phosphoproteins in tooth structure share remarkable similarity. When hard tissues are demineralized, the phosphoproteins which remain influence the ability of this tissue to remineralize.

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. 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.

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.

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. 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).

Conversely, under low calcium concentrations, remineralization is a chemical impossibility. There are significant inter-individual and time-related variations in pH, buffer capacity, and salivary concentrations of calcium and phosphate. These changes impact directly on the likelihood of mineral loss and gain, in terms of both dental erosion and dental caries.

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}

### Table 1

Requirements of an ideal remineralization material

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuses into the subsurface, or delivers calcium and phosphate into the subsurface</td>
</tr>
<tr>
<td>Does not deliver an excess of calcium</td>
</tr>
<tr>
<td>Does not favour calculus formation</td>
</tr>
<tr>
<td>Works at an acidic pH</td>
</tr>
<tr>
<td>Works in xerostomic patients</td>
</tr>
<tr>
<td>Boosts the remineralizing properties of saliva</td>
</tr>
<tr>
<td>For novel materials, shows a benefit over fluoride</td>
</tr>
</tbody>
</table>

Based on Zero, 2006.

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. 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 remineral balance in human subjects without actually causing caries in the natural dentition of those subjects.

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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. 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. A pH less than 5 causes loss of adsorbed phosphate, and triggers a slow dissolution of the calcium fluoride. To increase its surface area, nano-sized particles of calcium fluoride have been prepared, with a diameter of some 41nm. 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,
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. 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(PO₄)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). 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 as Proxal®, Proxal® 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. 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 cream, 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 casin 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 apatites. 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.

**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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**Table 2**

Some key proteins which stabilize calcium and phosphate

<table>
<thead>
<tr>
<th>Saliva</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>statherin</td>
<td></td>
</tr>
<tr>
<td>acidic proline-rich proteins</td>
<td></td>
</tr>
<tr>
<td>histatins</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td></td>
</tr>
<tr>
<td>Alpha and beta caseins</td>
<td></td>
</tr>
<tr>
<td>Hard tissues</td>
<td></td>
</tr>
<tr>
<td>Ameloblastin</td>
<td></td>
</tr>
<tr>
<td>Enamelin</td>
<td></td>
</tr>
<tr>
<td>Osteopontin</td>
<td></td>
</tr>
<tr>
<td>Bone sialoprotein</td>
<td></td>
</tr>
<tr>
<td>Dentine sialoprotein</td>
<td></td>
</tr>
</tbody>
</table>

Based on Huq et al. 2005®

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. This, however, is not a realistic manner in which to test for the true remineralizing capabilities of a particular agent or formulation.

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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. 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. 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. 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. 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. 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 cream, 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 casin phosphopeptides.

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PROGRAMME ANNOUNCEMENT

OSSEOINTEGRATION CONGRESS
2nd INTERNATIONAL CONGRESS ON IMPLANT DENTISTRY

IMPLANT COMPLICATIONS
From Treatment Planning to Solutions

8 – 10 March 2012
International Convention Centre, Cape Town, South Africa

Jointly presented by: The Global Council for Osseointegration (GCO), supported by the European Association for Osseointegration (EAO), The Cape Society for Dental Implantology (CSDII) and the South African Society for Dental Implantology (SASDI)

In association with: SBS Conferences

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 groundbreaking 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
Session 3: 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 Elie M Pinho, Denmark
Dr Franck Ronquer, 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 Rabele Goethem, South Africa
Dr Nel Sturdivant, South Africa
Dr Dale Howes, South Africa
Dr Werner Joubert, South Africa
Dr Johann Lochner, South Africa
Dr Jacques Malan, South Africa
Dr Johan Malan, South Africa
Dr Thabiti Peck, South Africa
Dr Lourens Swart, South Africa
Dr Wynand van der Linden, South Africa
Dr Peter van der Meulen, South Africa
Dr Hans van Heerden, South Africa
Prof André van Zyl, South Africa
Dr Paul van Zyl, South Africa
Dr Christian Vorster, South Africa
Dr Rone Walters, South Africa
Dr Gerrit Wyna, 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.

Enquiries: SBS Conferences
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Email: registrar@sbs.co.za | Website: www.sbs.co.za/oc2012

www.sbs.co.za/oc2012
Walsh

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. Recent data for bioavailable calcium and phosphate suggest only a low bioavailability from NovaMin. 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.

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. Enamelon™ is a dentifrice which is explicitly free of fluoride. Recent data for bioavailable calcium and phosphate suggest only a low bioavailability from NovaMin.

Table 3
Summary of current technology as at February 2009

<table>
<thead>
<tr>
<th>Material</th>
<th>Publication</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClinPro Tooth Crème™</td>
<td>1</td>
<td>Preliminary</td>
</tr>
<tr>
<td>NovaMin™</td>
<td>1</td>
<td>Preliminary</td>
</tr>
<tr>
<td>DCPD</td>
<td>2</td>
<td>Preliminary</td>
</tr>
<tr>
<td>Pronamel™</td>
<td>2</td>
<td>Preliminary</td>
</tr>
<tr>
<td>Enamelon™</td>
<td>3</td>
<td>Preliminary</td>
</tr>
<tr>
<td>ACP</td>
<td>4</td>
<td>Preliminary</td>
</tr>
<tr>
<td>Various Ca compounds</td>
<td>10</td>
<td>Preliminary</td>
</tr>
<tr>
<td>CPP-ACP/ACFP</td>
<td>45</td>
<td>Systematic reviews</td>
</tr>
<tr>
<td>Fluoride</td>
<td>&gt;5000</td>
<td>Systematic reviews</td>
</tr>
</tbody>
</table>

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.

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.

NovaMin™
NovaMin™ is a bioactive glass containing calcium sodium phosphosilicate, and comprises 45% SiO₂, 24.5% Na₂O, 24.5% CaO and 6% P₂O₅. There is some evidence of desensitizing actions of NovaMin™, as seen in a 6 week clinical trial, and some evidence regarding reductions in plaque index and gingival index, 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 website, 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. Recent data for bioavailable calcium and phosphate suggest only a low bioavailability from NovaMin. 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.

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. 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 remineralization.

The predominantly surface action of ACP does however explain its desensitizing effects,59,60 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 bioavailable 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 remineralization 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 mutants 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 suppress 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 CaHPO₄. 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 crémes.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 crémes such as MI Paste and Tooth Mousse75 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-ACP 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-51 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”.90,91 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.92

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 2006.93 It is perhaps not surprising given its ontogeny, particularly its similarity to other proteins which stabilize calcium and phosphate in body fluids (Table 2).94

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 technology95 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

Raffaele Paragliola,1 Vittorio Franco,2 Cristiano Fabiani,3 Luciano Giardino,4 Flavio Palazzi,5 Nicoletta Chieffi,6 Hani F. Ounsi,7 Simone Grandini8

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 walls2 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...
intracanal medications, into the dentinal tubules, 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.

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. 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.

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. The combination of these substances is capable of removing the smear layer, mainly from the middle and cervical thirds. However, the application of EDTA for more than 1 minute and in volume more than 1 ml 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. 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.

In 2003, Torabinejad proposed the use of an irritant to be used in association with 1.3% NaOCl to remove smear layer from canal walls and facilitate the elimination microorganism from infected dentin. This irritant (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 demonstrated the efficacy of this solution, other studies have shown several important limits. Tay et al. demonstrated that the solution was more aggressive against intertubular dentin, leading to a reduction of collagenic matrix exposed. A new irritant, 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. It is similar to MTAD but with a reduced amount of doxycycline (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
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 performed for 1 minute.
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irrigant used. When the levels were compounded, groups were ranked in the following order: 1>2 ≥ 3=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).

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

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≥3=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).

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.3.10.11 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 peri tubular dentin,11 1 min 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 when used without a chelant. When considering the whole root canal it was evident that the use of a chelant 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 peri tubular 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 al19 and Haznederozlu and Ersav20 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.21 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.2 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.23 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.24 Shuping et al.25 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.26 For this reason it was decided to prepare the apical foramens 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 antibiotic susceptibilities. 

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.

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The authors deny any conflict of interest.

References
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 the 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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