White Spot Lesions: Formation, Prevention, and Treatment

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As oral hygiene becomes more difficult in patients with fixed orthodontic appliances, the decalcification of the enamel surface adjacent to these appliances is prevalent. Decalcification is manifested as a white spot lesion (WSL), and orthodontic patients develop significantly more WSLs than nonorthodontic patients. If WSLs are left untreated, they may progress to produce carious cavitations, and may also present esthetic problems. Thus, the prevention, diagnosis, and treatment of WSLs is crucial to minimize tooth decay as well as tooth discoloration that could compromise the esthetics of the smile. (Semin Orthod 2008;14:174-182.)

Prevention of WSLs begins by implementing a good oral hygiene regimen including proper tooth brushing with a fluoridated dentifrice. Additional sources of fluoride such as mouth rinses or varnishes may be beneficial for those patients with an increased caries risk and should be considered by the clinician as part of the oral hygiene regimen. For less compliant patients, a continuous release of fluoride from the bonding system around the bracket base would be advantageous. Thus, using fluoride-containing sealants and adhesives to bond brackets has been attempted.

If the prevention of WSLs is unsuccessful and the white spots present an esthetic concern to the patient, treatment will be needed. Before orthodontic treatment begins, the clinician should document the extent and severity of any WSL present through the use of intraoral photographs for documentation and comparative purposes. In general, treatment of WSLs should begin with the most conservative approach. If such approaches do not resolve the problem, more aggressive treatment modalities can be pursued if the patient desires.

Decalcification of the enamel surface adjacent to fixed orthodontic appliances is an important and prevalent iatrogenic effect of orthodontic therapy. The banding and bonding of orthodontic appliances to teeth increases the number of plaque retention sites and, as a result, oral hygiene becomes more difficult. The low pH of plaque adjacent to orthodontic brackets hinders the remineralization process, and decalcification of enamel can occur.[1] As enamel translucency is directly related to the degree of mineralization, initial enamel demineralization usually manifests itself clinically as a "white spot lesion" (WSL).[2]

Classification of White Lesions on Enamel

White tooth discolorations can result from a number of factors, and in some cases an accurate diagnosis can be challenging. In general, white discolorations of enamel can be classified as dental fluorosis, opacities, or WSLs. Russell has developed a set of criteria to differentiate between fluorosis and opacities.[3] Russell's criteria describe fluorosis as white/yellowish lesions that are not well defined, blending with normal enamel, and having symmetrical distribution in the mouth (Fig 1A and B). Nonfluoride opacities, on the other hand, have a more defined shape, are well differentiated from surrounding enamel, often located in the middle of the tooth, and randomly distributed (Fig 2A-C).[3] In

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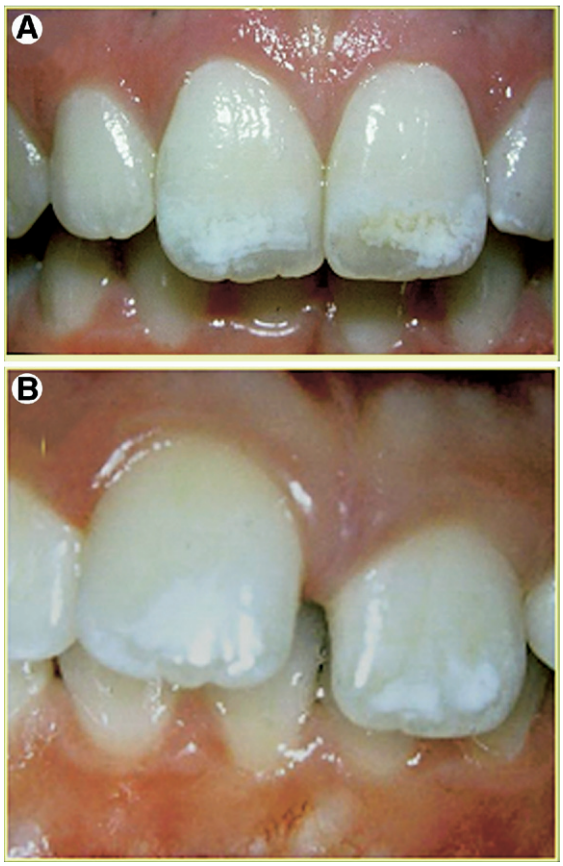

Figure 1. (A and B) Examples of fluorosis affecting the maxillary central incisors. Notice the symmetrical distribution of ill-defined lesions blending with normal enamel. (Color version of figure is available online.)

orthodontic patients, WSLs are often seen under loose bands, around the periphery of the bracket base, and in areas that are difficult for the toothbrush to access and for the patient to easily detect (Fig 3).

Figure 3. White spot lesions present and observed in a patient immediately following the removal of fixed orthodontic appliances. Notice that many of the lesions outline the periphery of the bracket base and are in areas that are difficult to access with the toothbrush. This is a more serious problem with patients who have poor oral hygiene. (Color version of figure is available online.)

Definition

The WSL has been defined as "subsurface enamel porosity from carious demineralization" that presents itself as "a milky white opacity . . . when located on smooth surfaces."[2]

Incidence

In general, orthodontic patients have significantly more WSLs than nonorthodontic patients, and these WSLs may present esthetic problems years after treatment.[4] One study found that the prevalence of at least one WSL in patients who underwent treatment with fixed

Figure 2. (A-C) Examples of a nonfluoride opacity on a mandibular canine (A), right (B), and left (C) central incisors. These lesions are usually randomly distributed and well defined. (Color version of figure is available online.)

orthodontic appliances was 49.6%; this compares to only 24% in an untreated control group.[5]

Formation of White Spots in Orthodontic Patients

Studies have shown that fixed orthodontic appliances induce a rapid increase in the volume of dental plaque and that such plaque has a lower pH than that in nonorthodontic patients.[6,7] Thus, the plaque-retentive properties of the fixed appliance predispose the patient to an increased cariogenic risk. Furthermore, there is a rapid shift in the composition of the bacterial flora of the plaque following the introduction of orthodontic appliances. More specifically, the levels of acidogenic bacteria, such as *S. mutans*, become significantly elevated in orthodontic patients. If these bacteria have an adequate supply of fermentable carbohydrates, acid by-products will be produced, lowering the pH of the plaque. As the pH drops below the threshold for remineralization, carious decalcification occurs. The first clinical evidence of this demineralization is visualized as a WSL. Such lesions have been clinically induced within a span of 4 weeks, which is typically within the time period between one orthodontic appointment and the next.[8] This is a significant finding and is important for both the patient and the clinician to realize.

In the highly cariogenic environment adjacent to orthodontic appliances or under loose bands, these lesions can rapidly progress. If left untreated, they may produce carious cavitations that will need an appropriate restoration. Thus, the prevention, diagnosis, and treatment of WSLs is crucial to prevent tooth decay as well as minimize tooth discoloration that could compromise the esthetics of the smile.

Prevention of WSL

Oral Hygiene, Dentifrices, Mouth Rinses, and Varnishes

Perhaps the most important prophylactic measure to prevent the occurrence of WSLs in orthodontic patients is implementing a good oral hygiene regimen including proper tooth brushing with a fluoridated dentifrice. Dentifrices typically contain either sodium fluoride, monofluorophosphate, stannous fluoride, amine fluoride, or a combination of these compounds. As orthodontic patients are at an increased caries risk, a fluoride concentration below 0.1% in dentifrices is not recommended.[9] This is because an appropriate level of fluoride ions is needed to provide an anticaries benefit by promoting enamel remineralization. When fluoride ions are incorporated into the surface of enamel, a fluoroapatite crystal structure is formed that has a lower solubility in the oral environment compared with hydroxyapatite.

In addition to its anticaries activity, stannous fluoride may have a plaque-inhibiting effect by interfering with the adsorption of plaque bacteria to the enamel surface.[10,11] Tin atoms in stannous products also block the passage of sucrose into bacterial cells, thus inhibiting acid production. It was observed that the use of a fluoridated antiplaque dentifrice may reduce enamel demineralization around brackets more than the use of a fluoridated dentifrice alone.[12] However, while this effect appears significant when used in patients with orthodontic brackets bonded with composite resins, the extra benefit is not discernible if the brackets are bonded with a resin-modified glass ionomer (RMGI). This is because the latter group of bonding materials is able to release fluoride ions that have a beneficial effect of their own.

For less compliant orthodontic patients, the use of a fluoridated dentifrice alone is ineffective in preventing the development of carious lesions,[13] and supplemental sources of fluoride are often suggested. This is particularly important when these patients do not follow the suggested proper oral hygiene regimen. Fluoridated mouth rinses containing 0.05% sodium fluoride used daily have been shown to significantly reduce lesion formation beneath bands. These mouth rinses have been combined with antibacterial agents such as chlorhexidene, triclosan, or zinc to improve their cariostatic effect.[14] While the proper use of these products provides the patient with increased caries protection, patient compliance is required and such cooperation can be difficult to obtain in some patients. Geiger and coworkers showed that less than 15% of orthodontic patients rinsed daily as instructed.[15] The conclusion reached is that orthodontic patients who do not comply with proper oral hygiene will probably not use fluoride rinses on a regular basis.

What can be done for these less compliant patients? The in-office application of a high concentration of fluoride in the form of a varnish may be beneficial and should be considered by the clinician. These products offer the combined benefit of delivering a high concentration of fluoride during the regular orthodontic visit while eliminating the need for patient cooperation that is required with fluoride rinses. However, since the application of the varnish usually occurs in the clinician's office only, there is a limitation on the frequency of exposures that the patient will receive. In addition, the repeated varnish applications may increase costs to the patient and/or chair time to the clinician. One disadvantage of varnish application is the temporary discoloration of the teeth and gingival tissue, with the use of most available products. However, it has been reported that the application of a fluoride varnish resulted in a 44.3% reduction in enamel demineralization in orthodontic patients.[16]

Sealants, Primers, and Adhesives

In general, the duration of orthodontic treatment places the patient at an increased caries risk for a prolonged period of time. As a result, continuous fluoride release from the bonding system around the bracket base would be extremely beneficial. Thus, using fluoride containing sealants and adhesives to bond brackets has been attempted. Glass ionomer cements (GICs) were initially introduced as orthodontic bonding adhesives to take advantage of some of their desirable characteristics, namely, their ability to chemically bond to tooth structure,[17,18] in addition to their sustained fluoride release following bonding.[19-26] Of particular interest, the fluoride release was shown to increase in the plaque adjacent to brackets bonded with GICs.[27] Unfortunately, because of their lower bond strengths[28-34] their use for bonding orthodontic brackets became fairly limited. In an attempt to increase the bond strengths of GICs, resin particles were added to their formulation to create RMGI bonding systems. These adhesives release fluoride like conventional GICs but can also be used to bond orthodontic brackets successfully because of their relatively higher bond strengths.[35-40] Although early studies indicated that RMGIs have lower shear bond strength (SBS) compared with composite resins,[41-44] particularly within the first half hour after bonding,[45] more recently these products were found to have an increased SBS and are able to bond orthodontic brackets successfully.[42-47] Additionally, in vivo studies have shown no significant differences in bracket failure rates between the RMGIs and composite adhesives.[41] Furthermore, it was also reported that no significant differences were found between the SBS of brackets bonded with RMGI or composite adhesives following thermocycling.[47] Because of the recent improvements in the fluoride-releasing capabilities and the SBS of RMGI, it has been suggested that these adhesives should play a greater role (ie, be more widely used) in bonding orthodontic brackets in the future.[48]

Effects of Adding Fluoride and Other Antibacterial Agents on the Shear Bond Strength of Orthodontic Adhesives

Although it is universally recommended to use a nonfluoridated pumice powder to prepare the teeth for bonding, it was found that using a fluoridated prophy paste did not significantly change the SBS.[49]

The application of fluoride-containing sealants has been shown to not affect the SBS of orthodontic adhesives and they are able to produce a sustained fluoride release. However, it was determined that the concentration of fluoride ions released significantly decreased with time, to the point of having barely detectable levels a few weeks after application.[50] Therefore, the important factors that need to be considered by the clinicians using these materials include the duration and concentration of fluoride that is being released as well as the ability of these sealants to be recharged with fluoride ions (ie, act as a fluoride pump). Recently, it was determined that a fluoride-releasing sealant (ProSeal; Reliance Orthodontic Products, Itasca, IL) was capable of releasing fluoride ions for 17 weeks.[50] While the sealant initially released ions at 0.074 ppm/wk/mm^2, this level dropped to 0.037 ppm/wk/mm^2 after the first 3 weeks and reached a low of 0.01 by the end of the 17th week. However, the sealant was shown to have the ability to be recharged with fluoride ions using a foaming solution of acidulated phosphate fluoride; fluoride release in the first week after recharging increased to 0.354

ppm/mm^2.[51] While these rates of fluoride release may be low, Ten Cate suggested that even sub-ppm levels of fluoride may have a significant impact on the remineralization process.[52] Furthermore, ProSeal as a sealant forms a mechanical barrier between plaque and the enamel surface under and around orthodontic brackets.

Although earlier reports have indicated that the use of a fluoride-releasing self-etching primer may have a detrimental affect on the SBS,[53] a recent study found no significant differences in SBS between brackets bonded using a fluoride-releasing sealant and a conventional primer.[53]

Antimicrobials have also been suggested as an adjunct for those patients with a higher caries risk. While repeated at-home applications of antimicrobials by the patient may reduce the patient's caries risk,[9] as explained earlier, patient compliance in using these materials is the critical factor. As a result, the addition of antimicrobials to the adhesive system would eliminate the need for patient cooperation and thus would have an obvious advantage. Combining chlorhexidene with the bonding primer or applying it after bonding is completed resulted in no significant decrease in SBS.[54,55] However, other methods of incorporating chlorhexidene into the bonding procedure resulted in significantly weaker bond strengths.[55] More specifically, the application of chlorhexidene as a separate varnish layer during the bonding process, either alone (ie, without applying a sealant) or as a separate layer over the sealant before placing the adhesive, resulted in a significant reduction in SBS when used to bond brackets.[55] A recent report that evaluated the use of another antimicrobial, cetylpyridinim chloride (CTC), found no significant differences in tensile bond strength between an adhesive impregnated with 2.5% cetypyridinium chloride and a control. Moreover, the adhesive containing 2.5% CTC was shown to inhibit bacterial growth for 196 days.[56] This may be an encouraging new development. Adhesives containing fluoride used with an antimicrobial primer have also been shown to bond brackets with no significant reduction in SBS.[57] Additionally, it was also found recently that using the combination of an antimicrobial self-etching primer and a fluoride-releasing adhesive had stronger SBS than a conventional composite resin used with the traditional acid-etch/primer procedure.[58]

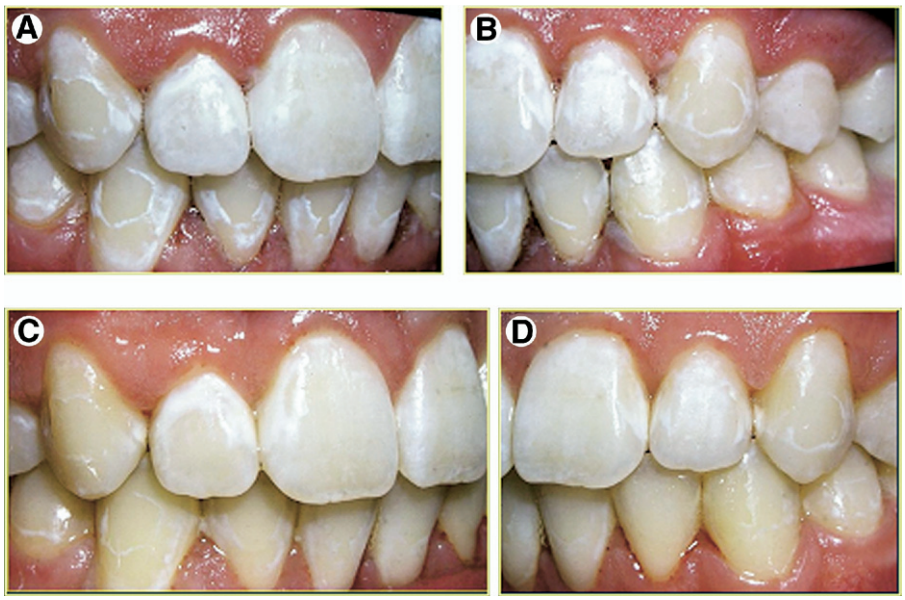

Figure 4. (A-D) Case illustrating the remineralization that could occur a few weeks following the completion of orthodontic treatment (A and B). The remineralization is the result of improved oral hygiene and from the available minerals in saliva, fluoridated toothpaste, and so forth (C and D). (Color version of figure is available online.)

Clinical Effects of Applying Different Varnishes

An in vivo study found that the use of either fluoride and chlorhexidene varnishes in combination or using a fluoride varnish alone resulted in a 30% reduction in WSLs at the time of debonding when compared with a control group that did not receive any varnish applications during treatment.[1] It was also found that the combination regimen did not result in significantly less WSLs than the application of fluoride varnish alone. However, it is important to emphasize that the findings also indicated that on the maxillary incisors, it was observed that only half as many WSLs developed when both varnishes were applied than when only the fluoride varnish was used. This is a clinically important finding, since WSLs on the maxillary incisors represent a significant esthetic challenge to both the patient and the orthodontist. Therefore, those patients whose inability or lack of motivation to maintain optimal oral hygiene during orthodontic treatment present a challenge to the clinician, that the use of products combining fluorides and antimicrobial agents should be seriously considered provided that such products do not significantly decrease the SBS of the adhesive system used.

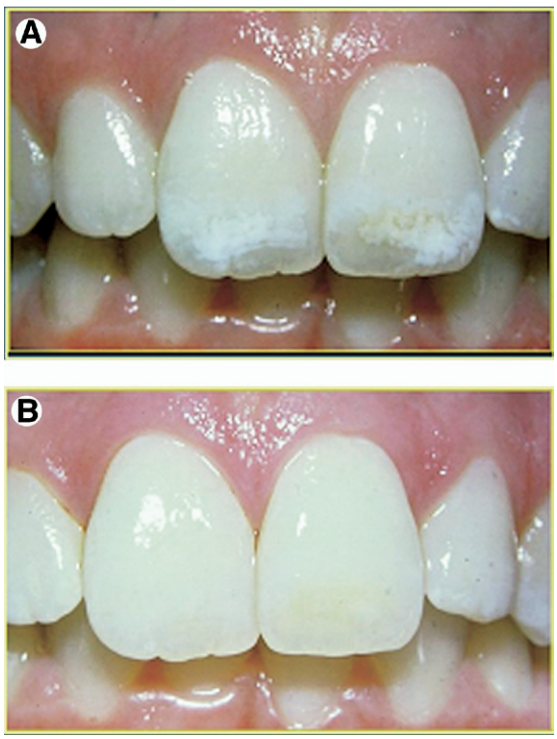

Figure 5. (A and B) Effect of the whitening procedure on lesions with mild/moderate fluorosis. (Color version of figure is available online.)

Figure 6. (A and B) Effect of microabrasion procedure on white spot lesions, performed 8 weeks following orthodontic treatment. (Color version of figure is available online.)

Treatment of White Spot Lesions

As patients respond differently to the presence of WSLs, the course of treatment will likely be unique to each patient. As explained earlier, before orthodontic treatment is initiated, the clinician should document the extent and severity of any WSL present through the use of intraoral photographs. These photographs can be used for comparative purposes both during and at the end of treatment for patient education as well as for the documentation of their presence.

In general, treatment of WSLs should begin with the most conservative approaches; if such approaches do not resolve the problem to the clinician's satisfaction, more aggressive treatment modalities can be pursued if the patient is interested.

The application of topical fluoride to the WSL is often considered by many clinicians as the first step in treatment. In theory, applying

high concentrations of fluoride to WSL may seem to be the most beneficial; in actuality, it might have some undesirable esthetic consequences. In patients who just completed orthodontic treatment, the effect of applying a high fluoride concentration may immediately remineralize the most superficial layer of enamel but leave the deeper enamel crystals relatively unaffected. Therefore, if WSLs are present immediately following orthodontic treatment (Fig 4A and B) it is advisable to first allow for a slower calcium and fluoride ion penetration of the WSL from saliva or through the application of lower concentrations of fluorides. This approach may ultimately produce more esthetically favorable results (Figs 4C and D). Such a treatment regimen may remineralize the mild WSL from the deeper parts of the lesion to the outer surface layers of the enamel, thus increasing the chances for a successful and more esthetic treatment result.

If time and fluoride do not improve or correct the esthetic concerns of the patient and clinician, tooth whitening should be considered as the next step. The purpose of this procedure is to camouflage mild and moderate fluorosis (Fig 5A and B) or WSLs by whitening the surrounding enamel surfaces. If whitening teeth is unsuccessful, the clinician may consider the use of microabrasion on the enamel surface (Fig 6A and B) in an effort to eliminate localized WSLs. The last resort to meet the esthetic objective of the patient and the clinician is having composite restorations (Fig 7A and B) or porcelain veneers placed. The latter treatment may require the removal of sound tooth structure and is typically more costly. However, it might be most successful in addressing the esthetic concerns of the patient in very severe situations.

Despite the fact that all these different options are available, it still needs to be emphasized that prevention of these lesions is the most desirable outcome esthetically and also the least costly for the patient.

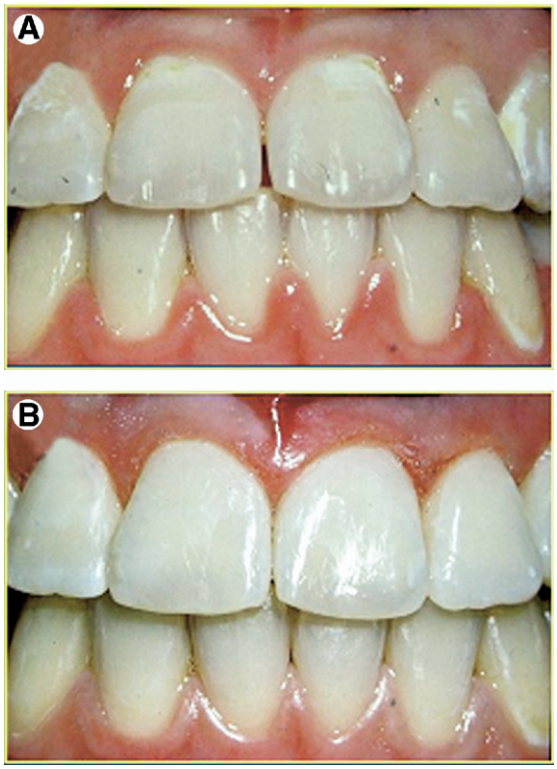

Figure 7. (A and B) Patient who needed composite buildups on the maxillary anterior teeth to esthetically improve areas of severe decalcification following orthodontic treatment and also close a midline diastema. (Color version of figure is available online.)

Conclusion

Decalcification of the enamel surface adjacent to fixed orthodontic appliances is an important and prevalent iatrogenic effect of orthodontic therapy. The banding and bonding of orthodontic appliances to teeth increases the number of plaque retention sites and, as a result, optimal oral hygiene becomes more difficult. In general, treatment of WSLs should begin with the most conservative approaches; if such approaches do not resolve the problem to the clinician's satisfaction, more aggressive treatment modalities can be pursued if the patient desires it.

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