White Spot Lesions After Orthodontic Treatment

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This article examines the prevalence and distribution of white spots after orthodontic treatment and reviews their management in the postorthodontic phase. Demineralized white spot lesions occur disturbingly frequently after orthodontic treatment, with some reports of high numbers of teeth affected, and approximately a third of orthodontic patients have at least one white lesion. Some teeth are more prone to demineralization, typically the maxillary lateral incisors and mandibular canine teeth. The distogingival area of the labial enamel surface is the most commonly affected. In the first few weeks after removal of appliances there is typically an exponential reduction of white spot lesion size by remineralization, and about half of the original lesion has remineralized after 6 months with no specific treatment. Various treatments have been proposed to assist remineralization. Fluoride must not be used in high concentration, as it arrests the remineralization as well as the demineralization and can lead to unsightly staining. Low concentrations of fluoride may assist remineralization, but this cannot be demonstrated in a prospective randomized study. Casein calcium phosphate materials and salivary stimulation by chewing gum may be effective in assisting remineralization, but as yet there are no clinical studies to demonstrate benefit over natural remineralization. For severe cases, acid microabrasion is recommended. (Semin Orthod 2008;14:209-219.) © *2008 Elsevier Inc. All rights reserved.*

White spot lesions and enamel demineralization can occur during and sometimes remains after some courses of orthodontic treatment.[1] This phenomenon has become a clinical problem since directly bonded orthodontic brackets were introduced.[2] The prevalence of the phenomenon is reported to vary from 4.9%[3] to 84%[4] of tooth surfaces.

In a longitudinal study, Mitchell[5] found an overall prevalence of 18.5% of tooth surfaces and reported that the average percentage of tooth surface area affected was 1.6%. Mizrahi[4] showed a high prevalence of 84%, which reflected the fact that he measured all (pre- and posttreatment) white enamel lesions and his results may have been affected by this patient group having a greater number of demineralized white lesions caused by local environmental effects.

In a study to compare bonding agents, Marcusson and coworkers[6] found an increase in all white lesions from 7.2% before treatment to between 24% and 40.5% after treatment, depending on the type of bonding agent used. Banks and coworkers,[7] in a prospective controlled study of fluoride releasing elastomerics, reported a prevalence of 26% of all teeth in the untreated control group.

It was shown some years ago that oral hygiene and topical fluoride regimens during treatment can reduce the prevalence of postorthodontic demineralized white spot lesions.[8] Benson and coworkers,[9] in a recent Cochrane systematic re-

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view, concluded that there is some evidence that the daily use of a sodium fluoride mouth rinse or glass ionomer cement to bond appliances may reduce the occurrence and severity of white spot lesions.

Preexisting white demineralization may be present in orthodontic patients, but not all white lesions are carious or are demineralization-related lesions.[10] The large variation in reported prevalence is due to the variety of methods used to assess and score the presence of demineralization and whether developmental or other idiopathic enamel lesions are included or excluded, local environmental factors, and the use or otherwise of a fluoride regimen during treatment.[11] Preexisting lesions depend very much on local environmental conditions.[12] In cross-sectional study designs (orthodontic patients after treatment compared with another group of patients who have not had orthodontics), it is difficult to distinguish between idiopathic white spots and demineralization, which artificially increases the prevalence quoted.

Zachrisson and Zachrisson[13] and Zachrisson[2] employed a longitudinal design and recorded only new white spots developing. Despite this, the prevalence they found was 89% and 15%, respectively. Stratemann and Shannon[14] and Mizrahi[4,15] have used photographs to back up their clinical assessment. Their results are more encouraging where the prevalence for teeth, rather than tooth surfaces, is quoted, and they found a prevalence of 0% to 24%. Gorelick and coworkers[3] were unable to detect any difference in the prevalence of white spot lesion formation when related to length of treatment time. Mizrahi[4] found a greater prevalence of lesions following orthodontic treatment in males and females, but there was no difference in the prevalence of pretreatment white opacities. Wisth and Nord[16] showed a greater proportion of buccal and lingual surface carious lesions in orthodontically treated individuals when compared with controls.

It would appear that the method used to assess and score either the presence or the absence of demineralization has a greater effect on the prevalence noted than the use of different bands or bonded attachments or the use of fluoride medicaments. In a Sheffield study,[17] the mean prevalence of postorthodontic demineralized white lesions expressed as percentage of tooth surfaces involved, for all cases in the study over 5 years, was 7.3%. Out of the 657 consecutively debonded subjects examined, 239 (36%) had one or more orthodontically related lesions. In this case controlled study, the prevalence of orthodontically related lesions was significantly greater in treated orthodontic arches ($P < 0.01$) when compared with untreated control arches in the same patients. The prevalence of demineralized white lesions is disturbingly high after orthodontic treatment.

Location of White Spots After Orthodontic Treatment

Few studies have been done on the location of the lesions on the labial enamel surface. Early studies investigated the distribution of these white spot lesions as part of wider investigations.[3,4,10,15] Some of these workers attempted to quantify the risks to orthodontic patients. These studies relied mostly on direct visual scoring. Precise localization of white lesions and their extent on different quadrants in different tooth groups has not been addressed in the literature. Mizrahi[15] examined the surface distribution of enamel lesions following orthodontic treatment, using the opacity index scoring system. His findings demonstrated that following fixed orthodontic treatment, an increase in the incidence and severity of white enamel lesions occurred on both the vestibular and the lingual surfaces of teeth. There was a significant increase in the prevalence on the cervical and middle thirds of the crowns. The increase was greatest on the cervical and middle thirds of the crowns of the maxillary and mandibular first molars, maxillary lateral incisors, and mandibular lateral incisors and canines, and mainly on the vestibular surfaces.

In general, the literature shows no clear attempt to precisely assess and measure the extent or surface area of such lesions on affected teeth. Working in Sheffield, Samawi[18] investigated patterns of location and surface area of white enamel lesions, commonly occurring on labial tooth surfaces of anterior teeth, after orthodontic treatment with bonded fixed appliances using computerized image analysis. The study design was a retrospective observational analysis of orthodontically treated cases in a university dental teaching hospital. The digital photographic

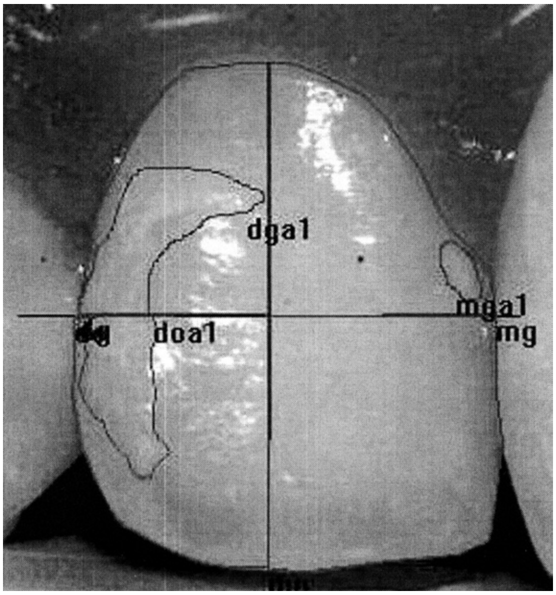

Figure 1. A white spot lesion outlined on the labial surface of a central incisor from the sample using the image analysis program. Labial surface division into four quadrants by the macro program is also shown.

records of 23 subjects (274 teeth) who had completed orthodontic treatment using bonded fixed appliances were used in the study. They had been identified consecutively as having demineralized enamel lesions on any of their anterior teeth. Pretreatment photographic slides were used to exclude any preexisting white lesions. Computer software was used to outline images and divide each labial tooth surface into quadrants (Fig 1). A repeatability study was initially performed to assess intra-examiner random error and systematic bias. The outcome measure was the location and surface area of the lesions. The results showed that postorthodontic demineralized white enamel spots followed a pattern in relation to their surface area on labial surfaces of affected anterior teeth. The surface areas of lesions depended on the particular tooth type and whether they were in the upper or lower arch ($P = 0.014$; Fig 2). Larger lesions occurred in gingival quadrants and in upper central and lateral incisors particularly. Lesions in gingival quadrants had a larger mean surface area than lesions in occlusal quadrants ($P = 0.001$). Upper anterior teeth showed larger mean demineralization surface area than anterior teeth in the lower arch. The distogingival quadrant of the upper lateral incisor teeth was particularly more affected than the mesiogingival quadrant for that tooth group. No significant differences were found between the right and left sides.

Remineralization and Regression of White Spots

Clearly the best approach during orthodontic treatment is to prevent lesions from occurring. Once formed, however, many of these early lesions appear to be surface demineralization rather than a subsurface lesion with an intact surface zone. Remineralization of these white lesions is a natural phenomenon resulting in the partial reversal of what is an early caries lesion.

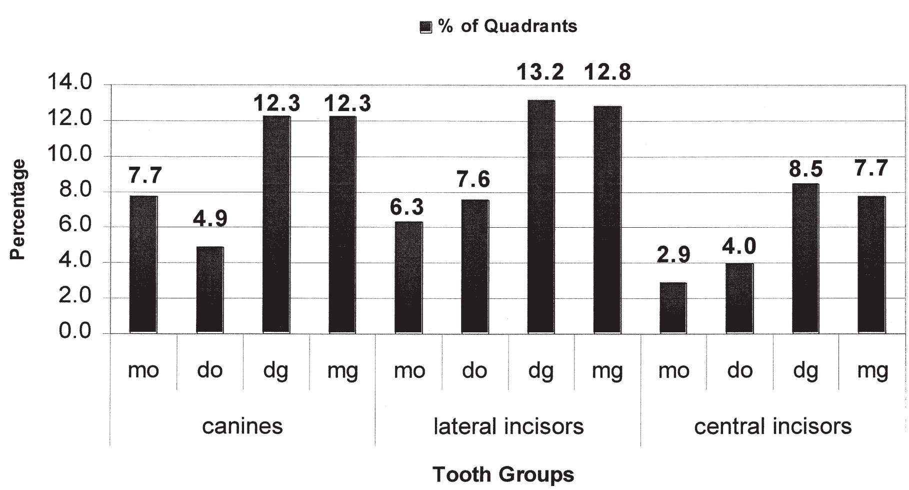

Figure 2. Histogram showing the percentage of affected quadrants in each tooth group. mo = mesio-occlusal; do = disto-occlusal; dg = disto-gingival; mg = mesio-gingival.

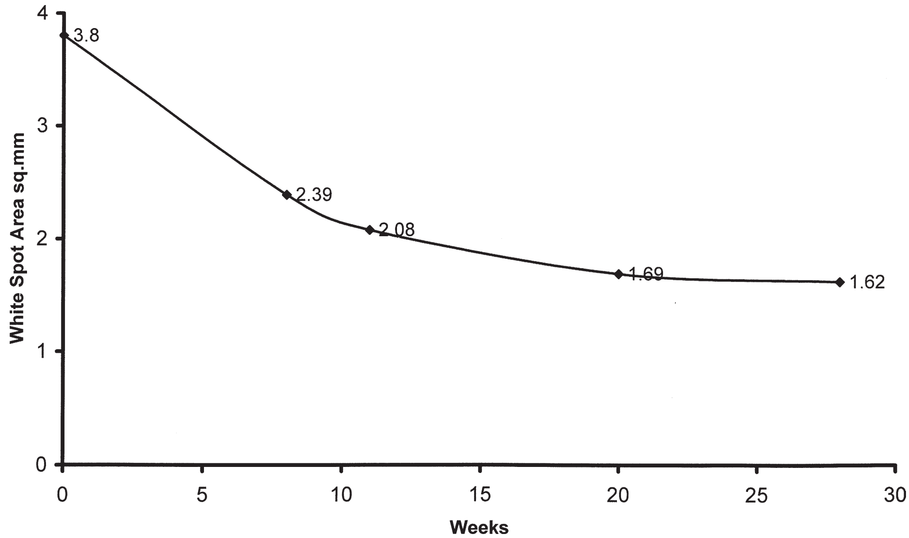

Figure 3. A graph showing change of mean white spot area from removal of fixed appliance to 28 weeks for a typical case in the study.

The factors involved are discussed in the proceedings of a workshop by Leach.[19] The mineral of the dental enamel is in equilibrium with its environment and saliva contains all the necessary elements for hydroxyapatite crystal growth. In the natural state, there is demineralization and remineralization continually taking place. An excellent example of this is the maturation of tooth enamel that occurs shortly after a tooth erupts. Examination of a group of 9-year-old children revealed 72 carious white lesions, which were carefully recorded.[20] Six years later, 50% of those lesions had disappeared, inferring that remineralization had taken place. Remineralization varies considerably from subject to subject and from site to site in the mouth.[21] These studies have shown an average remineralization of 20% to 30% over 2 weeks (measured as percent mineral change). Sometimes the amount of remineralization cannot totally overcome the amount of demineralization even with an effective agent present. Following removal of a fixed orthodontic appliance, some regression of postorthodontic lesions is known to occur provided other etiological factors are favorable.

Using polarized light and filters, it is possible to obtain photographic images of white spot lesions without the light reflections, which make image processing difficult.[22] Longitudinal measurements of the size of white spot lesions using such a method have shown that there was a reduction in size of white lesions with time.[23] The graph in Fig 3 shows the reduction of lesion area in a typical case from the Sheffield studies. It shows an exponential reduction in area of postorthodontic white spots with time, almost certainly due to enamel remineralization. In a study performed using lesion size as the outcome measure for 9 subjects who had suffered white spot lesions after fixed appliance orthodontic treatment, the mean size of lesions at debond was 2.72 mm^2 (SD ± 1.72).[23] After 26 weeks, the mean size was 1.30 mm^2 (SD ± 3.40). Using an unpaired t test, this change was significant (P = 0.037). In most cases, rapid size reduction occurred during the first 12 weeks after appliance removal. In four cases studied for more than 26 weeks, little further reduction occurred. The most rapid reduction occurred during the first 12 weeks after appliance removal. Lesion size reduced on average by [1/3] after 12 weeks and [1/2] of the size of the initial lesion after 26 weeks. More recent studies using light-induced fluorescence[24] have shown that small lesions show a rapid improvement 6 weeks after debonding ($P < 0.01$) and a further improvement after 6 months ($P < 0.01$) confirming the work of Willmot[23] but using a different imaging technique. It is clear that white lesions left untreated after removal of a fixed orthodontic appliance will naturally reduce in size with no intervention.

Treatment of the White Spots After Fixed Appliance Removal

Ogaard and coworkers[25] warned against treating visible white lesions on labial surfaces with concentrated fluoride agents, since this arrests both demineralization and remineralization in the lesion by surface hypermineralization. Instead, these workers advocated allowing remineralization by saliva, as this results in greater repair and a less visible lesion. The use of high doses of fluoride completely arrests the carious process, which is ideal for posterior carious lesions, but the white spot lesion of orthodontic origin presents a cosmetic challenge and regression is the therapeutic goal. If high doses of fluoride are used locally, the arrested lesion stays the same size and frequently becomes unsightly and stained with organic debris. Figure 4 shows a lower right canine that had a spot orthodontic white lesion, which was treated at debond with fluoride varnish. The lesion has not regressed and has stained brown. Natural remineralization also produces a greater resistance to further dissolution due to the fact that during remineralization, components are replaced with less soluble substance that may have larger crystals.[26] This has been reported as plugging of diffusion pathways of enamel by hydroxyapatite crystals as hyperremineralization.[27] Workers in this field, however, have recommended the remineralization of small lesions with low fluoride preparations.[28,29] They have shown that lesions smaller then 60 μm deep can be remineralized using these preparations. To avoid arresting the lesion and obtunding the surface layer, several workers have recommended low-dose fluoride applications to enhance subsurface remineralization. Lee Linton[28] showed that a 50-ppm fluoride mouth rinse had a higher efficiency for remineralization than a control solution or a regular mouth rinse containing 250 ppm. For lesions on surfaces other than on the visible labial surface, application of concentrated fluoride was suggested to prevent further progression. It has been suggested that acid etching of fluoride-treated lesions could facilitate remineralization of the lesion by oral fluids.[30]

Figure 4. Shows a lower right canine, which had an orthodontic white spot lesion that was treated at debond with strong fluoride varnish. The lesion has not regressed and has stained brown. (Color version of figure is available online.)

Use of Low Fluoride Mouth Rinses

In a study performed in Sheffield,[23] the purpose was to compare the fate of postorthodontic demineralized white lesions when subjected to intervention with a rinsing/toothpaste regimen of either a specially formulated low fluoride mouthrinse (50 ppm) test combination or a control fluoride-free mouth rinse/toothpaste combination. The study design was an experimental double blind, prospective, randomized, clinical controlled trial in a university dental school orthodontic clinic. The participants consisted of 26 patients identified as having postorthodontic demineralized white lesions on removal of their fixed appliances. On acceptance to the study they were randomly and blindly assigned to either a low fluoride mouth rinse/toothpaste treatment regimen or an inactive control of mouth rinse/toothpaste identical to the treatment regimen but without fluoride. Computerized image analyses of calibrated photographic images taken under polarized light were used to measure the lesions. The outcome measures were actual lesion size measured by image analysis and a proportional measurement used to eliminate calibration errors termed average difference percentage reduction (ADPR). These measurements were taken at debond and at 12 and 26 weeks after debond for all participants.

On completion, 5 participants had dropped out of the study; 12 participants had had the low fluoride regimen and 9 had not. After unlocking the randomization code, 12 participants had been exposed to the active low fluoride mouth wash/toothpaste regimen and 9 participants had been exposed to the inactive control. At 12 weeks the proportional measurement (ADPR) for the participants who had blindly been subjected to a test remineralizing mouth rinse/ toothpaste combination (n = 12) was 40.0%, and for those participants who had been given a control combination (n = 9) it was 51.5%. There was no statistically significant difference between the two groups. It was concluded that postorthodontic demineralized white spots reduced in size during the 6 months following treatment by approximately half the original size, but there was no clinical advantage in using the low fluoride formulation of mouth rinse/ toothpaste in this study.

For all 21 subjects for whom complete measurements were available, as a percentage of the total labial tooth area, the mean size of the lesions at debond was 8.1% (SD ± 3.7). After 12 weeks, the mean size of the lesions had reduced to 4.6% (SD ± 2.6), which was a significant reduction ($P = 0$). After 26 weeks, the mean size was 3.5% (SD ± 2.1), which was a very significant reduction ($P < 0.003$). This confirmed statistically that postorthodontic demineralized white lesions do reduce in size with time, reflecting remineralization or other enamel surface changes. Figure 5 shows a graph of combined lesion size plotted against time after debond from a case in the study.

This work did not therefore confirm the therapeutic affect of low fluoride (<50ppm) preparations observed by other workers.[28,29] The sample size used was sufficient to detect a 30% or greater difference in lesion proportion, between the groups, and this was not detected. It was considered that recruiting further participants to this study would not be able to demonstrate a useful clinical effect of using low levels of fluoride because the mean size of the lesions for both groups combined under consideration was 3.06 mm^2 at debond and 1.32 mm^2 at the end of recordings. A therapeutic effect of less than 30% would be clinically and visually insignificant.

The size reduction with time measured as a proportion plotted as graphs in the clinical trial showed the general exponential reduction in demineralized white lesion area seen in earlier longitudinal studies and reported in experimentally induced caries.[30] The reductions are similar to those reported using the very different measurement technique of quantitative light-induced fluorescence (QLF)[31-33] in a comparative in vitro study. Both image analysis of

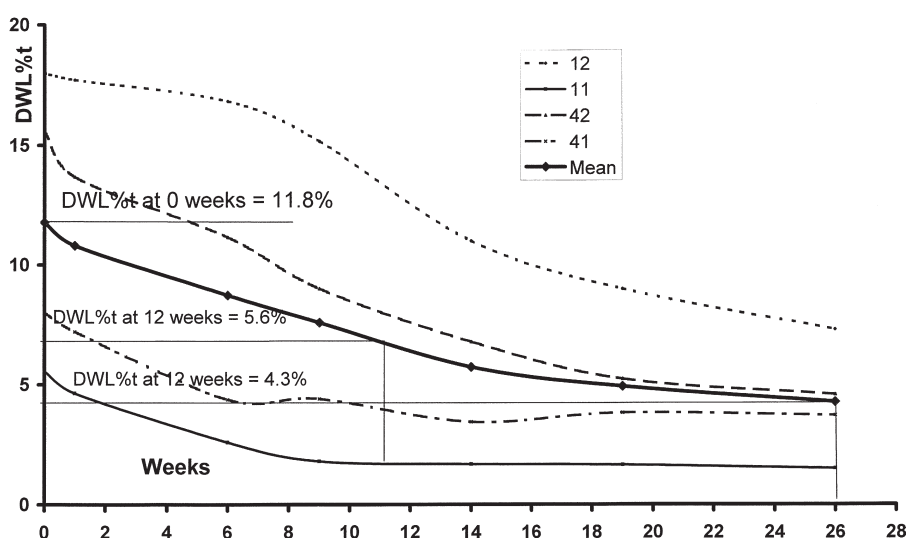

Figure 5. A typical graph of change in the percentage of labial tooth surface affected by white demineralization with time (DWL%t) for four teeth in one subject from the randomized clinical trial in Sheffield. The thick black plot shows the change in proportion with time as the mean of the lesions on the four teeth, the maxillary and mandibular right central and lateral incisors. From the mean curve, the percentage affected tooth surface at 0, 12, and 26 weeks has been identified. The difference between 0 to 12 and 0 to 26 weeks can then be calculated. For this case, the average percentage reduction was 6.2% (11.8-5.6) and 7.5% (11.8-4.3) at 12 and 26 weeks, respectively.

visible light and laser fluorescence methodologies and outcome appear to show similar size reduction after debond, which is most probably salivary remineralization of surface enamel. More recently, workers using a laser fluorescence method[34] to measure lesion size were unable to show a clinical advantage between professional cleaning and oral hygiene instruction only. They did, however, confirm the longitudinal natural reduction in lesion size in both groups over time.

Use of Casein Phosphopeptide Amorphous Calcium Phosphate (CPP-ACP)

In the 1980s, Reynolds[35] drew attention to the fact that casein phosphopeptide amorphous calcium phosphate, which is a product derived from milk casein, was capable of absorbing through the enamel surface and could affect the carious process. CPP-ACP is a delivering system that allows freely available calcium and phosphate ions to attach to enamel and reform into calcium phosphate crystals. The free calcium and phosphate ions move out of the CPP-ACP and into the enamel rods and freeform as apatite crystals.[36] A number of different media have been produced to deliver the CPP-ACP, including a water-based mousse, a topical cream, chewing gum, mouth rinses, and sugar-free lozenges. The material is marketed under the trade name "Recaldent." Studies of the effects of CCP-ACP have shown promising dose-related increases in enamel remineralization within already demineralized lesions.[37,38]

In Sheffield, clinical experience has been developed using the mousse (GC Tooth Mousse; Recaldent, Newport Pagnell, UK) to treat posorthodontic lesions using thermoplastic retainers as the delivery method. Figure 6 shows a patient wearing a thermoplastic retainer in which a pea sized amount of CPP-ACP mousse has been spread evenly. The patient places the mousse at night and wears the retainer throughout sleep. Figure 7 shows the condition of the teeth at debond with white spot lesions and after 3 months of treatment. Clearly, the lesions have regressed, but, as yet, we have no comparative studies to indicate whether this regression is greater than that which would have occurred naturally. Figure 8 shows the intraoral views of a patient who was treated in such a manner at 1 week, 4 weeks, and 12 weeks after debonding. At the present state of knowledge, we can see no harmful effect of this material and there is good reason to believe from in vitro reports that remineralization of enamel will provide benefits for the patient suffering from postorthodontic white spot demineralization.

Figure 6. Patient E wearing a thermoplastic retainer filled with "Recaldent" GC Tooth Mousse (CPP-ACP cream) and worn at night as part of the retention regimen. (Color version of figure is available online.)

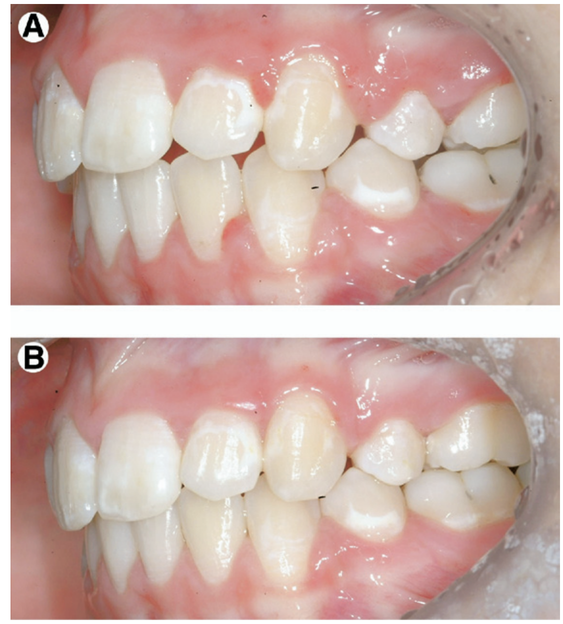

Figure 7. (A) Intraoral left view of patient E on the day of removal of fixed appliances (debond). (B) Intraoral left view of patient E 3 months after debond and having worn a thermoplastic retainer with "Recaldent" GC Tooth Mousse (casein phosphopeptide amorphous calcium phosphate, or CPP-ACP cream) placed before retiring. (Color version of figure is available online.)

Figure 8. (A) Patient H at debond. (B) Patient H after 1 week of casein phosphopeptide amorphous calcium phosphate (CPP-ACP) mousse treatment. (C) Patient H after 4 weeks of CPP-ACP mousse treatment. (D) Patient H after 12 weeks of CPP-ACP mousse treatment. (Color version of figure is available online.)

Chewing Gum to Promote Remineralization

For some time, the use of chewing gum has been recommended to assist enamel remineralization.[39] In nonorthodontic patients, a regimen using a sorbitol-based chewing gum chewed for 20 minutes, 5 times daily for 3 weeks, showed significant remineralization of demineralized enamel when compared with controls without chewing gum. The use of xylitol as an alternative sweetener may be superior when compared with sorbitol because of the potential anticaries properties.[40,41] It has been suggested that xylitol may affect the process of enamel demineralization and remineralization directly.[42] CPP-ACP has been used in chewing gum in an attempt to promote remineralization. In vitro studies[37,43,44] have shown enhanced remineralization, but the methodology of some of the experiments has been questioned. It is agreed that the beneficial remineralization effects seen with the use of chewing gum are attributable in a large measure to salivary stimulation. The use of sugar-free gums is to be recommended after the removal of fixed orthodontic appliances, although as yet we have no quantitative information to indicate a clinically significant beneficial effect over natural remineralization. There is every indication that such an effect may exist.

Microabrasion

Microabrasion has many applications and has been widely used for the removal of superficial noncarious enamel defects.[45-47] Recently, the technique of microabrasion has also been advocated for the removal of postorthodontic demineralized white lesions.[48,49] Few quantitative studies have assessed the success of the microabrasion technique in improving the cosmetic appearance of postorthodontic demineralized enamel lesions. Its effectiveness in treating various enamel lesions has been mainly empirical and anecdotal. Murphy and coworkers[50] performed a study, the aim of which was to quantify changes in postorthodontic demineralized enamel lesion surface areas after microabrasion. The study group comprised 8 orthodontic patients with multiple decalcified enamel lesions after fixed orthodontic therapy. Two demineralized areas were randomly selected for interventive treatment in each patient. Microabrasion was undertaken on these lesions by using a well-accepted 18% hydrochloric acid and pumice technique.[48] Standardized intraoral images were taken of the lesions before and immediately after microabrasion. Image-processing software was used to quantify the size, in mm^2, of the visible areas of the demineralized lesions before and after microabrasion. The total labial surface area of each tooth was also determined and the area affected by demineralization was expressed as a percentage of the total tooth surface. Images were reanalyzed a month later to determine the repeatability of the method. The results showed that microabrasion significantly reduced visible enamel demineralization ($P < 0.001$). The mean reduction in lesion size after treatment was 83% (SD ± 0.2%; range, 61-92%). The quantification methodology was found to be highly repeatable. Figure 9 shows before and after photographs of long-standing lesions treated by the microabrasion technique in the study. Microabrasion was shown to be an effective treatment approach for the cosmetic improvement of long-standing postorthodontic demineralized enamel lesions.

Conclusions

The prevalence of demineralized white lesions is disturbingly high after orthodontic treatment.

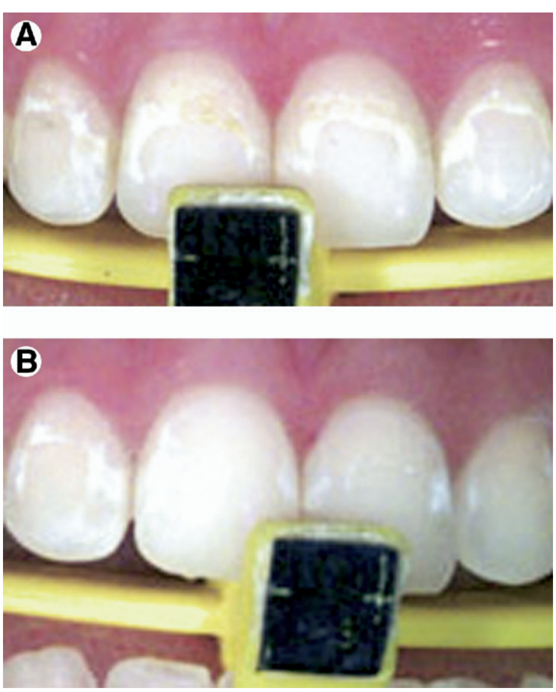

Figure 9. Clinical photographs showing severe long-standing white spot lesions treated by microabrasion technique. (A) Upper central incisors before microabrasion. (B) Upper central incisors after microabrasion. (Color version of figure is available online.)

1. Larger lesions occur in gingival quadrants and in upper central and lateral incisors particularly. Lesions in gingival quadrants have a larger mean surface area than lesions in occlusal quadrants.
2. It is clear that white lesions left untreated after removal of a fixed orthodontic appliance will naturally reduce in size with no intervention.
3. For white spot lesions on the visible labial surface of teeth following orthodontic treatment, the use of concentrated fluoride agents is not to be recommended. Such use will limit the possibility of remineralization and the resulting white spot will not naturally reduce in size and may become unsightly through staining.
4. For lesions on surfaces other than on the visible labial surface, application of concentrated fluoride is suggested to prevent further progression.
5. Casein phosphopeptide amorphous calcium phosphate materials will potentially enhance remineralization. At the present state of knowledge we can see no harmful effect of this material and there is good reason to believe from in vitro reports that remineralization of enamel will provide benefits for the patient who have postorthodontic white spot demineralization.
6. The use of sugar-free gums is to be recommended after the removal of fixed orthodontic appliances, although as yet we have no quantitative information to indicate a clinically significant beneficial effect over natural remineralization. There is every indication that such an effect may exist.
7. Microabrasion was shown to be an effective treatment approach for the cosmetic improvement of long-standing postorthodontic demineralized enamel lesions.

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