Sonic brushing and the delivery of fluoride through Streptococcus mutans biofilms

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The accumulation of dental plaque biofilms plays a role in the development of caries, gingivitis, and periodontitis. Bacteria in dental plaque biofilms constitute a visible community of microorganisms with complex ecological relationships. As the biofilm grows, it forms an irregular heterogeneous, irregular network of cells. The biofilm is composed of a matrix that acts as a reservoir for the bacteria and their metabolic byproducts. This matrix is composed of extracellular polysaccharides and other organic and inorganic materials.

Sonic brushing and the delivery of fluoride

Sonic brushing is a mechanical cleaning technique that uses high-frequency vibrations to dislodge plaque and biofilm from teeth. This process can enhance the delivery of fluoride to the biofilm, which can help prevent the development of dental caries.

Delivery of fluoride to the biofilm

The delivery of fluoride to the biofilm can be enhanced through the use of special toothbrushes and mouthwashes that contain fluoride. These products are designed to deliver fluoride to the biofilm, where it can be used to remineralize the tooth enamel and prevent the formation of new cavities.

The role of fluoride in preventing dental caries

Fluoride is a naturally occurring element that is found in water, food, and air. It is a key component of tooth enamel and helps to strengthen the teeth against acid attacks.

Fighting acid attacks

The formation of acids in the mouth, particularly by bacteria such as Streptococcus mutans, can cause the breakdown of tooth enamel and the formation of dental caries. Fluoride helps to neutralize these acids and protect the teeth from demineralization.

Conclusion

The use of fluoride in the prevention of dental caries is well-established. The delivery of fluoride to the biofilm can be enhanced through the use of special toothbrushes and mouthwashes that contain fluoride.

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References


Fig. 1: Schematic showing orientation of the brush (brushing chamber) to the biofilm colonized membrane (A), and the brushing chamber (biofilm side) and the fluoride electrode in the fluoride measurement chamber (B).

Fig. 2: In the left panel, fluoride is added to the brushing chamber and passes through a S. mutans biofilm after brushing into the measurement chamber, where fluoride accumulation is measured by specialized electrodes (a). Right panel illustrates the real-life brushing process in interproximal areas simulated by the in vitro experiment (b).

Fig. 3: Three-dimensional view of S. mutans biofilm grown on cellulose membrane and stained green with nucleic acid stains.

Acid formation from sucrose

Sonic brushing and the delivery of fluoride to the biofilm can prevent the formation of bacteria and their metabolic byproducts, which can help to reduce the development of dental caries.
following sonic brushing in the right hand chamber (Fig. 5). The brushing chamber was filled with 1,000 ppm fluoride solution, and over a four-minute monitoring period, the concentration in the measurement chamber never fell to less than 1,050 ppm, suggesting that the concentration gradient driving the fluoride film would remain more or less constant. Immediately prior to brushing, brush heads were positioned 1 cm from the biofilm-colonised membrane, to minimise biofilm removal during treatment, as the intent was to evaluate efficacy of fluoride delivery through the membrane rather than mechanical dislodgement of the biofilm. As fluoride diffused through the biofilm and membrane into the measurement chamber, fluoride accumulation measurements were recorded over a four-minute period, with 15 replicate measurements for the no-brushing control, and 17 replicates for the two power toothbrushes.

Results

Even with no brushing, fluoride concentration increased from 0.4 ppm to 0.5 ppm after four minutes, due to the difference in fluoride concentration between the two chambers (passive diffusion). With active brushing, the delivery of fluoride through the biofilm membrane increased considerably over the four-minute brushing period for both power toothbrushes. The fluoride concentration measured in the measurement chamber was 0.8 ppm after FlexCare brushing, while the concentration after Triumph brushing was 0.65 ppm (Fig. 4). Fluoride delivery rate through the colonised membrane was measured as the mass transfer coefficient, which was significantly greater with power brushing (P < 0.05) than with passive diffusion alone. FlexCare caused an increase of 129 per cent over no brushing compared to 79 per cent over no brushing for Triumph, while the mass transfer coefficient generated by FlexCare was significantly greater (P < 0.05), by 29 per cent than that generated by Triumph (Fig. 5).

Discussion and relevance

The application of an in vitro two-chamber method, to assess and compare rate of fluoride delivery through a viable microbial biofilm, is a useful one for comparative assessments of power brushing. S. mutans biofilms on esterase membranes are similar in structure to naturally grown human dental plaque biofilms. As this study demonstrated that fluid dynamics from powered brushing with both sonic and rotary brushes increased the transport of fluoride through the S. mutans biofilm compared with diffusion alone, the use of fluid dynamic activity generated by powered tooth brushing to enhance delivery of fluoride deep into the biofilm was significant. The potential for enhanced delivery becomes even more useful where plaque biofilms are located in hard-to-access areas that are typically beyond the impact of mechanical bristle activity, such that these biofilms could benefit from enhanced fluoride interventions. Clinically, a four-day trial revealed that sonic brushing increased the concentration of retained fluoride in plaque biofilm by more than 40 per cent compared to rotary brushing, manual brushing, and manual brushing and flossing. The combination of data from this clinical study and the in vitro data on enhanced fluoride delivery rates through S. mutans-colonised membrane biofilms indicates compelling evidence of the role of sonic brushing in driving fluoride into biofilms. Further research into the relationship between sonic brushing, fluid dynamic activity, and the role of oral biofilms in retention and delivery of other anti-cariogenic or anti-microbial agents should be explored. Many of the more pathogenic, anaerobic bacteria reside deeper in the plaque biofilm, where the availability of oxygen is low and they are protected from chemotherapeutic agents. However, this environment also represents a target area, where the potential is highest for improvement by increasing oxygen availability and by delivering anti-microbial agents directly to these anaerobes through sonic brushing. Should the enhanced delivery of fluoride be conclusively shown to result from the dynamics of sonic brushing-induced fluid motion, then the opportunity for delivering other broad-based, anti-cariogenic or anti-microbial agents as part of a regular oral brushing regimen will be significantly augmented.