DOI: 10.14260/jemds/2015/1544

REVIEW ARTICLE

REMINERALIZATION: AN APPROACH TOWARDS CONSERVATION OF TOOTH

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HOW TO CITE THIS ARTICLE:
Arun Verma, Saif Khurshid, Farah Parveen, Shruti Khanna, Piyush Pandey. "Remineralisation: An Approach towards Conservation of Tooth". Journal of Evolution of Medical and Dental Sciences 2015; Vol. 4, Issue 61, July 30; Page: 10713-10719, DOI: 10.14260/jemds/2015/1544

ABSTRACT: Remineralisation and demineralization have a significant impact on the strength and hardness of dental enamel. Since there is no connection between the bloodstream and tooth enamel, mineral supplements have no impact on the remineralisation process. Fluoride toothpastes have well- documented anti-caries benefits when used regularly. However, caries remain widespread in the population. During the past seven years there has been increased interest and development in the field remineralisation technology. Since these technologies are relatively new, the goal of this article is to increase the clinician's knowledge of the demineralization/remineralisation process, the products available, and ideas for implementation into daily practice.

KEYWORDS: Remineralisation, Fluoride, CPP-ACP, Ozone, Giomers.

INTRODUCTION: During the past seven years there has been increased interest and development in the field remineralisation technology. Since these technologies are relatively new, the goal of this article is to increase the clinician's knowledge of the demineralization/remineralisation process, the products available, and ideas for implementation into daily practice.

Remineralisation and demineralization have a significant impact on the strength and hardness of dental enamel. Remineralisation and demineralization are processes that occur on the tooth surface. Since there is no connection between the bloodstream and tooth enamel, mineral supplements have no impact on the remineralisation process.[1,2]

Fluoride toothpastes have well- documented anti-caries benefits when used regularly. However, caries remain widespread in the population. The decline in caries resulting from the effects of fluoride may have ended or may be reversing. Therefore preventive oral health care and managing dental caries without destroying healthy tooth structures are emerging as important strategies.

Throughout dental care we interact with the patients at regular intervals, assessing and treating as their oral condition requires. The ongoing progression of disease in dental hard and soft tissue is often multifactorial. It does not have to be. The dental team must fully understand the disease process and then proactively intervene to slow or preferably stop its progress. This is the concept of "Proactive Intervention Dentistry".

Why Does a Tooth Dissolve in Acid?: Although the solubility of some minerals, such as sodium chloride, is virtually independent of pH, the solubility of HA increases about 10-fold for each unit decrease in pH. At pH 7, the solubility of HA in water is about 30 mg/L, whereas at pH 4 it is about 30g/L.2

There are 2 reasons for the increased solubility of enamel in acid. First, the hydrogen ions remove hydroxyl ions to form water, as follows: H++ OH–H2O. The product of [H+][OH–] in water always equals 10–14 (mol/L) 2. Therefore, as the [H+] increases in an acid solution, the [OH–] must decrease in a reciprocal manner.

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Second, the inorganic phosphate in any fluid such as saliva or plaque fluid is present in 4 different forms, namely H3PO4, H2PO4–, HPO42– and PO43–, and the proportions depend entirely on the pH. Proportions of the 4 phosphate species vary with pH when the total phosphate concentration is 5.10–3mol/L, as is typical of saliva. The lower the pH, the lower the concentration of PO43–, the only species that contributes to the Ip of HA. Thus, as any solution is acidified, the calcium concentration is unaffected but the concentrations of both OH– and PO43– are reduced and so, therefore, is the Ip, often to a value less than the Ksp.

MECHANISM: Multiple events must occur at the same time for remineralisation to proceed. A molecule of carbonic acid must be produced. A very small fraction of the carbon dioxide from the breath is converted to carbonic acid. The carbonic acid molecule must be produced in proximity to a mineral molecule, which then dissolves into its ionic components.

The demineralized spot has to be clean and accessible so the mineral ion is attracted to the "hole" in the lattice by the opposite electric charges of the ion and the "hole." Many different ions have the correct charge, but only the correct ion has the correct shape and size to fit into the "hole." This all has to occur in proximity to a demineralized spot in the hydroxyapatite latticework that requires the exact mineral ion.

Sufficient minerals must be present in the saliva. Food is the principal source of minerals for the teeth, therefore an adequate diet and sufficient time spent chewing (This transfers minerals to the saliva) is vital.

The carbonic acid must convert to carbon dioxide and water before any of the above circumstances change. When this happens, a mineral ion is precipitated out of solution into the structure of the enamel.

ROLE OF PH & SALIVA IN REMINERALISATION: Human saliva has a marked ability to reharden softened enamel surfaces. This ability varies for individuals but seems to be fairly constant for each individual. The rehardening capacity of saliva is, however, less than that of synthetic solutions of calcium, phosphate and fluoride ions, both in rate and ultimate restoration of hardness. During the rehardening process, the pH of saliva usually rises about 0.3 to 0.4 units during each two hour exposure period, and this rise may have affected the results. In addition to the deposition of minerals, the deposition of organic material from the saliva may account for the lower rehardening values. In this connection, it is interesting that Savory and Brudevold (1959) found increased organic material in the outer surface of teeth extracted from older persons. A similar trend of increased organic material very likely originating from saliva was indicated in studies of specific gravity and nitrogen content of altered enamel (Bhussry, 1956, 1958, and 19586; Little, Cueto and Rowley, 1962).

REMINERALIZING AGENTS:

Fluoride: Fluoride ions promote the formation of fluorapatite in enamel in the presence of calcium and phosphate ions produced during enamel demineralization by plaque bacterial organic acids. Fluoride ions can also drive the remineralization of previously demineralized enamel if enough salivary or plaque calcium and phosphate ions are available. Availability of calcium and phosphate ions can be the limiting factor for net enamel remineralization to occur this is highly exacerbated under xerostomic condition.

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Fluoride Mechanisms: When fluoride is applied to the tooth substrate, for every two fluoride ions, 10 calcium ions and six phosphate ions are required to form one unit cell of fluorapatite (Ca10(PO4)6F2). Free fluoride ion combines with H+ to produce hydrogen fluoride, which migrates throughout acidified plaque. This ionized form is lipophilic and can readily penetrate bacterial membranes. Bacterial cytoplasm is relatively alkaline, which forces the dissociation of H+ and F-. Fluoride ion inhibits various cellular enzymes (Enolase, proton extruding ATPase) key to sugar metabolism. Hydrogen ions simultaneously acidify the cytoplasm, thus slowing cellular activities and inhibiting bacterial function. The fluoride integrated in the enamel surface (As fluorapatite, FAP) makes enamel more resistant to demineralization than HAP during acid challenge. Fluorapatite is less solublew due to incorporation of fluoride and washing out of carbonate. Fluoridated saliva not only decreases critical pH, but also further inhibits demineralization of the deposited Calcium fluoride at the tooth surface.[3]

Bioactive Glass: Bioglass one of the most important formulations, is composed of SiO2, Na2O, CaO and P2O5. Professor Larry Hench developed Bioglass at the University of Florida in the late 1960s.[4] Brauer et al. performed a study to understand the effect of addition of fluoride in the properties of bioactive glasses. CaF2 concentration was increased in SiO2-CaO-P2O5-Na2O system. The incorporation of fluorine made it more bioactive.[5] LitKowski et al. conducted an in vitro study on dentinal surfaces of teeth and demonstrated increased occlusion of dentinal tubules. Thereby proposed that it should also decrease dentine hypersensitivity in vivo.[6] In addition to remineralization, bioactive glasses have antibacterial effects, as they can raise the pH of aqueous solution.[7, 8]

Mechanism: There is a rapid exchange of Na+ or K+ or H3O+ from solution. This stage is usually controlled by diffusion and exhibits a t-1/2 dependence. There is loss of soluble silica in the form of Si (OH4) to the solution, resulting from breakgae of Si-O-Si bonds and formation of Si-OH (silanols) at the glass solution interface. This stage is usually controlled by interfacial reaction and exhibits a t1.0 dependence. Condensation and repolymerization of a SiO2- rich surface is depelted in alkalis and alkaline-earth cations. Migration of Ca2+ and PO3- 4 groups to the surface through the SiO2- rich layer forming a CaO-P2O5 rich film on top, followed by growth of amorphous CaO-P2O5 rich film by incoporation of soluble calcium and phosphates from solution. Crystallization of this film forms a mixed hydroxyl, carbonate, fluorapatite layer.

Theobromine: Theobromine (3, 7-dimethylxanthine), a white crystalline powder, is an alkaloid readily available in cocoa (240mg/cup) and chocolate (1.89%). Its levels are higher in dark chocolates (approximately 10 g/kg) than in milk chocolates (1–5g/kg). Higher-quality chocolate tends to contain more theobromine than lower-quality chocolate. The mean theobromine content of cocoa beans is approximately 20.3 mg/g [Craig and Nguyen, 1984]. In view of the above animal studies [Nakamoto et al.,1999, 2001] that demonstrated less 'net' dissolution of the various minerals from the enamel surface exposed to theobromine compared to the non-theobromine group, further studies using human teeth were conducted to investigate how theobromine exposure may alter the enamel surface in vitro [Sadeghpour and Nakamoto, 2011; Kargul et al., 2012]. The results indicated that the microhardness of the enamel surface of the theobromine group was greatly enhanced compared to the fluoride group.

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CPP-ACP AND CPP-ACPF: CPP-ACP substantially increases its ability to remineralize enamel subsurface lesions. In a commercial paste containing CPP-ACP minerals are available in a soluble form as they are carried in a special milk-derived protein known as RECALDENT TM (CPP-ACP).[9] Similar to GC Tooth Mousse, Tooth Mousse Plus contains RECALDENT TM (CPP-ACP) and fluoride (CPP-ACPF: casein phosphopeptide-amorphous calcium phosphate fluoride). The role of fluoride in strengthening and protecting teeth has been long understood and it is recognised that controlled fluoride uptake into teeth helps to promote a stronger and more acid resistant tooth structure.[10] The level of fluoride in Tooth Mousse Plus is 0.2%, or 900 parts per million (ppm) fluoride ions, a level just below that found in normal adult-strength toothpastes (1000ppm).

Fluoride together with calcium and phosphate in the correct ratio, is more effective at providing greater anti-caries protection. Significant difference has been found in dentin. There have been several reports of a substantial reduction in the numbers of cariogenic micro- organisms remaining in soft carious.

Tricalcium Phosphate (TCP): TCP is a bioactive formulation of tri-calcium phosphate and simple organic ingredients. It works synergistically with fluoride to produce superior remineralization of enamel subsurface lesions when compared to using fluoride alone.[11,12] When it is used in toothpaste formulations, a protective barrier is created around the calcium, allowing it to coexist with the fluoride ions. During tooth brushing, TCP comes into contact with saliva, causing the barrier to dissolve and releasing calcium, phosphate and fluoride.

Functionalized tri-calcium phosphate, is a smart calcium phosphate system that controls the delivery of calcium and phosphate ions to the teeth, works synergistically with fluoride to improve performance. Since the structure of TCP is similar to HA, once the functionalized calcium ions are released, they readily interact with the tooth surface and subsurface. While other calcium phosphate additives may require an acidic pH, TCP can offer optimal benefits when delivered in a neutral pH environment. This TCP ingredient can enhance mineralization and help build a high quality, acid-resistant mineral without the need for high levels of calcium.

TCP protects against lesion initiation and progression, prevents mineral loss, decreases hypersensitivity, sustains fluoride availability, prevents early lesions and also TCP is used in water fluoride systems.

GLASS IONOMER CEMENTS: Major developments in dental materials have resulted in products with improved mechanical properties, as well as improved adhesion to tooth structure, biocompatibility, anti-carcinogenicity and aesthetics. Glass ionomer cements were developed in the early 1970s.

They are especially valuable for initial carious lesions, abfractions/erosions/abrasions and for caries control in a high caries risk patients.

Glass ionomers have a true chemical bond with dental tissue. They are bioactive; they encourage remineralization of the surrounding tooth structure and prevent bacterial microleakage through the ion-exchange adhesion that they develop with both enamel and dentin. This creates a new, ion-enriched material at the tooth-glass ionomer interface. The material consists of phosphate and calcium ions from the dental tissues, and calcium (or strontium), phosphate and aluminum from the glass ionomer cement. The remineralization process creates a harder dentin surface. Restoration failure is usually cohesive, leaving the ion exchange layer firmly attached to the cavity wall. The

dentinal tubules are sealed and protected from bacterial penetration. Prominent among these materials is polyalkenoate/man made dentin/glass (ionomer) cement (GIC).

BIOACTIVE RESTORATIVE MATERIALS: Although the contribution of fluoride in reducing caries levels in the clinical field is well justified, it still appears to be inadequate in some subjects, for example, those with either a high caries incidence or frequent dietary or gastric acid erosive challenges. This highlights the need to find new strategies to promote the enamel remineralisation process or reduce the demineralisation process, with bioactive materials being one of the promising new leads.

"A bioactive material is defined as a material that stimulates a beneficial response from the body, particularly bonding to host bone tissue and to the formation of a calcium phosphate layer on a material surface." Bioactive materials including bioactive glasses, glass-ceramics and bioceramics have been studied as artificial materials for bone grafting. As the tooth is also a kind of bone tissue, bioactive materials have been considered for potential dental applications.

Ozone: Ozone (O3) is a powerful oxidizing agent which neutralizes acids and effects on cell structures, metabolism of micro-organisms.[13,14] O3 attacks many biomolecules - cysteine, methionine, histidine residues of proteins and change the surface ecology of the carious lesion. Ozone plays an important role in caries reversal by shifting the microbial flora in carious lesion to one containing normal oral commensals. Reversals of primary root caries lesions by remineralizing plus reduction in acidogenic and aciduric micro-organisms.[15] some proteins, which are natural inhibitors to remineralization are reduced. Bioavailable minerals - patients supersaturated saliva, aided by the remineralizing rinses, sprays and toothpastes. Currently only one device that has approval for the treatment of caries in the mouth – Heal Ozone (KaVo GmbH, Germany). 2100 ppm of ozone ±5% at a flow rate of 615 cc/minute for 40s is regularly used. Heal Ozone remineralizing solution contains xylitol, fluoride, calcium, phosphate and zinc.[16]

Giomer: Giomers (Shofu Dental, San Marcos, CA) are the latest category of hybrid restorative materials and they are bioactive as well. Giomer technology represents the true hybridization of glass ionomers and composite resins. There is an ideal combination of the properties of these two distinct restorative Categories: the fluoride release and recharge of glass ionomers and the esthetics, physical properties and handling of composite resins.

The Giomer concept in based on PRG (Pre Reacted Glass) technology: a glass core, surrounded by a glass ionomer phase enclosed within a polyacid matrix. Studies show that dentin remineralization occurs at the preparation surface adjacent to the giomer. The ions within the pre reacted glass particles have distinct biological effects. The fluoride, as discussed above, improves acid resistance through the formation of fluorapatite, remineralizes decalcified tooth substance and is antibacterial.

CONCLUSION: Prevention of dental caries by remineralization is a whole new concept and philosophy focusing on intervention at the earliest possible stage with long term protection of the patient as a whole entity. In the upcoming future, it will lead to more conservation towards human health rather than conserving the tooth by the use of restorations.

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DOI: 10.14260/jemds/2015/1544

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FINANCIAL OR OTHER COMPETING INTERESTS: None

Date of Submission: 11/07/2015.
Date of Peer Review: 12/07/2015.
Date of Acceptance: 24/07/2015.
Date of Publishing: 30/07/2015.