Chapter 5

The Relationship between Orthodontic Treatment and Dental Caries

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Additional information is available at the end of the chapter

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Abstract

Orthodontic treatment is the main treatment procedure to achieve a well-aligned dental arch and an esthetic smile. For this purpose, various types of removable or fixed orthodontic appliances are designed. However, each has their specific disadvantages. The most important one is that orthodontic appliances especially the brackets and the ligation mode create new retention areas in addition to blocking plaque-removing shear forces arising from fluid flow and masticatory loads with a resultant undesired effect of accumulation of dental plaque. Increased amount of dental plaque containing cariogenic bacteria is the main etiologic factor in decalcification of enamel during orthodontic treatment. This demineralization of the tooth surfaces results in appearance of white spots or even caries. However, in the literature, there are conflicting results in the relationship between orthodontic treatment and development of dental caries. Many preventive methods such as topical fluoride application, using bonding materials releasing fluoride, using mouth rinse with sodium fluoride, applying chlorhexidine, and so on were defined. The general comment of the authors is that supplying an adequate oral hygiene has the main role in prevention of demineralization-caries during orthodontic treatment. In the light of the previous studies' results, it can be concluded that professional application like a varnish can be provided for patients who have high caries incidence.

Keywords: orthodontic treatment, conventional brackets, self-ligating brackets, enamel demineralization, white spot lesion, dental caries, microbial colonization

1. Introduction

Malocclusions are not life-threatening conditions; however, they can affect the health of oral tissues and may cause psychological and social problems [1]. Nonalignment of the teeth on

Figure 1. Extreme enamel demineralization and cavitation.

the jaws may cause dental caries due to the accumulation of dental plaques resulting from difficult-to-reach areas in the mouth. For this reason, dental caries is seen as an important side effect of malocclusions. However, the fact that caries formation is directly related to individual oral hygiene leads to many differences in results. There are studies reporting that there is no significant association between malocclusion and caries formation [2, 3]. On the other hand, other authors are reporting a negative correlation which notes that dental caries is less common in individuals with malocclusions [4].

There are many orthodontic treatment methods based on the existing malocclusion type. However, the common goal of all orthodontic treatment methods is to ensure that the teeth are aligned properly on the jaws, as well as in harmony with each other. A balanced soft tissue appearance and an esthetic smile are virtually the greatest passion of patients and orthodontists. Fixed or removable orthodontic treatment appliances used for this purpose may cause some undesirable side effects, as it may be seen in every treatment process. The most common side effect of orthodontic treatments is that they cause changes in mouth flora due to the formation of non-cleanable surfaces, and therefore they cause areas of decalcification on the enamel and eventually periodontal diseases (**Figure 1**) [5–7].

In this chapter, effects of orthodontic treatments on the development of enamel decalcification/caries were discussed in detail. The effects of bracket materials, designs, and different ligations on the levels of cariogenic bacteria were evaluated, the associated microbiota were discussed in conjunction to previous studies' result. Additionally, the prevention methods such as topical fluoride application, using bonding materials releasing fluoride, using mouth rinse with sodium fluoride, applying chlorhexidine, and so on were evaluated.

2. Relationship between orthodontic appliances and dental caries

In conjunction to the malocclusion characteristics, many types of removable or fixed orthodontic appliances are preferred for orthodontic treatments. However, in addition to their usefulness, they may cause undesired side effects. The use of either fixed or removable orthodontic appliance may affect the quantitative and qualitative distribution of the oral microbiota [5, 8]. After the insertion into the mouth, the salivary proteins will adsorb on the surfaces of orthodontic appliances, which play a considerable role in microbial adhesion. Their irregular surfaces act as a retention area for bacterial biofilm. Additionally, the presence of the orthodontic appliances in the oral cavity limits the mechanical self-cleaning process providing by saliva and musculature movement. With the resultant effect of all these factors, pH value of dental biofilm drops in the presence of fermentable carbohydrates and accelerates the accumulation and maturation of cariogenic biofilm. The biofilm especially contains *Streptococcus mutans* (*S. mutans*) which are aciduric and acidogenic microorganisms and considered to be the primary etiologic factors of dental caries [9].

2.1. Removable appliances

When the use of removable orthodontic appliances was assessed in terms of active dental caries or tooth loss due to caries, no difference was reported between children with and without removable orthodontic appliances. Oral hygiene in children with removable orthodontic appliances was found to be as good as the oral hygiene of children without removable orthodontic appliances. In another words, in terms of oral hygiene assessment, no difference was observed between individuals using removable orthodontic appliances and those using no orthodontic appliances [10]. In support, Karkhanechi et al. [11] reported that in patients treated with removable orthodontic appliances (**Figure 2**), as indicated by the lower BANA test results, the amount of anaerobic bacteria in supragingival plaque samples was lower due to the better oral hygiene. No such risk was observed in removable orthodontic appliances. Instead, it was found to be safer, especially in patients with poor oral hygiene control [8].

On the contrary, other authors [12, 13] reported the undesired effects of removable appliances on tooth enamel. Batoni et al. [14] reported a higher amount of *S. mutans* in children using removable appliances. Considering the acrylic removable appliances; there may be plaque accumulation and even calculus on the unpolished acrylic surfaces, especially in noncompliant patients. Acrylic structure of them may influence the proliferation of microorganisms when it acts as a food deposit. Depending on its smoothness and size, it may provide plaque accumulation that leads to enamel decalcification [9, 12, 14]. Addy et al. [15] showed that palatal plaque scores were significantly higher in wearers of removable appliances compared with a control group without orthodontic treatment. As these appliances mainly cover the lingual/palatal surfaces of the teeth, plaque occurrence in that region tend to be higher than other sides.

Figure 2. Acrylic removable appliances.

Lessa et al. [16] reported that *S. mutans* colonies were observed on all acrylic base plate in a week, which showed that the acrylic surfaces of appliances act as a sponge for microbial colonization. It has been noted that microorganisms can penetrate into the acrylic base of removable appliances as deep as 1–2 mm, making disinfection difficult. For this reason, oral hygiene control in patients wearing acrylic orthodontic removable appliances is essential. However, frequency and skill of brushing the teeth is related mainly to patient compliance and awareness. Besides, toothbrushes cannot clean the appliances completely. In addition to brushing, using antimicrobial agents for disinfection has been advised. Both methods need cooperation of the patient [16]. Professional compliance-free methods are preferred to overcome these problems. For this purpose, Farhadin et al. [12] evaluated the effect of silver (Ag^{+1}) nanoparticles added into acrylic baseplates on the amount of *S. mutans* colonization. Ag^{+1} particles have been defined as antimicrobial agents, which destroy bacterial membranes. The authors reported that including Ag^{+1} nanoparticles into the acrylic plate had a strong antimicrobial effect against *S. mutans*. On the other hand, the risk of silver toxicity has to be taken into consideration.

Different form the acrylic removable appliances, the thermoplastic appliances that are being used both for the treatment, correction of the malocclusion, and retention purposes cover all surfaces of the teeth and 1–2 mm of the gingiva (**Figure 3**). They might influence oral microbial flora during the retention period because they avoid the cleaning effect of saliva on tooth and oral mucosa; thus, colonization of *S. mutans* and *Lactobacillus (LB)* on dental surfaces increase [13]. Also, Low et al. [17] reported that thermoplastic appliances had micro abrasions and irregularities that might contribute to bacterial adhesion.

Figure 3. Thermoplastic appliance.

2.2. Fixed appliances

Compared to removable ones, fixed appliances pose a significant risk due to the changes in the normal flora of oral cavity. It is noteworthy that plaque accumulation is greater in individuals treated with fixed orthodontic appliances compared to those treated with removable ones [5, 8, 11].

In fixed orthodontic treatment, orthodontic bands, and brackets, ligatures, and so on placed on the teeth cause an increase in the number of plaque retention areas and also they result in difficulty in ensuring proper oral care. Also, they construct a barrier for the tooth enamel to plaque removing shear forces arising from masticatory loads and fluid flow, so that dental plaque accumulation and formation arises. In conjunction with poor oral hygiene, the number and percentage of oral microorganisms are tended to increase during fixed orthodontic treatment [18, 19].

A significant increase in the amount of *Porphyromonas gingivalis, S. mutans, Streptococcus sobrinus* (*S. sobrinus*), *Lactobacillus casei (L. casei)*, and *Lactobacillus acidophilus (L. acidophilus)* in the saliva are observed with the start of the fixed orthodontic treatment [5, 20]. Among other species, mainly *S. mutans* and *Lactobacillus* bacteria have high concentration in oral flora and higher adhesion capacity on brackets and primarily responsible for dental caries [20, 21]. *S. mutans* uses sugars and produces acids that cause enamel demineralization, which will eventually turn into cavitation. Although *S. mutans* increases in mouth flora especially with the start of fixed orthodontic treatment, at the end of the treatment, there is a decrease because oral hygiene can easily be attained after the debonding of fixed orthodontic appliances. On the other hand, it has to be taken into consideration that the amount of *S. mutans* may increase due to the formation of retention areas by fixed or removable appliances used for retention.

The plaque accumulation and microbial adhesion during orthodontic treatment with fixed appliances depend on different variables [22]. Such as:

1. Bracket design and material (surface roughness of materials, surface free energies),
2. Material of ligation,
3. Proximity of the gingival sulcus to the bracket,
4. Surface area of the labial enamel relative to the bracket,
5. Excess bonding around the bracket,
6. Position of the teeth in the dental arch,
7. Oral hygiene habits, poor decayed, missing, and filled tooth scoring (DMFS), and age.

2.2.1. Bracket design and material (surface roughness of materials, surface free energies)

Surface characteristics such as the surface roughness and surface free energy affect the amount of bacterial adhesion to orthodontic materials. A rough surface provides suitable niches for bacterial colonization, and a material with high free surface energy attracts more bacteria. In bacterial retention, other than surface roughness of materials, surface free energies also play a decisive role. It is stated that the most important factor initiating bacterial accumulation is surface free energies [21, 23–27].

Various bracket types with differentiated morphological characteristics and physical properties showed different influence on the adhesion of dental plaque and that of the microbiota. Given that, the porous structure of the material of the brackets would maintain an ecologic niche for microorganism adherence and biofilm formation [28, 29]. The microorganisms exhibited the highest adherence to the esthetic brackets (**Figure 4a**). In-vitro studies showed that the affinity of the microorganism for metal brackets (**Figure 4b**) was significantly lower than that for brackets made of plastic or porcelain [30].

The level of oral hygiene, diets, fluoridation, potential local differences in the saliva wetting, and the presence of an early salivary pellicle might influence the amount of iatrogenic enamel decalcification and/or white spot lesion (WSL). Considering the local differences in saliva wetting and distribution by intraoral soft tissue dynamics, it may be hypothesized that labial and lingual enamel areas may be differentiated in terms of WSL formation [31]. Wiechmann et al.

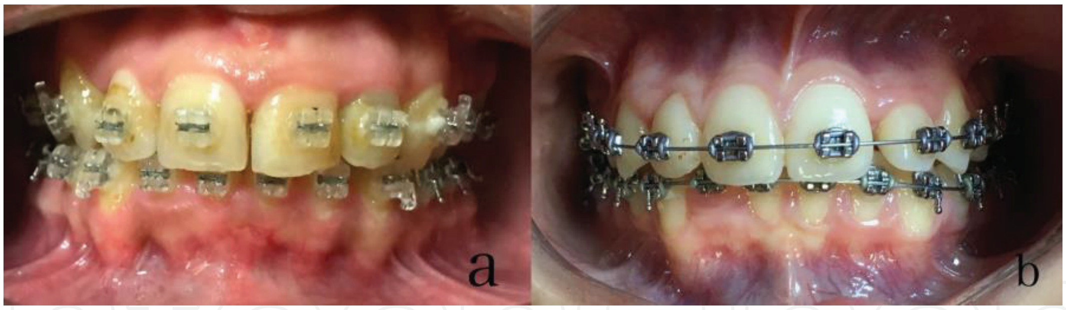

Figure 4. Esthetic brackets (a), metal brackets (b).

[31] evaluated the incidence of WSLs in subjects treated with customized lingual multibracket appliances and reported distinct reduction in WSLs when compared with previous reports of enamel decalcification after conventional labial multibracket treatment [31].

2.2.2. Material of ligation

In addition to morphology and design of orthodontic brackets, the bracket ligation type may provide an increased number of retention sites for microbial colonization. The effects of bracket materials, designs, and various ligation modes on the levels of cariogenic microbiota have been evaluated in the literature [1, 22, 23, 25, 32]. However, conflicting results were declared.

Teeth ligated with elastomeric ligatures have been found to attract higher numbers of bacteria than steel wire ligations [32]. The elastomeric ligatures in the oral environment allow for the adsorption of potassium and sodium in the initial phase followed by calcium and potassium precipitations, which stabilize the formed film that accumulates the dental plaque [33]. For this reason, it was suggested that the use of elastic ligatures should be avoided in patients with inadequate oral hygiene [19]. On the contrary, Sukontapatipark et al. [34] reported that the method of ligation did not appear to influence the bacterial quality on tooth. Similarly, Forsberg et al. [32] reported no difference in the periodontal conditions of the treated patients with either elastic or metallic ligatures. These results may be due to the frequent change of the elastomeric ligatures on a monthly basis during the orthodontic treatment. Therefore, the renewal of elastic ligature eliminates the previous bacterial attachment, and each time, a new cycle of colony formation is initiated on new elastic rings.

To eliminate the undesired effect of ligation materials self-ligating (SL) brackets which rely on mobile opening closing mechanism/clips rather than ligatures, to hold the arch wire in place may be preferred [28]. Given that lack of ligature materials, SL brackets were expected to have better values for periodontal status and caries development because of having less retentive sites. In another words, SL brackets might be considered presumably hygienic. On the contrary, the expected beneficial effect of the self-ligating brackets is not confirmed. Even though the SL brackets eliminate the use of ligatures, they often consist of opening and closing mechanisms, which may provide additional plaque retention sites. In addition, there might be plaque and food impactions in the space under the closing mechanism, which could not be brushed by the patient without opening the mechanism. Thus, a theoretical advantage may be eliminated in reality [35].

In literature, there are few studies with diverse results comparing the SL brackets with elastomeric ligated conventional brackets (CB) [36–38]. Some researchers defined that elastomeric ligated CB causes more plaque accumulation and periodontal inflammation than SL brackets [19, 36, 38]. However, others reported no significant difference [37]. On the contrary, higher bacterial colonization and poorer periodontal health with SL brackets was also reported [39]. When the SL and CB with steel ligatures compared, it was revealed that SL brackets do not have an advantage over CB with steel ligatures with respect to colonization of *S. mutans* and *LB* [40].

2.2.3. Proximity of the gingival sulcus to the bracket

Plaque formation is common in the gingival and lateral regions of the bracket base and behind tie-wings. Following the fixed orthodontic application on the tooth surface, the most plaque build-up is observed on tooth surfaces between the two brackets and behind the arch wire [34].

2.2.4. Surface area of the labial enamel relative to the bracket

Plaque accumulation is seen more in gingival region, and plaque accumulation is least seen in the incisal parts of the teeth [41]. O'Reilly and Featherstone [42] noted that decalcification formed immediately around the brackets and bands, not farther away along the buccal enamel surface.

2.2.5. Excess bonding around the bracket

In fixed orthodontic treatments, excessive composite around the bracket base are the most suitable areas for plaque retention due to their rough surface structure. Surface free energy characteristics play an important role in the initial *S. mutans* adhesion to orthodontic materials. Many different adhesive agents, such as composite, compomer, and resin modified glass ionomer cement, are used in bonding fixed orthodontic attachments to the teeth. It is a known fact that bacteria accumulate more on adhesive agents rather than the brackets on the teeth. The higher the surface free energy, the greater the bacterial retention on the material is. The difference between surface free energies of the adhesive agents is all related to the chemical structures, the hardening mechanisms, and the reactive activities on adhesive surfaces. In this respect, composite, compomer, and resin modified ionomer cement can be listed in accordance with the level of surface free energies from low to high [23, 24, 26, 27].

2.2.6. Position of the teeth in the dental arch

Buccal surfaces of the maxillary molars and the lingual surfaces of the mandibular molars accumulate more plaque than other sites do [43]. At the posterior region, there might be greater food impactions between archwire and soft tissue. In spite of the tendency for more effective and thorough brushing of anterior rather than posterior teeth, maxillary and mandibular lateral incisors were declared to have the highest incidence of white spot lesions (WSLs) [35, 44].

2.2.7. Oral hygiene habits, poor decayed, missing, and filled tooth scoring (DMFS) and age

Especially younger patients seem to have higher DMFS. The colonization of *S. mutans* progressively increases with age [45–49]. The highest amount of *S. mutans* colonization occurs at completion of the deciduous dentition, as the fissures and tight approximal contact areas between deciduous molars provide suitable sites [49]. Previous researches have reported increased caries activity in preadolescents and adolescents compared with young adults [45, 46]. The composition and amount of salivary secretion may vary with age, and thus, the bacterial adherence may differ [47].

In a study [48] in which caries evaluations were made from the mixed dentition stage to the permanent dentition stage, patients were treated with both removable and fixed orthodontic appliances. It was reported that at the end of the treatment, no difference was observed between patients who received an orthodontic treatment and those received no orthodontic treatment in terms of decayed, missing, and filled tooth scoring (DMFS) results. However, it should be noted that patients with a high pre-treatment DMFS score, especially in the first molar teeth and the second premolar teeth, form the high risk group, and these individuals must be included in prophylaxis programs [48].

3. Methods for preventing caries during fixed orthodontic treatment

Iatrogenic decalcification of tooth enamel and the development of visible WSLs are undesirable side effects of orthodontic treatment with fixed appliances. This enamel decalcification undermines the esthetic appearance even though the correction of the malocclusion is achieved (**Figure 5**).

Prevention and treatment of WSLs have become matters of concern among orthodontists. There are many approaches to prevent the accumulation of dental plaque and subsequent enamel demineralization around brackets and bands. Fluoride releasing glass ionomer cement or resin-based composite and fluoridated elastomers have been presented. However, the success in the prevention of demineralization is questionable [50, 51]. Subsequent oral hygiene procedures, such as daily sodium fluoride mouth rinses, may effect protection of enamel demineralization, but the patients' compliances may play important role [52].

Methods to prevent caries in orthodontic patients can be examined under three headings:

1. Struggle against microbial agents; plaque removal and plaque control, use of probiotics, vaccinations.
2. Increasing tooth resistance; fluoride and chlorhexidine applications, casein derivatives, laser applications.
3. Regulation of diet; diet control, restriction of the intake of sucrose-containing foods and beverages, use of non-cariogenic sweeteners, and phosphate supplement.

3.1. Struggle against microbial agents

The best policy to prevent periodontal diseases and caries is daily removing of the dental plaque on the teeth. For this purpose, numerous interventions exist, including mechanical, chemical, and biological methods.

Figure 5. White spot lesions occurred due to fixed orthodontic treatment.

3.1.1. Mechanical methods

Mechanical methods of plaque control involve tooth brushing and interdental cleaning with a wide range of products currently available. Powered toothbrushes are a new high-tech solution to remove dental plaques. Powered toothbrushes with a rotation oscillation action remove plaque more than manual brushes. Other forms of powered brushes produce a less consistent reduction of plaque [53, 54]. The use of a powered toothbrush, especially with an orthodontic brush head, may be of benefit in promoting gingival health and can be recommended for orthodontic patients with fixed appliances. A comparison between the two electric brush heads shows that the orthodontic brush head removes greater plaque than does the regular brush head. Difference of the amount of plaque removed is about 9% between regular brush head and orthodontic brush head, the latter is better in cleaning [55, 56]. Additionally, sonicare brush has been found significantly more effective in reducing supragingival plaque than the manual brush. Improvement in clinical signs, such as reduction in bleeding on probing and pocket depth during orthodontic treatment, is more common in sonicare brushes when used twice daily for 2 min [57]. However, when used three times daily for 2 min, no superiority was observed among ultrasonic, electric, and manual toothbrushes, on microbiologic parameters in orthodontically banded molars [58].

3.1.2. Chemical methods

Commonly used chemical plaque control agents are flour, chlorhexidine, cetylpyridinium chloride, listerine, and triclosan. Chemical methods utilize compounds such as toothpastes and mouth rinses [59]. Fluoride containing toothpastes commonly contain 0.76% sodium monofluorophosphate or 0.22% sodium fluoride. It has been reported that this type of toothpaste reduces tooth decay by 20%. The fluoride concentration of toothpastes should be over 1000 ppm and toothpastes with higher fluoride concentrations are more effective. Daily use of high-fluoride toothpastes can significantly reduce the prevalence and incidence of enamel lesions during the treatment of adolescents with fixed orthodontic appliances [60]. Additionally, daily use of fluoride mouthwashes, which contains 0.05% sodium fluoride, is recommended. Daily rinsing for 1 min with these mouthwashes provides a 50% tooth decay reduction [61]. There is no consensus about the risks associated with using fluoride toothpaste (due to fluorosis) and also about the effect of chronic ingestion of excessive amounts of fluoride in young children [62].

The use of dentifrices with a lower concentration of chlorhexidine (0.50%) was found to be effective for treating gingivitis and bleeding without the risk of tooth staining in orthodontic patients [63].

A 0.2% chlorhexidine gluconate mouth rinse is another type of mouthwashes used to prevent rinse plaque formation and enamel lesions. Compared to fluoride-containing mouthwashes, it is superior in terms of bacterial plaque inhibition and the control of pathogenic organisms. However, chlorhexidine has adverse effects such as tooth and soft tissue staining associated with long-term use [64–66].

The essential oil-containing mouth rinse, Listerine, is effective in reduction of plaque accumulation as well. However, it was mentioned to be less effective than chlorhexidine gluconate [67, 68].

The other chemical compound Triclosan is one of the most commonly used samples of chlorinated diphenyl ether as an antibacterial agent. It has been proved in clinical studies that toothpastes containing triclosan and zinc citrate reduce dental plaque [69].

3.1.3. Biological methods

Biological methods on the other hand consist of probiotics and vaccines, which have recently gained popularity and are being researched extensively. Food and Agriculture Organization and the World Health Organization defined probiotics in 2001 as "live microorganisms which, when administered in adequate amounts, confer health benefits on the host." Probiotics must prevent the proliferation of cariogenic bacterial species, especially *Streptococci* and *Candida* species, on teeth surface. This property of probiotics of neutralizing acidic condition helps in the management of caries [70, 71].

In probiotics-related studies on orthodontics, a reduction in the amount of Streptococcus has been reported; however, no positive effect on white spot lesions has been observed [72, 73].

There is no tooth decay in the areas where the plaque is removed. By effective plaque control achieved by oral hygiene, gingival inflammation is eliminated and remineralization of the enamel surface is ensured. Plaque control requires a little skill and much motivation. The typical order of oral hygiene is defined as flossing, tooth brushing, and mouth rinsing. However, by changing the order of brushing and mouthwash stages, more use of fluoride via toothpaste residues left on the tooth after brushing can be obtained. However, very few numbers of children and adults practice ideal tooth brushing.

Most children spend less than 1 min for tooth brushing and do not brush 38% of the tooth surface, especially those involving lingual surfaces. Adults spend 45–90 s [74, 75]. Thus, using only standardized general prophylactic measures, the development of enamel demineralization during fixed orthodontic treatment is a frequent undesired side effect. Taking this into consideration, improved prophylactic measures, possibly including more stringent in office protocols such as fluoride varnish, are required [76].

3.2. Increasing tooth resistance

Trace amounts of fluoride increase the demineralization resistance of the tooth structure and are of particular importance in tooth decay prevention. The use of fluoride to reduce caries risk was first achieved by fluoridation of drinking water, and then used in diets, toothpastes, mouthwashes, and professional topical applications [77]. However, fluoride is listed in class 4 drug group, which is a highly toxic drug group. A daily dose of 1–3 mg fluoride has been reported as the appropriate dose and reported to be quite safe. Even though 5–10 g of sodium fluoride (2.5–5 g fluoride) intake is fatal for an adult, much less of this amount has toxic effects for children [61].

Topical fluorides (2% sodium fluoride, 8% stannous fluoride, and 1.23% acid fluid phosphate) are used by dentists in the form of solutions or gels. The solutions can be applied directly to the cleaned teeth for 4 min, and the gel forms can be applied directly or by means of plastic, wax, or polystyrene spoons. With these types of applications, tooth decay can be reduced by 40% [78].

It is not clear yet which type of fluoride application is more effective, but it is indicated that fluoride mouthwashes (0.05% sodium fluoride) are more effective [52, 79].

Additionally, fluoride varnishes are among the successful applications in professional anti-caries methods. The first developed products to prevent caries were Duraphat (5% sodium fluoride in a colophony base, Colgate Oral Pharmaceuticals Inc., Canton, MA) and Fluor protector (a clear, transparent polyurethane lacquer containing 0.1% weight fluoride ion as difluorosilane; Ivoclar Vivadent, Inc., Amherst, NY). Fluorinated varnishes are safer, easier to apply, and have more fluoride concentration on the enamel surface compared to other topical fluoride applications [80–82]. They are effective bactericidal and anti-caries agents. Since fluorinated varnishes harden when they come into contact with moisture, the isolation of the applied zone is not necessary. Calcium fluoride builds up on the surface and usually forms fluoroapatite. The high concentration of fluoride on the surface can provide fluoride storage for remineralization [78]. In vitro and in vivo fluoride varnishes studies on orthodontics reported a reduction in the mean areas and depths of enamel lesions adjacent to brackets. Researchers noted that the teeth treated with a single application of a fluoride varnish, exhibited 40–50% less enamel demineralization than the controls [83–85]. Two or three applications per year have been found to be effective [86, 87]. In addition, it has been reported that they cause a decrease in the number of *S. mutans* in plaques and saliva [88]. Even though fluoride varnish is one of the most concentrated fluoride products, they defined to be safer; no acute toxicity has been reported [89, 90].

As another method use of fluoride releasing adhesive can decrease the formation and the severity of enamel demineralization surrounding the orthodontic brackets with independent of patient cooperation as well. Sustained release of a low level of fluoride leads to the formation of a calcium-fluoride layer at the enamel surface. This layer can provide fluoride for remineralization and calcium for neutralization of the acid attack [91, 92]. All the methods used for fluoride application are effective to some degree. The goal of clinicians is to design the most effective combination for each patient, which should be made according to the patient's co-operation status, age, decay history, general health, and oral hygiene.

Similar to fluoride, chlorhexidine is also an agent with an antimicrobial activity. It is available in a varnish form as well as in a mouthwash form. Chlorhexidine varnishes increase remineralization and reduce the occurrence of *S. mutans* [93, 94]. In addition, chlorhexidine-containing varnish is effective in the reduction of gingival inflammation and of plaque accumulation adjacent to the band and brackets [95]. Researchers noted that high-frequency application of chlorhexidine-containing varnish did not result in a greater suppression of *S. mutans* than low frequency application. At the same time, the varnish effect is indiscernible 2 months after application [96].

Various antimicrobial agents are also used to prevent caries. In some rare cases, antibiotics are used, but they are not preferred considering their systemic effects [97, 98].

Casein phosphopeptides amorphous calcium phosphate (CPP-ACP) is a product derived from milk and has anticariogenic activity. During the orthodontic treatment, monthly application of CPP-ACP paste on teeth does not completely prevent WSL development, but it significantly decreases the number of WSL [99]. Using of CPP-ACP with fluoride (MI paste plus, GC America, Alsip, Ill) by a fluoride tray for a minimum of 3–5 min each day at night after brushing prevents the development of new WSL during orthodontic treatment and decreased the number of WSL already present [100]. CPP-ACP is not only available as a paste for home use but also in the form of varnish in combination with fluoride, chewing gum, mouth rinses, lozenges, dentifrices, spray, and energy drinks. The varnish containing CPP–ACP is shown to be more effective than the fluoride varnish to prevent WSL around orthodontic brackets [101–103].

In recent years, the use of argon laser because of its ability to bond brackets in just 5 s has a promising potential in orthodontics. In addition to reducing the chair-time, one of the other beneficial effects is strengthening the enamel to acid attacks. Laser beams resulted in changes in surface morphology, but maintained an intact enamel surface. An in vitro study showed that orthodontic brackets cured with the argon laser could be effective in reducing enamel decalcification and had similar yielded bond strengths with the conventional light-cured brackets [104]. Similarly, an in vivo study showed that argon laser irradiation was effective in reducing enamel decalcification during orthodontic treatment [105].

Nanoparticles (NPs), the insoluble particles smaller than 100 nm in size, are also being used in health. Especially, nanosilver particles, in the form Ag^{+1}, are introduced to be antimicrobial agents given that destroying bacterial membranes through direct contact. Two broad strategies exist to prevent microbial adhesion and/or enamel demineralization during the fixed orthodontic treatment. These are including certain NPs, such as nanofillers, silver, TiO_2, SiO_2, hydroxyapatite, fluorapatite, fluorohydroxyapatite, into orthodontic bonding materials or acrylic resins and coating surfaces of brackets and bands. Information of using nanotechnology is lacking; thus, further investigation to assess possible toxicity related to the NP sizes is required [106–108].

3.3. Regulation of diet

Responsibilities of the dentist or assistant staff to the patient for whom dietary modification is desired are as follows: guidance, providing information, motivation, and encouragement. The patients with braces should be advised about the importance of including foods like fruits, vegetables, grains, and cereals in their diet rather than taking foods such as cakes, pastries, carbonated beverage, and so on, which are high in simple sugars and fats [109–111].

The sucrose taken as part of the diet has two damaging effects on the plaque. First, the frequent intake of sucrose-containing foods provides a stronger *S. mutans* colonization and increases the plaque's potential for caries-formation. Second, the mature plaque frequently exposed to sucrose metabolizes sucrose faster than organic acids, which results in dense and long-lasting low plate pH values. Caries activity is stimulated by the frequency rather than the amount of sucrose taken. The objectives of the diet guide are to identify the sources of sucrose and acidic food in the diet and to reduce the frequency of their consumption. Despite this knowledge, diet change is far from being a very successful method against tooth decay because of the difficulties in providing patient motivation. However, more successful results can be obtained with simple suggestions such as avoiding sugary foods in the form of snacks and avoiding acidic drinks [109, 110]. Additionally, the use of Polyols (the sweeteners that are weakly metabolized (sorbitol) or not metabolized (xylitol) by cariogenic bacteria) is beneficial. Xylitol lozenges can be sucked after a sucrose challenge, which will neutralize the acidity of dental plaque [111].

4. Conclusion

1. Removable appliances are rather safer than the fixed ones in terms of causing iatrogenic enamel decalcification.
2. The design and the material of orthodontic brackets as well as the ligation methods may provide an increased number of retention areas. Thus, facilitating dental plaque accumulation and consequently increased levels of oral microbiota.
3. If there is a good oral hygiene, bracket and ligation type may not cause caries formation. Oral hygiene has the main role in prevention of the iatrogenic demineralization/caries during orthodontic treatment.
4. Patients with a high pre-treatment DMFS score form the high-risk group and, these individuals must be included in professional prophylaxis programs during orthodontic treatment.

Finally, it can be said that although there is an increase in the number of microorganisms in the oral flora following the placement of orthodontic appliances, this cannot play an effective role in the caries formation providing that the oral hygiene is well maintained and the amount of dietary sugar is reduced. Home-care prophylaxis methods should be advised to all orthodontic patients. Additionally, patients' oral hygiene statue and DMFS score have to be evaluated carefully at the beginning of the orthodontic treatment, and professional varnish application can be preferred, if required.

Conflict of interest

There is no conflict of interest to declare.

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