



Effect of Demineralization and Remineralization during and after orthodontic treatment

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Abstract:

Background: White spot lesions are white opacity on the surface of the tooth enamel which occurs as a result of subsurface enamel demineralization around the fixed orthodontic brackets is often considered as one of the major clinical challenge in orthodontic patients that can have a psychological impact on the overall treatment outcome. Literature studies have postulated that the position, angulation and alignment of fixed orthodontic appliances creates a favourable environment for the accumulation of debris and microorganisms, which causes enamel demineralization or exacerbates the effects of pre-existing carious lesion.

Aim: The present literature review was carried out to elaborate the effect of demineralization and remineralization during and after orthodontic treatment with special emphasis on various remineralizing agents and methods currently available to prevent and/or treat white spot lesions.

Discussion: Early management strategies includes patient education, oral prophylaxis, and appropriate good oral hygiene habits along with use of remineralizing fluoridated and nonfluoridated agents such as topical fluorides, varnish, CPP-ACP containing pastes or bioactive glasses before and after orthodontic treatment to reverse demineralization effects and to enhance remineralization process to restore normal oral environment.

Conclusion: From the present review it can be postulated that application of remineralizing agents repeatedly over a period of time during and after orthodontic treatment significantly increase their mode of action by producing inhibition effect on enamel demineralization and promote remineralization.

Keywords: Decalcification, Fluorides, Hydroxyapatite crystals, Orthodontic brackets, Selfetch Primers, White spot lesions.

Introduction:

Discoloration and appearance of white spot lesions (WSLs) on the tooth surface caused by demineralization of enamel around the fixed orthodontic brackets is one of the major clinical challenge in orthodontic patients that can have a psychological impact on the treatment outcome. Enamel demineralization or decalcification is the process of removal or loss of minerals from the enamel in the form of mineral ions and remineralization is the reversal cyclic process of restoring lost minerals to hydroxyapatite latticework structure with the help of remineralizing agents that requires early detection and implementation [1, 2].

White spot lesions (WSLs) are white opacity on the surface of the tooth enamel which occurs as a result of subsurface enamel demineralization [3]. These often occurs due to accumulation of oral debris, plaque, and calculus for a prolonged time around fixed appliances commonly due to inadequate oral hygiene practices and excessive frequency of carbohydrate intake [4]. The first clinical evidence of enamel demineralization often occurs around 3 to 4 weeks as a white spot on the tooth surface representing the initial carious process, an optical phenomenon caused by loss of subsurface minerals at the enamel layer [5]. Carious WSL and non-carious WSLs can be clinically differentiated by Rough, opaque, porous surface or by presence of smooth shiny surface correspondingly. Prevalence studies have shown an overall WSLs prevalence rate between 2% and 96% among patients undergoing fixed appliance brackets or band either during or after orthodontic treatment [6-8].

Several studies have postulated that the position, angulation and alignment of fixed orthodontic appliances creates a favourable environment for the accumulation of debris and microorganisms, which causes enamel demineralization or exacerbates the effects of any pre-existing carious lesion [9, 10]. Similarly remnants of bonding materials adjacent to orthodontic appliances also have shown influencing acceleration on accumulation of dental plaque. Under these favourable conditions, acid from the cariogenic or acidogenic bacteria decreases the pH and leads to demineralization of the enamel. If this process is not reversed or stopped, early lesion can eventually become a well differentiated cavity that required extensive management [11, 12].

Numerous studies have shown difficulty in performing appropriate oral hygiene and prophylactic practices in patients with orthodontic brackets, bands and attachments increases the risk of developing gingival inflammation and enamel decalcifications that can lead to white spot lesions and dental caries [13-15]. Though WSL developed during orthodontic treatment possess limited ability to regress after appliance removal frequently may either disappear or will therefore remain visible as permanent spots on the surface of the enamel.

Management of these early WSLs and demineralization process largely depends on use of strategies to arrest these lesions, prevent plaque accumulation and induce remineralization to reverse this early process by use of fluorinated or Non-fluorinated oral hygiene aids such as fluoridated tooth paste, mouth rinse, fluoride creams, varnish, APF gel, fluoride releasing cements, Casein phosphopeptide–amorphous calcium phosphate complexes (CPP-ACP), nano hydroxyapatite crystals, calcium sodium phosphosilicate glass infiltrates, micro-abrasion, selfetching primer adhesives and bonded facets [16, 17].

Over the years many remineralizing agents have been introduced and researches were carried out to determine their effectiveness, efficiency, durability, biocompatibility and their potential to induce remineralization along with inhibition of the demineralization process [18]. Nonetheless, very few studies were carried out to review the use of various strategies in preventing enamel demineralization and role of remineralizing agents during and after fixed orthodontic appliance therapy. Hence the present literature review was carried out to elaborate the effect of demineralization and remineralization during and after orthodontic treatment with special emphasis on various remineralizing agents and methods currently available to prevent and/or treat white spot lesions.

Methodology:

A structured literature search for articles written in the English language in PubMed/MEDLINE, EBSCOhost, Google Scholar, Scopus, IEEE Xplore Digital Library and Web of Science databases was retrieved by using MeSH terms “White Spot Lesions” OR “Orthodontic appliance therapy” AND “Dental”, “Demineralization” AND “Remineralization” "Fixed appliance therapy,

Dental" OR “Fluorides” OR “Enamel Remineralization” OR "All Metadata", “Dental, Remineralization agents”, “Orthodontic brackets”.

Literature overview:

O'reilly and Featherstone (1987) in an in-vivo study to determine the amount of demineralization quantitatively and evaluate the effect of fluoride products with orthodontic materials in process of remineralization revealed demineralization was seen only after 1 month of bracket placement and observed this process can be completely reversed by using sodium fluoride mouth rinse, APF

(Acidulated Phosphate Fluoride) gel or combination of commercially available fluoride products [3].

Ogaard B (1988) in a clinical trial study to investigate the effect of fluoride on early carious lesions and white spot lesions (WSLs) during fixed orthodontic appliance therapy revealed more than half of the subjects with no preventive fluoride programs experienced an increase of WSLs during treatment with fixed appliance therapy however WSLs may disappear or remineralize following the completion of appliance therapy since remineralizing capacity of saliva was found to be rapid even in the absence of fluoride agents [11].

Rolla et al (1991) demonstrated the inclusion of adhesives and cements containing fluorides, CPP-ACP along with topical fluoride application, sealants has proven to be effective against demineralization during orthodontic treatments and considered caries reduction with synergistic effect from the enhanced oral hygiene [19].

Miller JR (1997) incorporated the use of remineralizing agents in orthodontic bonding composites to reduce WSLs during the treatment phase that was not accepted widely owing to the nature of bonding adhesives and oral environment [20].

Gorton and Featherstone (2003) in an in-vivo study on demineralization around orthodontic appliances reported significant inhibition using GIC (Fluoride releasing glass Ionomer cements) for bonding orthodontic brackets and other attachments. This cariostatic effect was seen only after 4 weeks localized around the fixed orthodontic appliances indicating role of inadequate oral hygiene, long intervals between appointments, and potentially poor patient cooperation as a contributing factor in preventing carious and non-carious WSLs [21].

Benson PE et al (2005) in a systematic review on role of fluorides and demineralization among orthodontic patients undergoing fixed appliance therapy concluded that reduction in demineralization and WSLs were seen among individuals performing 0.05% sodium fluoride mouth rinse regularly [22].

Boersma et al (2005) established a positive correlation between caries prevalence, occurrence of white spot lesions, Lactobacillus counts and orthodontic therapy and found that the caries lesions remained 6 weeks even after the completion of orthodontic treatment however the conventional caries risk factors did not explain the incidence of these white spot lesions [6].

Al-Suleiman et al (2012) suggested that application of either fluoride varnish or amorphous calcium phosphate (ACP) as a preventive method for enamel decalcification and promote remineralization at the time of bonding using self-etching primer simultaneously had no effect on stainless steel metal brackets shear bond strength [9].

Baysal and Uysal (2012) conducted a study to evaluate the effect of CPP-ACP application on the shear bond strength of orthodontic brackets bonded to demineralized enamel surface and concluded that pre-treatment of enamel with CPP-ACP improves bond strength and prevent demineralization process [23].

Montasser et al (2015) in an In vitro study observed resin infiltrate, fluoridated varnish and selfetch primer systems increases enamel resistance to demineralization around the orthodontic brackets if applied before bonding without compromising the shear bond strength [10].

Korkut B et al (2017) demonstrated significant amount of demineralization at the end of 3 weeks following fixed orthodontic appliances often increased over a period of time that can be completely inhibited and/or reversed by use of fluoridated tooth paste, remineralizing cream and similar commercially available products [12].

Dai Z et al (2019) evaluated the mineralization efficacy of white spot lesions following fixed orthodontic appliance therapy and compared the remineralization potential of fluoride toothpaste, fluoride varnish and Casein phosphopeptide–amorphous calcium phosphate complexes (CPPACP). The study revealed similar remineralizing efficacy after 1 month and higher degree of remineralization using combination of CPP-ACP and Fluoridated tooth paste after 3 months [13].

Kawsar MA et al (2019) performed a prospective observational study to determine the prevalence of WSLs among patients undergoing orthodontic treatment. The study revealed 21.8% and 26.1% WSLs prevalence rate after 6 months and 12 months at the maxillary incisors (incisal region) respectively among individuals during orthodontic treatment predominantly among 12 to 16 years of age [1].

Suen S (2021) in a literature review on white spot lesions following orthodontic treatment showed Casein phosphopeptide–amorphous calcium phosphate complexes (CPP-ACP) and tricalciumphosphate (TCP) are effective for short duration while fluoridated tooth paste showed positive effects on remineralizing white spot lesions for long-term orthodontic treatment [14].

Yadav J et al (2022) in a narrative review revealed white spot lesions during and after fixed orthodontic therapy can be eliminated by using application of fluoride prophylactic agent, tooth bleaching agents, antiseptics, probiotics, CPP-ACP and resin infiltrations [2].

Discussion:

Accumulation of debris, plaque and calculus for a prolonged duration causes common oral health problems like gingivitis, periodontitis and dental caries. Inappropriate oral hygiene practices, improper use of oral hygiene aids and tooth brushing techniques involving excessive pressure may not efficiently or effectively remove plaque but also considerably impact the fixed orthodontic appliance placed on the surface of the tooth. Demineralization or decalcification of the enamel by organic acids produces a subsurface porosity clinically appear as white chalky opaque spots on the smooth surfaces that significantly affects the aesthetic appearance and impact the treatment outcome [1-5].

The first clinical evidence of enamel demineralization occurs around 3 to 4 weeks as a white spot on the tooth surface representing the initial carious process, an optical phenomenon caused by loss of subsurface minerals at the enamel layer. Prevalence studies have shown varying ranges of 21.8% [1], 38% [24], and 40% with WSLs increases from 6 months to 12 months during orthodontic treatment [25]. Approximately more than half of the orthodontic patients develop white spot lesions in at least 1 tooth with higher prevalence on maxillary central incisors followed by laterals, canines, premolars and maxillary first molars (least) in contrast to 24% in those not undergoing orthodontic treatment [1, 7, 8].

Cariou WSL and non-cariou WSLs can be clinically differentiated by Rough, opaque, porous surface or by presence of smooth shiny surface correspondingly. Electron microscopic and histopathological studies have shown variable degree of mineralization in mild to moderate WSLs while severe lesions demineralize at a faster rate even after 3 months of post- orthodontic treatment [1, 2, 7, 26]. These findings emphasizes the need for advanced detection method for WSLs in their early stage since standard visual examination requires air-drying often limited to the outer half of the enamel, while the depth of white spot lesions which are not evident without

air-drying was located in the inner half. Currently, Optical methods were recommended to enable early detection and quantification of caries lesions that includes Light-induced fluorescence (QLF), electrical caries monitor (ECM), digital imaging fibre-optic trans illumination (DIFOTI), auto-fluorescence and Scanning electron microscope (SEM) [13, 27].

Studies have shown acidogenic bacteria predominantly Mutant streptococcus (MS) and lactobacillus produces organic acids creating a favourable environment at the periphery of the orthodontic brackets and bands for demineralization by lowering the pH of the accumulated plaque. A recent study had revealed elevated levels of Mutant streptococcus (MS) in orthodontic patients with fixed appliance therapy [6, 9, 12]. Linear correlation between number of lactobacilli, MS, and occurrence of WSLs was observed by Benson PE et al and revealed that reduction in bacterial counts was more distinct for lactobacilli, which may specify that MS levels need longer duration to return to normal, or that the natural balance between these plaque inducing bacteria is shifted during course of orthodontic treatment [22]. Insertion of fixed orthodontic appliances with irregular surfaces (brackets, bands, wires and other attachments) creates stagnation areas for plaque accumulation along with other contributing factors such as age, gender, poor oral hygiene, inadequate cleaning effect of the saliva, consumption of high carbohydrate diet, and intake of fermentable foods frequently drops pH further, below the remineralization range, hence initiating the carious decalcification process [1, 28].

Researchers have presented high caries incidence rate and risk association among patients undergoing appliance therapy due to poor oral hygiene practices. Tooth surfaces that are more frequently exposed to dietary carbohydrate with less accessible to salivary action such as maxillary anterior tooth region, and cervical areas of the orthodontic brackets and bands are the common sites for demineralization to occur. Effective removal of plaque biofilm using fluoridated tooth paste twice a day using specially designed orthodontic tooth brushes, interdental orthodontic brushes along with use of mouth rinses is highly recommended. It was also evident that this demineralization process can be reversed by deposition of calcium, phosphate, fluoride and other mineral thus increasing the pH and initiating the remineralization process [1, 7, 28, 29].

Various fluorinated and non-fluorinated methods were proposed to induce remineralization through the use of oral hygiene aids such as fluoridated tooth paste, mouth rinse, fluoride creams, varnish, APF gel, CPP-ACP, nano hydroxyapatite crystals, calcium sodium phosphosilicate glass infiltrates, xylitol chewing gums, Probiotics, and Amorphous calcium phosphate systems. Some clinical studies found that use of fluoride toothpaste after debonding could be sufficient to improve and remineralize the area of WSLs. However, long-term follow-up studies after orthodontic treatment showed that despite reduction in WSLs involvement on the subsurface enamel. The lesions did not disappear completely but stabilized in a certain region on the tooth surface [1, 2, 8, 9].

Among the fluorinated remineralizing agents, use of toothpaste with a high fluoride concentration (5000 ppm), twice daily, by orthodontic patients was found to be more effective than traditional practices. Similarly daily use of sodium fluoride containing mouth washes had showed marked reduction in WSLs and plaque accumulation

around the fixed appliance brackets and bands. Ogaard B et al demonstrated fluoridating agents with a very low pH (1.9) promotes remineralization of enamel in the form of fluoro-hydroxyapatite and induces large amount of calcium fluoride formation underneath the fixed orthodontic brackets and bands. He also verified that 0.2% solution sodium fluoride (NaF) mouth rinse retarded lesion development significantly, whereas the fluoride solution with low pH inhibited lesion formation completely if used on a daily basis [11].

Fluoride application either topically or as fluoridated agents underneath orthodontic fixed appliance brackets or bands had retarded lesion progression. Application in the form of Resin infiltrates, topical fluorides, Varnish, and Bioactive glass showed better remineralization potential and was found to be effective against WSL's due to its ability to immediately repair enamel surface, low cytotoxicity, and high biocompatibility. Schmidlin R et al in an in-vitro study found resin infiltrates decrease the dissolution of enamel and limit the occurrence of WSLs [30].

Chadwick BL et al observed use of topical fluorides in addition to fluoridated tooth paste decreased the incidence of decalcification among patients undergoing orthodontic treatment with fixed appliances [31]. Marinelli G et al revealed topical application of remineralizing agents, micro abrasion, and bleaching represent attempts to reverse enamel demineralization and/or to improve tooth appearance [32]. Gontijo L et al considered application of fluoride varnish as an effective method to enamel resistance against the cariogenic challenges during orthodontic therapy [33].

Montasser et al witnessed applying fluorinated varnish to the enamel surface of the tooth decreases the demineralization process by increasing the calcium, phosphate, and fluoride ions available freely when contact with saliva thus change in the oral environment significantly. Similarly a single topical application of FV with a high concentration can decrease enamel lesion depth adjacent to bonded brackets by about 40% for 3 months and does not affect the bond strength of orthodontic brackets and bands to enamel with conventional bonding or self-etch systems [10]

Non-fluoride remineralizing agents like CPP-ACP, calcium sodium phospho-silicate glass infiltrates had been preferred to induce calcium-phosphate balance, and remineralization/demineralization cycle. Studies by Beerens MW et al [34], Cochrane NJ et al [35] has demonstrated the anti-cariogenic property that largely depends on casein protein which transport calcium and phosphate ions and aggregate of nanocomplexes into the dental plaque and on the tooth surface (calcium-phosphate reservoir). The presence of CPP-ACP delays the biofilm formation and favours nucleation and crystallization of calcium phosphates, possibly in hydroxyapatite form, in matured biofilms.

Baeshen et al observed combined effect of calcium ions with phosphate ions to produce an ion reactivity product for ACP, increases its solubility product results in the precipitation of ACP or, in the presence of fluoride ions, amorphous calcium fluoride phosphate (ACFP) [15]. Tulumbaci in an invitro study noted varying results on using remineralizing agents including CPP-ACP, fluoridated tooth paste, gel, and cavity protection cream under artificially formed enamel white spot lesions for 2minutes, 2 times a day for 4 weeks that largely depended on

pH, bacterial flora, and temperature of the oral environment [36]. Baysal A et al [23], Sudjalim TR et al [37] revealed application of CPP-ACP before bonding using composite material significantly improves the shear bond strength to demineralized enamel.

Munjal et al in an in-vivo assessment on the effect of remineralizing agent (CPP-ACP) among 679 permanent first molars of children ages 8 to 16 years undergoing orthodontic lesions revealed children who applied CPP-ACP cream two times a day for 12 weeks had a reduction in the severity of the demineralized enamel or the white spot lesion and concluded that CPP-ACP does have beneficial effects for orthodontic white spot lesions [38].

Over the years with advancement in technologies and techniques along with demand for more esthetically pleasing fluoride containing agents, sealants or bonding agents, self-etch primer (SEP) agents to be applied before or after bonding along with use of mouthwash and/or CPP-

ACP was recommended to reduce the incidence of WSL's and enhance remineralization. Conversely, the fluoride containing and releasing adhesives and primers predominantly showed their greatest levels during the initial weeks after fixed appliance bonding.

Self-etch primer (SEP) acts by slowing the transport of acidic component into the enamel surface by attaching with the etching monomers and/ or neutralizing by formation of complex with the calcium from the hydroxyapatite [1, 10]. Several in-vitro studies observed the efficacy of SEP as an effective bonding agent to prepare enamel for orthodontic attachments. The failure at the enamel-adhesive interface declines the probability of enamel damage by decreasing the required mechanical removal of the residual adhesive after debonding [1, 10, 39]. Al-Suleiman et al suggested that the application of ACP at the same time of using SEP agents for 10 seconds has no effect on shear bond strength in stainless steel metal brackets. It was also revealed that SEP bonding systems brings about lesser irreversible changes to enamel surface when compared with conventional acid etchings and primers [9, 10].

Nano hydroxyapatite (n-HAP), a biologically active, biocompatible material showed increased affinity to enamel surface and enhances remineralization by calcium or fluoro-apatite crystals infusion. Combination of CPP-ACP and Nano hydroxyapatite as a remineralizing agent produces double enhancing effect however high amount of fluoride content may increase the fluoride toxicity risk in long-term usage of these products. Previous studies showed that fluoride-containing cements (GIC) and composite adhesives decrease enamel decalcification around orthodontic brackets. Other agents like xylitol chewing gums sweeteners, fluoride enhancing probiotics inhibits the effect on dental plaque and MS strain thus reducing the occurrence of WSLs and dental caries [1, 2, 5, 9, 30, 35]. Within the limitation, it can be postulated that application of fluoride-containing dentifrices and remineralizing agents repeatedly over a period of time during and after orthodontic treatment significantly increase their mode of action by producing inhibition effect on enamel demineralization and promote remineralization.

Conclusion:

The present review observations illustrates that fixed orthodontic brackets, bands, wires and other attachments are source of inducing potential demineralization (WSLs) on surrounding enamel tissue owing to several oral hygiene related factors as discussed above that are often reversible if detected at an early stage. Early management strategies that includes patient education, oral prophylaxis, and appropriate good oral hygiene habits must be implemented to accomplish successful treatment outcome. One should also give emphasis that use of additional remineralizing agents such as topical fluorides, varnish, CPP-ACP containing pastes or bioactive glasses before and after orthodontic treatment for a specific period besides fluoridated toothpastes and mouthwashes to reverse demineralization effects and to enhance remineralization process to restore normal oral environment.

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