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REVIEW ARTICLE

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Incidence and Prevention of White Spot Lesions Associated with Fixed Orthodontic Appliances: A Literature Review

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Abstract

Background: White spot lesions (WSLs) are a common adverse effect of fixed orthodontic treatment, resulting from enamel demineralization associated with plaque accumulation around orthodontic appliances. Their prevention remains a clinical challenge in orthodontic practice. The present review aimed to evaluate the available evidence regarding the effectiveness of preventive strategies for reducing the risk of white spot lesion development in patients undergoing fixed orthodontic treatment.
Materials and Methods: A literature search was performed in Medline/PubMed and the Cochrane Library for English-language clinical studies published up to 2010. Controlled in vivo human studies reporting the incidence and/or prevalence of WSLs in patients undergoing fixed orthodontic treatment were included. Studies with a minimum treatment duration of 12 months were considered. Data regarding incidence, prevalence, risk factors, and preventive measures were extracted and analyzed descriptively.
Results: Ten studies involving 1,241 patients were included. The overall incidence of WSLs was 45.8%, while the prevalence was 68.4%. Reported risk factors included poor oral hygiene, younger age at treatment initiation, male sex, and longer treatment duration. Protective factors included adequate salivary flow and the use of fluoride-based preventive measures, which were associated with reduced lesion development.
Conclusion: WSLs are a frequent complication of fixed orthodontic treatment. Their development is multifactorial, with identifiable patient- and treatment-related risk factors. Preventive strategies, particularly fluoride-based interventions and improved oral hygiene measures, should be integrated into routine orthodontic care to reduce the risk of enamel demineralization.(**International Journal of Biomedicine. 2026;16(3):327-332.**)

Keywords: white spot lesions • orthodontic treatment • enamel demineralization • caries • fluoride • fixed appliances

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Introduction

The demand for orthodontic treatment has increased considerably over recent decades, particularly in developed countries, owing to growing awareness of oral health and dental aesthetics.[1] Orthodontic treatment is indicated for the correction of dental malocclusions and craniofacial skeletal discrepancies resulting from genetic, familial, and environmental factors through the use of fixed or removable appliances.[2]

Despite the significant functional and aesthetic benefits achieved through orthodontic therapy, treatment with fixed appliances is frequently associated with adverse effects, among which white spot lesions (WSLs) are one of the most common complications. WSLs are early manifestations of enamel demineralization that appear clinically as opaque, chalky-white areas on the tooth surface. Their reported prevalence varies widely in the literature, ranging from 33.8% to 97%, depending on the diagnostic criteria, assessment methods, and units of analysis employed, as well as the inclusion or exclusion of pre-existing enamel lesions.[3-7]

Enamel demineralization may initially be reversible through natural remineralization processes mediated by saliva and its mineral components. Salivary proteins can partially restore mineral content and reduce the visual appearance of early lesions.[8] However, in patients undergoing orthodontic treatment, persistent plaque accumulation around orthodontic appliances often promotes the progression of these lesions, resulting in irreversible enamel damage and an increased risk of caries development.[9]

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Dental caries is a multifactorial disease influenced by biological, behavioral, environmental, and socioeconomic factors. Established risk factors include frequent consumption of fermentable carbohydrates, inadequate oral hygiene, insufficient fluoride exposure, and irregular dental attendance. Demographic variables such as age, sex, educational level, income, and ethnicity may further influence susceptibility to caries.[10] Consequently, maintaining adequate oral hygiene practices and regular exposure to fluoride remain fundamental components of caries prevention.

The association between dietary sugar intake and dental caries has been extensively documented.[11,12] Frequent consumption of sugar-containing beverages, including soft drinks, fruit juices, and sports drinks, as well as confectionery products, contributes significantly to the risk of enamel demineralization. Dietary assessment and individualized nutritional counseling may therefore play an important role in reducing exposure to fermentable carbohydrates and limiting caries risk.[13] Although dietary habits are not routinely evaluated in orthodontic practice because of time and resource constraints, such assessments may contribute significantly to the prevention of WSL development.

Fixed orthodontic appliances create conditions that favor biofilm accumulation and enamel demineralization. Orthodontic brackets, bands, ligatures, and archwires introduce additional retentive sites that complicate oral hygiene procedures and facilitate plaque retention.[14] Furthermore, the surface characteristics of orthodontic materials influence bacterial colonization. Materials with greater surface roughness and higher surface free energy promote bacterial adhesion and biofilm formation, while bracket design and size also affect plaque accumulation. Consequently, simpler and smaller bracket designs have been suggested to reduce bacterial retention and minimize the risk of enamel demineralization.[15]

White spot lesions may develop on any tooth surface where microbial biofilm is allowed to accumulate over time. Numerous patient-related factors, including medical and dental history, medication use, dietary habits, salivary composition, fluoride exposure, and genetic predisposition, influence their development.[16] According to the American Dental Association Caries Classification System (ADA CCS), WSLs are classified as incipient non-cavitated carious lesions resulting from bacterial plaque activity.[17]

Host susceptibility plays a fundamental role in the pathogenesis of WSLs. Systemic factors, including salivary flow rate, buffering capacity, and enamel resistance to acid dissolution, contribute significantly to lesion development. Local factors such as dental malposition and the presence of fixed orthodontic appliances further increase the risk of demineralization by promoting plaque retention and impairing effective oral hygiene.[18]

Although fixed orthodontic appliances remain the most effective method for correcting many malocclusions, their use is associated with increased plaque accumulation and elevated levels of cariogenic microorganisms.[19] These changes in the oral environment contribute to enamel demineralization and the subsequent development of WSLs and dental caries. Nevertheless, evidence regarding the relationship between orthodontic treatment and caries development remains inconsistent, with some studies reporting conflicting findings.[20,21]

A variety of preventive strategies have been proposed to minimize the occurrence of WSLs during orthodontic treatment. These include topical fluoride applications, fluoride-releasing bonding materials, sodium fluoride mouth rinses, chlorhexidine products, and reinforcement of oral hygiene practices.[22-24] Adequate oral hygiene remains one of the most effective measures for preventing enamel demineralization and caries development during treatment.[24] In addition, the increasing use of fixed bonded retainers following both aligner-based and conventional orthodontic therapy may prolong plaque retention and potentially increase the risk of WSL formation after active treatment has been completed.[25]

Clinically, enamel demineralization initially presents as white, opaque lesions that may resemble dental fluorosis. However, unlike fluorosis, these lesions are associated with active mineral loss and an increased susceptibility to caries progression due to enamel porosity and enhanced plaque retention.[26,27] Demineralization involves the dissolution of mineral ions from hydroxyapatite crystals within enamel and other mineralized tissues, whereas remineralization refers to the restoration of these minerals. Although substantial mineral loss may occur without compromising enamel integrity, affected teeth often exhibit increased sensitivity to thermal, mechanical, and chemical stimuli.[28,29]

The characteristic appearance of WSLs is attributable to alterations in the refractive index (RI) of enamel. Sound enamel possesses an RI of approximately 1.66, whereas demineralized enamel exhibits lower values that vary according to lesion hydration. The presence of air within porous lesions increases light scattering, causing dehydrated WSLs to appear as opaque, milky-white areas that are more readily detectable during clinical examination.[30,31]

Several studies have investigated the prevalence and severity of WSLs among orthodontic patients. Mizrahi[32] reported significant increases in both lesion prevalence and severity following fixed appliance treatment, with male patients exhibiting greater lesion severity than females. Similarly, Gorelick et al.[33] observed a significantly higher frequency of WSLs in teeth fitted with fixed appliances compared with untreated controls, particularly in the maxillary lateral incisors. The absence of lesions on the lingual surfaces of mandibular incisors retained with bonded retainers suggested a protective effect of salivary flow.[34] Furthermore, Geiger et al.[7] demonstrated a significant association between poor compliance with preventive home-care measures and the development of WSLs.

White spot lesions are also recognized as important indicators of caries risk. Along with frank cavitation, proximal lesions, and recent restorations or extractions resulting from active disease, WSLs are considered strong clinical predictors of future caries activity.[35] Despite the availability of preventive measures, their routine implementation in orthodontic practice remains limited. Derks et al.[36] reported that although most orthodontists provide oral hygiene instructions, preventive agents such as fluoride varnishes, high-fluoride toothpaste, and chlorhexidine products are prescribed less frequently.

Fluoride remains a cornerstone of preventive dentistry because of its ability to enhance enamel remineralization and inhibit demineralization. By replacing hydroxyl ions within hydroxyapatite crystals, fluoride promotes the formation of fluorapatite, which exhibits greater resistance to acid dissolution and caries progression.[38] In contrast, patients presenting with enamel defects such as molar-incisor hypomineralization, amelogenesis imperfecta, or fluorosis may require special consideration before orthodontic treatment because of compromised enamel integrity and an increased risk of plaque accumulation and demineralization.[37]

Therefore, the present review aimed to evaluate the available evidence regarding the effectiveness of preventive strategies for reducing the risk of white spot lesion development in patients undergoing fixed orthodontic treatment.

Materials and Methods

Search Strategy

A literature search was conducted to identify studies investigating the incidence, prevalence, risk factors, and prevention of white spot lesions (WSLs) associated with fixed orthodontic treatment. Electronic searches were performed in the Medline/PubMed and Cochrane Library databases for studies published in English up to 2010.

The search strategy included combinations of the following keywords and Medical Subject Headings (MeSH) terms: orthodontics, fixed appliances, white spot lesions, demineralization, decalcification, and caries. Reference lists of relevant articles were also manually screened to identify additional eligible studies.

Eligibility Criteria

Studies were included in the review if they met the following criteria:

1.Human clinical studies involving patients undergoing fixed orthodontic treatment

2.Controlled in vivo study design

3.Assessment of the incidence and/or prevalence of white spot lesions

4.Outcomes reported at the patient level rather than at the tooth or surface level

5.Minimum orthodontic treatment duration of 12 months

6.Full-text articles available in English

Studies were excluded if they:

1.Included patients treated exclusively with removable appliances

2.Reported outcomes only at the tooth or surface level without patient-based data

3.Were case reports, narrative reviews, conference abstracts, letters, or in vitro studies

4.Did not provide sufficient information regarding WSL incidence or prevalence

Study Selection

Titles and abstracts identified through the electronic search were screened for relevance. Full-text articles were subsequently assessed according to the predefined inclusion and exclusion criteria. Studies meeting all eligibility criteria were included in the final analysis.

Data Extraction

The following information was extracted from each included study:

- Author and year of publication
- Study design
- Sample size
- Patient demographics
- Duration of orthodontic treatment
- Incidence and prevalence of white spot lesions
- Reported risk factors associated with WSL development
- Preventive measures evaluated during treatment

Outcome Measures

The primary outcomes of interest were the incidence and prevalence of white spot lesions in patients undergoing fixed orthodontic treatment. Secondary outcomes included the identification of risk factors associated with WSL development and the effectiveness of preventive strategies aimed at reducing enamel demineralization during treatment.

Results

Study Characteristics

A total of 10 studies fulfilled the eligibility criteria and were included in the review. These studies evaluated patients undergoing treatment with fixed orthodontic appliances and reported data regarding the incidence and/or prevalence of white spot lesions.

Incidence of White Spot Lesions

Across the included studies, 1,241 patients were assessed for the development of new white spot lesions during orthodontic treatment. A total of 635 patients developed at least one new lesion, corresponding to an overall incidence of 51.1%. These findings indicate that approximately one out of every two patients undergoing fixed orthodontic treatment experienced enamel demineralization during treatment.

Prevalence of White Spot Lesions

Data regarding WSL prevalence were available for 923 patients. Among these individuals, 640 presented with one or more white spot lesions, resulting in an overall prevalence of 69.3%. This finding demonstrates that WSLs are highly prevalent among orthodontic patients and represent a significant clinical challenge.

Summary of Findings

The results of the included studies consistently demonstrated that fixed orthodontic appliances are associated with a substantial risk of enamel demineralization. The high incidence and prevalence of WSLs observed across the reviewed literature emphasize the need for effective preventive strategies, including rigorous oral hygiene measures, fluoride therapy, dietary counseling, and regular professional monitoring throughout orthodontic treatment.

Discussion

The findings of the present review indicate that white spot lesions (WSLs) are a common adverse effect of fixed orthodontic treatment. The development of these lesions is multifactorial and influenced by patient-related, treatment-related, and

environmental factors. Understanding these risk factors is essential for implementing effective preventive strategies and reducing enamel demineralization during orthodontic therapy.

Gender

Several studies have suggested that gender may influence the incidence and severity of WSLs. Most authors reported a higher prevalence of lesions among male patients. Khalaf observed that males were nearly three times more likely to develop WSLs than females, while Boersma et al. reported a greater proportion of demineralized buccal surfaces in male patients. Similar findings were described by Julien et al., Tufekci et al., Lucchese and Gherlone, and Enaia et al., who also noted increased lesion severity among males.[39-44] These differences may be attributed to variations in oral hygiene practices, dietary habits, and compliance with preventive recommendations. However, the association between gender and WSL development remains controversial, as Gorelick et al. reported a higher incidence among female patients.[33] Consequently, although gender may contribute to lesion susceptibility, it should not be considered an independent predictor of WSL development.

Age

Patient age appears to play a significant role in the occurrence of WSLs. Adolescents have consistently been reported to be at greater risk than adults, potentially due to less effective oral hygiene practices and lower compliance with preventive measures. Khalaf found that adolescent patients were approximately twice as likely to develop WSLs as adults.[39] Similarly, Richter et al. reported a negative association between age and lesion development, demonstrating that the number of newly formed lesions decreased with increasing age.[45] These findings suggest that younger patients may require more intensive preventive interventions and closer monitoring throughout treatment.

Salivary Flow

Saliva plays a crucial protective role in maintaining enamel integrity through its buffering capacity, remineralizing potential, and mechanical cleansing action. Evidence supporting this protective effect was provided by Gorelick et al., who observed no WSLs on the lingual surfaces of mandibular incisors retained with a canine-to-canine bonded retainer.[33] The authors attributed this finding to the continuous exposure of these surfaces to salivary flow. Therefore, variations in salivary exposure may partly explain the distribution and severity of WSLs observed during orthodontic treatment.

Duration of Treatment

Treatment duration is consistently identified as one of the most important risk factors for WSL development. The prolonged presence of fixed orthodontic appliances promotes plaque accumulation and increases the likelihood of enamel demineralization. Khalaf reported a 3.65-fold increase in the risk of WSL formation among patients treated for more than 36 months compared with those treated for less than 24 months.[39] Likewise, Tufekci et al. and Lucchese and Gherlone demonstrated that lesions may develop within the first six months of treatment, with prevalence increasing as treatment progresses.[42,43] Richter et al. further confirmed a positive relationship between treatment duration and lesion development, reporting a substantial increase in the number of affected surfaces with longer treatment periods.[45] These findings emphasize the importance of minimizing treatment duration whenever clinically feasible.

Fluoride Use During Orthodontic Treatment

The preventive effect of fluoride on enamel demineralization has been well documented. Regular use of fluoride-containing products has been associated with significant reductions in both the incidence and prevalence of WSLs. Khalaf reported a significant reduction in lesion development among patients who routinely used fluoride mouth rinses during treatment.[39] Similarly, Geiger et al. observed a 30% reduction in prevalence and a 25% reduction in incidence among orthodontic patients using fluoride mouthwash.[7] These findings support the routine incorporation of fluoride-based preventive measures into orthodontic treatment protocols, particularly for patients at elevated risk of caries development.

Distribution of White Spot Lesions

The distribution of WSLs is not uniform throughout the dentition. Most studies reported a higher prevalence of lesions in the maxillary arch, particularly affecting the lateral incisors and canines.[7,33,39,41,46] These teeth are characterized by relatively small areas between the bracket and gingival margin, creating favorable conditions for plaque retention and hindering effective oral hygiene. In contrast, Mizrahi identified the first molars as the most frequently affected teeth[32], suggesting that lesion distribution may vary according to patient characteristics, oral hygiene practices, and appliance design.

The predominance of lesions in the maxillary arch may also be related to reduced salivary exposure compared with mandibular teeth. Furthermore, differences in brushing efficiency across various tooth surfaces may contribute to the observed distribution patterns.

Surface Distribution

Concerning lesion location, the gingival margin was consistently identified as the area most susceptible to WSL development. Khalaf reported that while lesions occurred throughout the maxillary dentition, they were predominantly localized to the gingival margins of mandibular teeth.[39] This finding is clinically relevant, as plaque accumulation is typically greatest in the region immediately adjacent to orthodontic brackets and gingival tissues. Consequently, preventive efforts should focus on improving plaque control in these high-risk areas.

Clinical Implications and Preventive Strategies

The management of WSLs should prioritize prevention, as established lesions can be difficult to reverse completely and may compromise the aesthetic outcomes of orthodontic treatment. Effective prevention requires a multifactorial approach that includes patient education, reinforcement of oral hygiene practices, dietary counseling, regular professional prophylaxis, and the use of preventive agents.

The combined use of fluoride and chemical plaque-control measures is particularly effective in reducing enamel demineralization. Geiger et al. demonstrated the benefits of fluoride mouth rinses during orthodontic treatment[7], while Ogaard et al. reported a 48% reduction in lesion depth following the application of fluoride varnish.[47] Various fluoride delivery systems, including toothpastes, mouth rinses, gels, varnishes, fluoride-releasing bonding materials, and fluoride-containing

elastomeric modules, have been proposed as effective adjuncts to conventional preventive measures.

Given the high prevalence of WSLs reported in the literature, orthodontists should identify high-risk patients before treatment initiation and implement individualized preventive protocols throughout treatment. Particular attention should be directed toward younger patients, individuals with poor oral hygiene, and those expected to undergo prolonged orthodontic therapy.

Conclusion

White spot lesions (WSLs) represent a common complication associated with fixed orthodontic treatment, with reported incidence and prevalence rates of 45.8% and 68.4%, respectively. These findings underscore the clinical relevance of enamel demineralization during orthodontic therapy and highlight the need for effective preventive strategies.

Multiple factors influence the development of WSLs. Increased risk has been associated with poor oral hygiene, younger age at treatment initiation, male sex, and prolonged treatment duration. Conversely, adequate salivary flow and the use of fluoride-based preventive measures appear to reduce the likelihood of lesion development.

Given the high prevalence of WSLs, careful patient risk assessment should be performed before and during orthodontic treatment. Particular attention should be given to individuals presenting with early signs of enamel demineralization, with preventive protocols tailored accordingly. Continuous monitoring and reinforcement of oral hygiene measures are essential to minimize adverse outcomes.

Overall, the evidence indicates that the risk of WSL development during fixed orthodontic treatment should not be underestimated, and greater emphasis should be placed on prevention, patient education, and individualized risk management strategies.

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