Correlation between surface characteristics of different orthodontic materials and adherence of microorganisms

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Abstract

Orthodontic appliances serve as different impact zones and modify microbial adherence and colonization, acting as foreign reserves and possible sources of infection\(^1\). In a healthy situation, a dynamic equilibrium exists on these surfaces between the forces of retention and those of removal. However, an increased bacterial accumulation often results in a shift toward disease. Mechanisms favour the retention of dental plaque: adhesion and stagnation\(^2\). Through a careful analysis of the scientific literature, we want to analyze a correlation between surface characteristics of different orthodontic materials and adherence of microorganisms in orthodontic patients; we were chosen from "PubMed" several publications about surface characteristics, orthodontic materials, mutans streptococci, adhesion. Many studies of bacterial adhesion to orthodontic materials have been published. In addition, few studies have explained why oral bacteria differentially adhere to the different orthodontic materials\(^3\).

Introduction

In the oral cavity, an open growth system, bacterial adhesion to the non-shedding surfaces is for most bacteria the only way to survive\(^2\). Orthodontic appliances serve as different impact zones and modify microbial adherence and colonization, acting as foreign reserves and possible sources of infection. These appliances can be associated to difficulty in cleaning. During treatment, retentive areas are created that favor biofilm accumulation and bacterial growth\(^4\). One of the greatest challenges in orthodontics consists in maintaining proper oral hygiene during treatment. Brackets, bands and other accessories further aggravate these conditions by retaining dental plaque, which can lead to gingivitis and enamel demineralization, causing white spots and caries\(^5\). This adhesion occurs in 4 phases: the transport of the bacterium to the surface, the initial adhesion with a reversible and irreversible stage, the attachment by specific interactions, and finally the colonization in order to form a biofilm. Different hard surfaces are available in the oral cavity (teeth, filling materials, dental implants, or prostheses), all with different surface characteristics. Rough surfaces will promote plaque formation and maturation, and high-energy surfaces are known to collect more plaque, to bind the plaque more strongly and to select specific bacteria. Although both variables interact with each other, the influence of surface roughness overrules that of the surface free energy\(^2\). The placement of orthodontic appliances creates a favorable environment for the accumulation of microorganisms, which cause demineralization or exacerbate the effects of any preexisting caries. The incidence of enamel demineralization after fixed orthodontic appliance can involve up to 50% of the patients\(^6,7\). Enamel demineralization is a commonly recognized complication of orthodontic treatment with a fixed orthodontic appliance. The enamel demineralization is caused by organic acids produced mainly by mutans streptococci (MS), which have been shown to be the prime causative organisms of dental caries\(^8\). Many orthodontic adhesives are commercially available. Composite and glass ionomer are the two main classes of orthodontic bonding adhesives. Differences in bacterial adhesion to the different orthodontic adhesives may be expected because of their different characteristics and the release of incorporated fluoride. In particular, glass ionomers have demonstrated an inhibitory effect on growth or adhesion of oral bacteria because of their fluoride-releasing properties. However, the effect of glass ionomer adhesive on the adhesion of cariogenic bacteria has not been directly compared with that of composite adhesives\(^9\).

Methods

We carried out a careful analysis of the scientific literature about a correlation between surface characteristics of different orthodontic materials and adherence of microorganisms in orthodontic patients. We were chosen from "PubMed" several publications about surface characteristics, orthodontic materials, mutans streptococci, adhesion. Many studies of bacterial adhesion to orthodontic
materials have been published. We reported most important studies like Ahn et al’s study about the adhesion of cariogenic streptococci to orthodontic metal brackets in terms of the type of bacterial strains, the incubation time, and saliva coating. Also Ahn et al reported a study about the amount of cariogenic streptococci adhesion to various orthodontic adhesives and to compare the effect of fluoride release on the adhesion amount regarding the type of bacteria, incubation time, and saliva coating. Orthodontic appliance serves as different loci for biofilm formation. In a study by Eliades et al., stainless steel presented the highest critical surface tension and can be expected to have a higher plaque retaining capacity. Metallic orthodontic brackets have been found to induce specific changes in the oral environment such as reduced levels of PH and affinity of bacteria to a metallic surface because of electrostatic reactions, also it increased plaque accumulation, and elevated S. mutans colonization. Therefore, it is difficult to make a clear assessment that metal brackets have a lower cariogenic effect on the teeth than plastic or ceramic brackets.

Saloom et al. claim that the insertion of orthodontic wire tends to create new surfaces available for plaque formation and therefore to increase the level of microorganisms in the oral cavity. It has long been suggested that orthodontic bands and wires lead to an increased plaque accumulation and elevated levels of streptococci and lactobacilli. In addition, orthodontic patients with fixed appliances frequently present an abundance of S. mutans in plaque compared with untreated orthodontic patients.

**Review**

Microbiological studies have established that, after placement of a fixed orthodontic appliance, the number of bacteria raises significantly, particularly streptococci and lactobacilli, subjecting the oral environment to an imbalance and enabling the emergence of diseases. Although dental biofilm is composed of numerous species of bacteria, it is believed that S. mutans is involved in the early development of carious lesions. Saloom et al. conducted a study to investigate the effect of different types of fixed orthodontic appliances on the growth and adherence of microorganisms in oral flora which are Streptococcus mutans (S. mutans) and Candida albicans. Sixty-four of four different fixed orthodontic appliance-samples were used, divided into four groups of sixteen. Type I: Sapphire brackets- Stainless steel wires, type II: Sapphire brackets- Coated wires and type III: Stainless steel brackets- Coated wires and type IV: Stainless steel brackets- Stainless steel wires. Oral strains of S. mutans and Candida albicans were studied in the present study using biochemical test then microbial suspensions were prepared to do the tests of each microorganism including the antimicrobial effects of different appliance-samples on the growth of microorganisms and their adhesion tests. The results showed significant differences between the different appliances in terms of inhibition zone formation (P<0.001). The adhesion test, which is classified into low, medium and high, showed the adhesion of S. mutans, is low with type I and II, medium with type III and high with type IV, whereas the adhesion of Candida albicans is medium with both type I and II and high with both type III and IV with high significant differences (P<0.001). Ahn et al.’s study about a quantitative analysis of the adhesion of cariogenic streptococci to orthodontic metal brackets indicate that two main factors such as the type of strains and incubation times had significant effects on the adhesion of the cariogenic streptococci, whereas the saliva coating did not have a significant influence on the binding affinities. Unstimulated whole saliva (UWS) was collected from a 33-year-old healthy volunteer using a spitting method. Saliva was collected into a chilled centrifuge tube in the icebox and centrifuged at 3500 3 g for five minutes, as described previously. The resulting supernatants were immediately used for the pellicle formation and bacterial adhesion assays. A difference in the interaction effects was statistically significant only between saliva coating and incubation times. The saliva coating did not significantly influence the adhesion of the cariogenic streptococci. However, the adhesion as a result of the saliva coating was affected significantly by the incubation times. The saliva coating tended to gradually decrease the adhesion by the extended incubation time, compared with the noncoated control. Another study of Ahn et al. talking about quantitative determination of adhesion patterns of cariogenic streptococci to various orthodontic adhesives. Five light-cure orthodontic bonding adhesives were selected, consisting of three non–fluoride-releasing composites, one fluoride-releasing composite, and one resin-modified glass ionomer cement (RMGI). Specimens were prepared with Teflon templates with 3.0-mm wide and 2.0-mm deep holes. The results showed a characteristic adhesion pattern according to the type of bacterial strains used. Streptococcus mutans LM7 showed the highest amount of adhesion, whereas S. sobrinus B13 showed the lowest amount of adhesion. The cariogenic streptococci adhered to the glass...
ionomer significantly more than to the composites, whereas there was no significant difference in the adhesion amount among the four composites. The extended incubation time significantly increased bacterial adhesion. However, saliva coating did not significantly alter adhesion patterns of cariogenic streptococci. Papaioannou et al. examined the differences in the adherence to stainless steel, ceramic, and plastic orthodontic brackets and the effect of the presence of an early salivary pellicle and Streptococcus mutans on adhesion. Three adhesion experiments were performed using stainless steel, ceramic, and plastic orthodontic brackets. In the first experiment a clinical strain of S. mutans adhered to the three different types of brackets. For the second, the brackets were treated with saliva before adhesion of S. mutans. Finally, the third experiment concerned saliva coated brackets, but before S. mutans, S. sanguis bacteria were allowed to adhere. There were consistently no differences in the adherence to stainless steel, ceramic, or plastic brackets. The presence of an early salivary pellicle and S. sanguis reduced the number of adhering S. mutans to all three types of brackets.

Discussion

Saloom et al.'s study show a significant difference in the inhibition zones formed with four types of the appliances used with both S. mutans and Candida albicans, the highest inhibition zone was found with type I, followed by type II then type III and the lowest with type IV, this mean that type I which include no metal in its component can inhibit the bacteria and yeast more than type II which has metal arch wire which in turn inhibit bacteria and yeast more than type III that has metal bracket which inhibit bacteria more than type IV that has metal bracket and arch wire. The differences in the bacterial adhesion amount can be explained by the difference in the surface characteristics of each material, including the surface roughness. Since the monocrystalline sapphire brackets (used in types I and II) had smoother surfaces than metal brackets (used in types III and IV) this could be confirmed by the findings of Lee et al. who found smoother surface of sapphire than metal bracket in their study, therefore more bacterial adhesion was seen with type III and the most with type IV and this disagree with the findings of Fournier et al., who found that the affinity of microorganism for metal brackets was significantly lower than that for brackets made of plastic or porcelain, others like Papaioannou et al., they found that there were consistently no differences in the adherence to stainless steel, ceramic, or plastic brackets. The presence of an early salivary pellicle and S. sanguis reduced the number of adhering S. mutans to all three types of brackets. In the orthodontic bracket surface exposed to oral environment, initially, on a nanosecond scale, a water monolayer binds to a biomaterial surface by either oxygen or hydrogen bonding. Some water molecules may dissociate to hydroxyl groups, which may form surface hydroxyls. Then, a second water layer binds to the first monolayer. On hydrophilic surfaces, for example, to which water molecules bind strongly, repulsive hydration (longrange) and steric (short-range) forces are generated when two such surfaces come in contact because of the energy required to dehydrate the surfaces; these forces are controlled by the presence of cations or pH. On hydrophobic surfaces on the other hand, the orientation of water molecules towards the surfaces is entropically unfavorable. Thus, in the event that two such surfaces approach each other, water is ejected into the bulk solution, reducing the total free energy of the system and establishing attractive long-range hydrophobic forces between the two surfaces. Ahn et al. reported a significant difference in the amount of adhesion was observed among the cariogenic streptococci strains. This study showed that fluoride release from the orthodontic adhesive cannot alter the adhesion patterns of cariogenic streptococci. There was no difference in the adhesion amount between fluoride-releasing and non–fluoride-releasing composites. In addition, RMGI increased the adhesion of the cariogenic streptococci significantly more than did the composite adhesives. Although RMGI increased the adhesion of cariogenic streptococci in this study, previous studies reported that glass ionomers are significantly more resistant to demineralization than are non–fluoride-releasing composites. This may be mainly attributed to the effect of sustained fluoride release from glass ionomers. Ahn et al.’s study about a quantitative analysis of the adhesion of cariogenic streptococci to orthodontic metal brackets reported a significant difference in the adhesion was observed among the cariogenic streptococci strains. S. mutans OMZ65 adhered to the orthodontic bracket surface exposed to oral saliva coating. The orthodontic brackets are covered instantly by the salivary pellicle in the oral cavity. In contrast to the noncoated samples, the amount of adhesion in the saliva-coated samples was largely influenced by the salivary pellicle formed on the underlying materials. The salivary pellicle as a binding receptor can not only promote the adhesion but can...
also prevent the adhesion by decreasing the surface-free energy of the underlying materials. If a specific receptor is present in the salivary pellicle formed on the underlying material, the amount of adhesion will increase significantly because of saliva coating. This study will provide a primary step in identifying a means to interfere with the process of adhesion of pathogenic bacteria to the pellicle or plaque on the orthodontic appliances.

**Conclusion(s)**

Analyzed studies show that an extended incubation time increased the level of bacterial adhesion, irrespective of the bacterial strains, whereas the effect of saliva coating did not significantly alter the adhesion trend of cariogenic streptococci. Also these studies prove that the adhesion pattern of the cariogenic streptococci is different between composite adhesives and RMGI, and the adhesion amount is not strongly influenced by fluoride releasing and saliva coating. No obvious difference was found in the adhesion of S mutans, whether they were alone or in presence of S sanguis, to stainless steel, plastic, and ceramic orthodontic brackets. S sanguis seems to have an antagonistic relationship with S mutans, interfering with its adhesion.

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