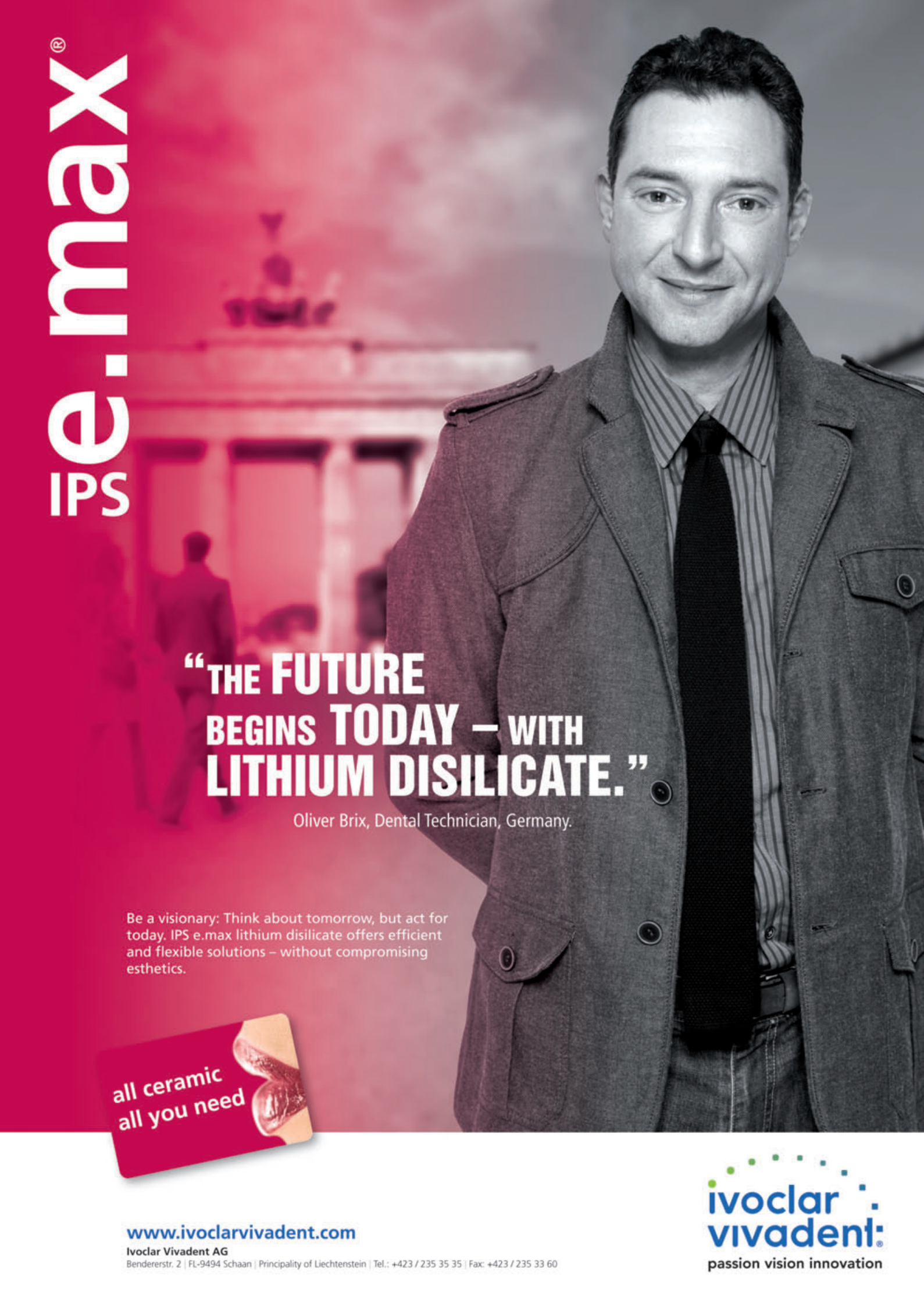
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