REMINERALIZATION: A DENTAL SUCCESS STORY

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ABSTRACT

Human dentin is a hard, avascular & heterogenous tissue with tubular as well as calcified structures present throughout its thickness. This is a tissue which we so fondly like to preserve, nurture, care for and treat. Dental caries is a continuous and unidirectional process of demineralization. Reviving dentin in deep carious lesion is crucial for protection of pulp against various insults. It is still a tough task to remineralize dentin. Modern day dentistry focuses on remineralization of demineralized dentin via biomimetic strategy and noninvasive treatment modalities using various remineralizing agents thereby preserving dentin to maximum extent possible.

Keywords: Dentin, Demineralization, Remineralization, Biomimetic strategy, Remineralizing agents.

INTRODUCTION

Dental caries is caused by the by-products (organic acids) of bacteria present in the biofilm on tooth; the organic acids which are produced by bacteria, damage dental hard tissues and structures, leading to tooth decay or cavities.[1]

The outer layer of caries is irreversibly denatured, infected and incapable of being remineralized, and this layer should be removed; the inner layer is reversibly denatured, shows no collagen breakdown, is not infected, and is capable of being remineralized and thus it should be preserved.[2] Therefore, the remineralizion of non-infected carious dentine is significant for retaining tooth tissues to a maximum degree during vital pulp therapy, which is in line with the concept of minimally invasive dentistry (MID).[3]

Currently, it is still a challenge to remineralize the remaining demineralized dentine in deep caries. Dentine remineralization is more difficult than enamel remineralization due to the abundant presence of organic matrix in dentine. This could be attributed to an accepted notion that dentine remineralization occurs neither by spontaneous precipitation nor by nucleation of mineral on the organic matrix (mainly type I collagen).[4] Remineralization is a natural repair process, 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.[5]

Remineralization can be done by various remineralizing agents namely, Fluorides, Non-fluoride remineralizing agents, Herbal products, Self assembling peptides, Electric field- induced remineralization etc.

REQUIREMENTS OF A REMINERALIZING AGENT

- Should deliver calcium and phosphate into the sub-surface
- Should not deliver any excess of calcium

- Should not favor calculus formation
- Should work at an acidic pH so as to stop demineralization during a carious attack
- Should be able to work in xerostomic patients as saliva cannot effectively stop the carious process
- Should be able to boost the remineralizing properties of saliva
- The novel materials should be able to show some benefits over fluoride.[6]

INDICATIONS

- As adjunct preventive therapy to reduce caries in high-risk patients
- Reduce dental erosion in patients with gastric reflux or other disorders
- To reduce decalcification in orthodontic patients
- To repair enamel in cases involving white-spot lesions
- Orthodontic decalcification or fluorosis, before and after teeth whitening and to desensitize sensitive teeth.[7]

CLASSIFICATION

- Fluorides
- Non-fluoride remineralizing agents

➢ Alpha tricalcium phosphate (α-TCP) and beta TCP (β-TCP)

➢ Amorphous calcium phosphate

➢ CPP–ACP (Casein phosphopeptide-amorphous calcium phosphate)

➢ Sodium calcium phosphosilicate (bioactive glass)

➢ Xylitol

➢ Dicalcium phosphate dehydrate (DCPD)

➢ Nanoparticles for remineralization

- Calcium fluoride nanoparticles
- Calcium phosphate-based nanomaterials.
- NanoHAP particles (Nano-Hydroxyapatite particles)
- Amorphus Calcium Phosphate nanoparticles (ACP nanoparticles)
- Nanobioactive glass materials
- Polydopamine
- Proanthocyanidin (PA)
- Oligopeptides
- Theobromine
- Arginine
- Self-assembling peptides
- Electric field-induced remineralization.[8]

FLUORIDES

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.[9]

Mechanism of action of Fluoride

Fluoride inhibits demineralization because the fluorapatite crystals, formed after reaction with enamel apatite crystals, are more resistant to acid attack compared to HAP crystals. Second, fluoride enhances remineralization as it increases the growth of the new fluorapatite crystals by bringing calcium and phosphate ions together. Third, it inhibits the activity of acid producing carious bacteria, by interfering with the production of phosphoenol pyruvate (PEP) which is a main intermediate of the glycolytic pathway in bacteria. And, the flouride retains on dental hard tissue, the oral mucosa and in the dental plaque to decrease demineralization and enhance remineralization.[10]

TRI-CALCIUM PHOSPHATE

TCP is a new hybrid material created with a milling technique that fuses beta tricalcium phosphate (β-TCP) and sodium lauryl sulfate or fumaric acid. This blending results in a "functionalized" calcium and a "free" phosphate, designed to increase the efficacy of fluoride remineralization.[11] It provides a barrier that prevents premature TCP–fluoride interactions and also, facilitates a targeted delivery of TCP when applied to the teeth.[12]

AMORPHUS CALCIUM PHOSPHATE

ACP is the initial solid phase that precipitates from a highly supersaturated calcium phosphate solution and can convert readily to stable crystalline phases such as octacalcium phosphate or apatite products.[12] The conversion of ACP to apatite at physiological pH; initially, there is dissolution of ACP, then reprecipitation of a transient OCP solid phase through nucleation growth, and, finally, hydrolysis of the transient OCP phase into the thermodynamically more stable apatite by a topotactic reaction.[13]

CPP–ACP

This is a protein nanotechnology, where CPP is a milk-derived protein, and it can stabilize clusters of ACP into CPP–ACP complexes , because at neutral pH, the “acidic motif” in CPP is a highly charged region which can bind to minerals such as Ca2+, Zn2+, Fe2+, Mn2+, and Se2+. CPP–ACP is a two-phase system which when mixed together reacts to form the ACP material that precipitates onto the tooth structure and elevates calcium levels in the plaque fluid.[6] It is available as toothpastes, chewing gum, lozenges, and mouth rinses.[14]

BIOACTIVE GLASS

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.[15] Bioglass (BG) is a class of bioactive material which is composed of calcium, sodium, phosphate, and silicate. They are reactive when exposed to body fluids and deposit calcium phosphate on the surface of the particles. BG particles get deposited onto dentine surfaces and subsequently occlude the dentinal tubules by inducing the formation of carbonated HAP-like materials.[16]

XYLITOL

Xylitol is a non-cariogenic five-carbon sugar alcohol that occurs naturally in plants and is used as a substitute for sugar. Sources are fruits, berries, mushrooms, lettuce, hardwoods and corn on the cob. It reduces dental plaque formation, make plaque less adhesive, neutralizes plaque acids by decreasing the production of lactic acid, reduces the levels of S. mutans, assist in the remineralization of tooth enamel, increases salivary flow, help with dry mouth and bad breath. Xylitol has been employed for many years as a non-acidogenic sweetener in numerous applications as it cannot be fermented by plaque bacteria. It works by interfering with the metabolism of S. mutans. When S. mutans is transported into a cell, xylitol makes it to bind to proteins. This bond is unbreakable and the transport protein is unable to go out of the cell and bring more glucose into the cell. Because the bacteria are bound, they are unable to produce the sticky extracellular polysaccharides that bind bacteria together. As a result, there is less plaque buildup and the decay-causing bacteria cannot stick to the enamel.[17] It has also been shown that a combination of fluoride and xylitol is more effective than fluoride alone.[18]

NANOPARTICLES

Nanoparticles have better ion release profiles than microparticles. Since it is difficult to directly use nanomaterials to remineralize teeth in the oral environment, these materials are often added to restorative materials as inorganic fillers, such as resin composites to release calcium, phosphate, and fluoride ions for remineralization of dental hard tissues.[19]

The addition of nanoCaF2 increases the cumulative fluoride release compared to the fluoride release in traditional glass ionomer cements because the CaF2 nanoparticle (nano-CaF2) has a 20-fold higher surface area compared with traditional glass ionomer cements.[19]

Calcium Phosphate nanomaterials include nanoparticles of HAP, TCP, and ACP as sources to release calcium/phosphate ions and increase the supersaturation of HAP in carious lesions.[19]

ACP Nanoparticles are small spheroidal particles. ACP nanoparticles, as a source of calcium and phosphate ions, have been added to composite resins, ionomer cements, and adhesives.[19] In vitro studies by Xu Zhang have confirmed that the remineralizing rate of CMC–ACP complexes' treatments were significantly higher than that of fluoride treatment.[1]

PROANTHOCYANIDINS

Polyphenols are plant-derived substances that have antioxidant and anti-inflammatory properties. They interact with microbial membrane proteins, enzymes and lipids, thereby altering cell permeability and permitting the loss of proteins, ions and macromolecules. One such polyphenol is proanthocyanidin (PA), which is a bioflavanoid-containing benzene-pyran-phenolic acid molecular nucleus.[20] The PA accelerates the conversion of soluble collagen to insoluble collagen during development and increases collagen synthesis.[21]

Grape seed extract (GSE) has a high PA content. PA-treated collagen matrices are non-toxic and inhibit the enzymatic activity of glucosyl transferase, F-ATPase and amylase. Inhibition of glucosyl transferases by PA in turn inhibits caries. GSE can act as a potential adjunct or alternative to fluoride in the treatment of root caries during minimally invasive therapy.[22]

SELF-ASSEMBLING PEPTIDE

Treatment with peptide gives combined effect of increased mineral gain and inhibition of mineral loss from the tooth. The β-sheet-forming peptides, P114, that self-assemble themselves to form three-dimensional scaffolds under defined environmental conditions have been shown to nucleate HAP. The anionic groups of the P114 side chains attract Ca++ ions, inducing the precipitation of HAP in situ.[23]

ELECTRIC FIELD-INDUCED REMINERALIZATION

This technique remineralize the completely demineralized dentin collagen matrix and also to shorten the mineralization time, which it achieved in the absence of both calcium phosphates and their analogs with the help of electrophoresis.[24]

CONCLUSION

Modern day dentistry, nowadays, has been directed toward a conservative approach, out of which remineralization procedures are the most preferred and optimal way of regeneration of lost tooth structure. Minimal intervention dentistry is not a strategy, it is a philosophy. The future of dentistry will rely on regeneration of tooth structure. Understanding the remineralization process allows dentist to treat the lesion before cavitation. An attempt has been made to review the various remineralization agents and technologies currently being employed to remineralize dentin. More clinical trials are required for better success in the remineralization of dentin.

REFERENCES

1. Chen Z, Cao S, Wang H, Li Y, Kishen A, Deng X, Yang X, Wang Y, Cong C, Wang H, Zhang X. Biomimetic remineralization of demineralized dentine using scaffold of CMC/ACP nanocomplexes in an in vitro tooth model of deep caries. PLoS One. 2015 Jan 14;10(1):e0116553.

2. Sakoolnamarka R, Burrow MF, Kubo S, Tyas MJ. Morphological study of demineralized dentine after caries removal using two different methods. Aust Dent J. 2002 Jun;47(2):116-22.

3. Christensen GJ. The advantages of minimally invasive dentistry. J Am Dent Assoc. 2005 Nov 1;136(11):1563-5.

4. Klont B, Ten Cate JM. Remineralization of bovine incisor root lesions in vitro: the role of the collagenous matrix. Caries Research. 1991;25(1):39-45.

5. Featherstone JD. Dental caries: a dynamic disease process. Aust Dent J. 2008 Sep;53(3):286-91.

6. Walsh LJ. Contemporary technologies for remineralization therapies: A review. Int Dent SA. 2009 Jan;11(6):6-16.

7. Zero DT. Dentifrices, mouthwashes, and remineralization/caries arrestment strategies. BMC Oral Health. 2006 Jun; 6(1):S1-S9.

8. Arifa MK, Ephraim R, Rajamani T. Recent Advances in Dental Hard Tissue Remineralization: A Review of Literature. Int J Clin Pediatr Dent. 2019 Mar;12(2): 139–144

9. Featherstone JD. Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol. 1999 Feb;27(1):31-40.

10. Soi S, Vinayak V, Singhal A, Roy S. Fluorides and their role in demineralization and remineralization. J Dent Sci Oral Rehabil. 2013 Jul:19-21.

11. Karlinsey RL, Mackey AC. Solid-state preparation and dental application of an organically modified calcium phosphate.JMaterSci. 2009 Jan 1;44(1):346-9.

12. Li X, Wang J, Joiner A, Chang J. The remineralisation of enamel: a review of the literature. JDent. 2014 Jun 1;42:S12-20.

13. Kalra DD, Kalra RD, Kini PV, Prabhu CA. Nonfluoride remineralization: An evidence-based review of contemporary technologies. J Dent Allied Sci. 2014 Jan 1;3(1):24.

14. Amaechi BT, Van Loveren C. Fluorides and non-fluoride remineralization systems. Toothpastes. Monogr Oral Sci. Basel, Karger Publishers.2013;23:15-26.

15. Jones JR. Review of bioactive glass: from Hench to hybrids. Acta Biomater.2013 Jan 1;9(1):4457-86.

16. Andersson ÖH, Kangasniemi I. Calcium phosphate formation at the surface of bioactive glass in vitro. J BiomedMaterRes. 1991 Aug;25(8):1019-30.

17. Mäkinen KK. Can the pentitol-hexitol theory explain the clinical observations made with xylitol?. Medhypotheses. 2000 Apr 1;54(4):603-13.

18. Smits MT, Arends J. Influence of xylitol-and/or fluoride-containing toothpastes on the remineralization of surface softened enamel defects in vivo. Caries Res. 1985;19 (6):528-35.

19. Aggarwal S. Nanotechnology in endodontics: Current and potential clinical applications. Endod. 2016 Jan 1;28(1):78-78.

20. Ferrazzano GF, Amato I, Ingenito A, Zarrelli A, Pinto G, Pollio A. Plant polyphenols and their anti-cariogenic properties: a review. Molecules. 2011 Feb;16(2):1486-507.

21. Mount GJ, Ngo H. Minimal intervention: a new concept for operative dentistry. Quintessence Int. 2000 Sep 1;31(8):527-33.

22. Xie Q, Bedran-Russo AK, Wu CD. In vitro remineralization effects of grape seed extract on artificial root caries. JDent. 2008 Nov 1;36(11):900-6.

23. Amaechi BT. Remineralization therapies for initial caries lesions.Curr. Oral Health Rep.2015 Jun 1;2(2):95-101.

24. Wu XT, Mei M, Li QL, Cao C, Chen JL, Xia R, Zhang ZH, Chu C. A direct electric field-aided biomimetic mineralization system for inducing the remineralization of dentin collagen matrix. Materials. 2015;8(11):7889-99.

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