Patterns and Risk Factors for White Spot Lesions in Orthodontic Patients with Fixed Appliances

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Objective: *To evaluate the development and risk factors of white spot lesions (WSLs) in orthodontic patients with fixed appliances in a Chinese population.*
Methods: *A total of 202 subjects participated in the cross-sectional study. Clinical examination of the state of the entire labial (buccal) enamel surface was conducted under artificial light using a clinical mirror and an explorer. A face-to-face interview was conducted through a structured questionnaire to collect a range of information, including demographic data, family income, level of education, toothbrushing frequency, fluoride toothpaste usage and the use of a professional toothbrush (V type).*
Results: *WSLs appeared on 57.9% of the subjects after orthodontic treatment with fixed appliances; the mean tooth number of WSLs was 4.8. A higher prevalence was observed in subjects whose time of therapy was 17 months or longer (OR = 3.2, P < 0.050), and who had modified their unhealthy dietary habits (OR = 3.7, P < 0.001). Younger individuals or individuals who consumed food with sugar at least once a day during the course of their orthodontic treatment also exhibited a higher likelihood of experiencing WSLs.*
Conclusion: *The prevalence of WSLs after orthodontic treatment with fixed appliances was relatively high in China. Clinicians should be aware of the risk factors of WSLs that may occur during the treatment period.*

Key words: *orthodontic treatment, risk factor, white spot lesions*

In orthodontic patients, zones of enamel decalcification appear as white spot lesions (WSLs) on the surface of the enamel surrounding the brackets, while these lesions are rarely observed in non-orthodontic patients[1]. Patients with fixed orthodontic appliances fall under moderate or high-risk categories for caries development according to the American Dental Association[2]. In addition to enamel damage, WSLs present an aesthetic problem[3].

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The prevalence of WSLs is relatively high after orthodontic treatment, a fact that should be considered by both patient and clinician when considering this form of treatment[1,4,5]. Dental plaque and dental biofilm that is formed around orthodontic brackets, play an important role in the aetiology of WSLs. Installation of a fixed orthodontic appliance alters the oral environment, causing both quantitative and qualitative changes in dental plaque. The amount of dental biofilm around the bands and brackets increases[6] and the composition of the oral flora changes soon after the placement of a fixed orthodontic appliance[7]. Although dental biofilm is composed of numerous multispecies bacteria, it is believed that *Streptococcus mutans* is involved in the early development of caries lesions, and also increases, particularly in patients with a history of caries[8,9]. As a result, the risk of developing additional dental caries increases in many patients with fixed orthodontic treatment, particularly in proximity to WSLs[2].

Several studies have been conducted on the prevalence of WSLs using different examination techniques

at the end of orthodontic treatment[4,10]. Using the visual examination technique, Gorelick et al[4] reported that the prevalence of post-orthodontic demineralised WSLs was 50%. Another study showed that 97% of subjects had one or more WSLs by using quantitative light fluoroscopy after orthodontic therapy with fixed appliances[10]. Furthermore, these studies tend to be interventional experimental investigations based on a small number of patients[11]. Although there is a high incidence of WSLs, epidemiological data is limited. Determination of the incidence of WSLs in patients with fixed orthodontic appliances is essential for maintaining general dental health, especially given the increased use of orthodontic appliances, greater awareness of oral health and increasing life expectancy.

To date, few studies have been conducted on the pattern and risk factors of WSLs after orthodontic treatment with fixed appliances. Therefore, this study aims to evaluate the development and risk factors of WSLs in orthodontic patients with fixed appliances in the Chinese population.

Materials and methods

Ethical approval for the pilot study was obtained from the Ethics Committee of the School and Hospital of Stomatology, Wuhan University.

Study population

The study population was chosen as a convenience sample. The sample size needed to detect a WSL prevalence of 50% was calculated to be 198 patients with a power of 80% and a two-sided significance of $P < 0.05$. In total, 202 subject participants were recruited from a group of patients who completed therapy with full fixed appliances from May to August 2009 in the orthodontic department of the Hospital of Stomatology, Wuhan University, China. The inclusion criteria included satisfactory general health, a treatment period with fixed appliances which had lasted for at least 1 year before the debonding appointment, and informed consent signed by the participant or by the parents or guardians for participants under 18 years old. All patients briefly received oral hygiene instructions before orthodontic treatment by the orthodontist. The oral hygiene instructions involved diet instructions, the use of fluoride toothpaste and brushing methods during orthodontic treatment, however, no professional topical application of fluoride was regularly provided in the dental clinic.

Interview

A face-to-face interview was conducted by a trained clinician after orthodontic treatment with fixed appliances, using a structured questionnaire to collect a range of information, including demographic data, family income, level of education, toothbrushing frequency, fluoride toothpaste usage, professional toothbrush (V type) usage, and changes in unhealthy dietary habits. Changes in unhealthy dietary habits refer to if the participant reduced the consumption of sugary foods and soft drinks following installation of the appliance. The participants were also asked about their respective intake of carbonated beverages, juices and food items high in sugar (e.g. milk products with sugar, candy, chocolate, sweet breakfast cereals, cakes, biscuits and ice cream).

Clinical examination

The presence or absence of lesions on the buccal surfaces of all teeth except for the third molars was determined during the debonding visit. The normal cleaning measures were taken to remove fixed appliances and bonding material. Using sterilised acutenaculum (needle holders), the bracket was gently wiggled loose from the enamel surface. After debonding of the bracket, the excess bonding material around the bracket was removed using tungsten carbide debonding burs. Then, discs were used with a low-speed headpiece to polish the enamel surface. Clinical examination of the state of the entire labial (buccal) enamel surface was conducted with the participants lying down under an artificial white light using a clinical mirror and an explorer. Finally, the surface was dried using sterilised gauze. The criteria used for scoring the WSL index were as described by Gorelick[4]. The score criteria were as follows: Score 1- no lesion; Score 2- small lesion (line shape); Score 3 - severe lesion (band shape); and Score 4 - cavitation. This index is an indicator of the presence or absence of lesions and, to a certain extent, the severity of decay.

The dental examinations were performed by one examiner who was requested to participate in an initial calibration trial. The kappa statistic was used to assess inter-examiner reliability; all four categories (Score 1, 2, 3 and 4) were included in the kappa statistics. The final kappa scores exceeded 0.75. To test intra-examiner reliability during the survey, 15 patients who participated in the study were randomly chosen to be reexamined by the same examiner; Kappa values also exceeded 0.75.

Statistical analysis

Data from hard copies of the questionnaires as well as the clinical examinations were analysed using Windows SPSS 15.0. The prevalence of WSLs was defined as the proportion of individuals with teeth containing WSLs (Scores 2 to 4) in the study population. A chi-square test was used for categorical variables. All explanatory variables, which were significant at the $P < 0.05$ level in a bivariate analysis, were then included in a multivariate logistic regression analysis, to determine the independent effect of each explanatory variable on the dependent variable while controlling all other variables.

The dependent variable was the proportion of patients with WSLs (Scores 2 to 4). This variable was categorised into 'patients with WSLs > 1', which is given a value of 1, and 'patients with WSLs ≤ 1', which is given a value of 0. Independent variables included age, gender, orthodontic therapy time, frequency of toothbrushing, the use of fluoride toothpaste, the use of a V-type toothbrush, changing unhealthy dietary habits, frequency of consuming carbonated beverages, juices and foods high in sugar, the level of education of parents and monthly family income. Independent variables were then entered in a single step. Odd ratios (ORs) with 95% confidence intervals (95% CI) were calculated for the discrete variables in the logistic regression model.

Results

The samples analysed in this study consisted of 5612 permanent teeth from 60 males and 142 females (mean age 17.5 ± 4.6 years, ranging from 11 to 24 years old) with an average implantation time of 16.7 ± 5.2 months (ranging from 12 to 36 months). Amongst the total, 57.9% of the patients had WSLs after orthodontic treatment with fixed appliances. The mean number of teeth per patient with WSLs was 4.8 (972/202). Amongst the 5612 permanent teeth, post-orthodontic white spot lesions were found on 972 (17.3%). The proportions of WSLs (Gorelick index Scores 2 to 4) in different teeth were as follows: Score 2 - 808 teeth (14.4%); Score 3 - 103 teeth (1.8%); and Score 4 - 61 teeth (1.1%).

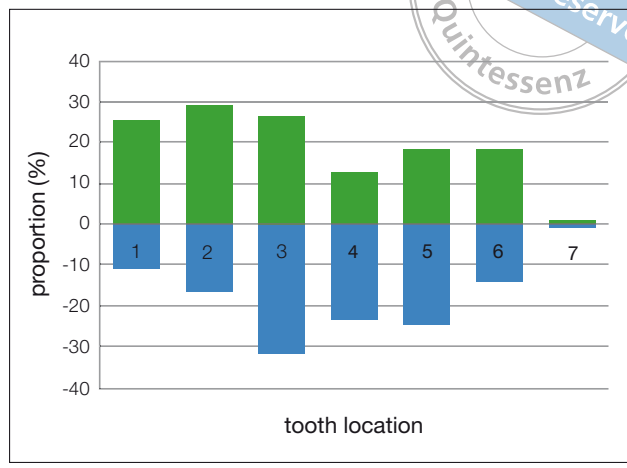

Fig 1 Proportion of WSLs in different teeth: 1 - incisor; 2 - lateral incisor; 3 - canine; 4 - first premolar; 5 - second premolar; 6 - first molar; 7 - second molar.

Females had a higher prevalence of WSLs (59.2%) than males (55.0%), but this difference was not statistically significant. A difference between patients who were 11 to 15 years old, and those who were 16 to 24 years old was also observed. The prevalence of WSLs was significantly higher in participants with an orthodontic therapy period ≥ 17 months.

Table 1 and Figure 1 shows the frequency with which each type of tooth was affected by WSLs. White spots occurred on all teeth but were most frequently observed on the facial surfaces of maxillary lateral incisors (25.2%), maxillary canines (26.5%), and mandibular canines (31.8%), whereas lower frequencies were

Table 1 Proportion of WSLs in different teeth.

	Maxilla							Mandible						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
No. of teeth analysed	404	399	404	385	404	404	404	404	403	403	388	403	403	404
No. of WSL teeth	102	115	107	50	74	31	4	44	66	128	91	99	57	4
Proportion of WSL teeth (%)	25.20	28.80	26.50	13.00	18.30	7.67	0.99	10.90	16.40	31.80	23.50	24.60	14.10	0.99

1 - incisor; 2 - lateral incisor; 3 - canine; 4 - first premolar; 5 - second premolar; 6 - first molar; 7 - second molar.

Table 2 Background variables associated with the presence of WSLs.

Variables		N	Percentages of respondents with WSLs	*P*
Age	11 to 15 years old	137	62.8	
	16 to 24 years old	65	47.7	0.042
Gender	Male	60	55.0	
	Female	142	59.2	0.641
Orthodontic therapy time	Less than 17 months	112	50.9	
	17 months or longer	90	66.7	0.024
Frequency of toothbrushing	Twice a day or less	182	60.4	
	Thrice a day or more	20	35.0	0.034
Using fluoride toothpaste	Yes	91	54.9	
	No	19	47.3	
	Don't know	92	63.0	0.473
Using V type toothbrush	Yes	18	50.0	
	No	184	58.7	0.618
Change in unhealthy dietary habits	Yes	80	36.2	
	No	122	72.1	< 0.001
Carbonated beverages	Twice a week or less	188	58.0	
	Once a day or more	14	57.1	0.462
Consumption of food with sugar	Twice a week or less	167	53.9	
	Once a day or more	35	77.1	0.014
Juices	Twice a week or less	176	56.2	
	Once a day or more	26	69.2	0.149
Education level of parents	Low (scores 2 to 5)	111	54.1	
	High (scores 6 to 8)	91	62.6	0.248
Monthly family income	< 450 US dollars	48	58.3	
	450 to 750 US dollars	88	60.8	
	> 750 US dollars	66	54.5	0.400

recorded in second maxillary molars (1.0%), mandibular molars (1.0%) and first maxillary molars (7.7%).

Almost all participants did not receive professional application of topical fluoride during orthodontic treatment, except two who used fluoride foam. Table 2 shows the results of the chi-square tests, indicating the associations between various independent variables and the number of respondents with WSLs. This analysis revealed that the occurrence of WSLs was significantly associated with age, orthodontic therapy time,

Table 3 Logistic regression analysis of the probability of occurrence of WSLs (n = 202).

Independent Variable		*P*	OR	95% CI	
				Lower	Upper
Age	11 to 15 years old	0.013	2.49	1.21	5.13
	16 to 24 years old				
Orthodontic therapy time	17 months or longer	0.001	3.22	1.60	6.47
	Less than 17 months				
Consumption of food with sugar	Once a day or more	0.021	2.91	1.18	6.20
	Twice a week or less				
Change in unhealthy dietary habits	No	< 0.001	3.72	1.92	7.19
	Yes				

frequency of toothbrushing, consumption of food with sugar and change in unhealthy dietary habits during orthodontic treatment.

Table 3 shows the results of the multivariate logistic regression analysis. Only statistically significant associations are presented. A higher prevalence was observed in participants with a therapy duration of 17 months or longer (OR = 3.2, $P < 0.050$) and in those who changed unhealthy dietary habits during treatment (OR = 3.7, $P < 0.001$). In addition, younger individuals and those who consume food with refined sugar at least once a day during orthodontic treatment were also at a higher risk of WSLs.

Discussion

In the People's Republic of China, the prevalence of malocclusion amongst children has increased from 40% to 67% over the last 40 years[12]. With the rapid economic growth of China, facial appearance has become more important to most people, resulting in an increasing demand for orthodontic treatment. Few systematic studies have investigated the prevalence and the risk factors of WSLs, a major side effect of prolonged orthodontic treatment. The present study is the first attempt to measure the status of WSLs in China and the risk factors involved.

Several previous studies looked into the relationship between socioeconomic status and oral health behaviour[13,14]. However, questionnaires used for collecting data on oral health behaviour have certain limitations. Individual perceptions of ideal oral self care and lifestyles may lead some to overestimate their positive oral hygiene habits, whereas risky behaviour such as consumption of sugary foods and drinks may be underreported.

In the present study, 57.9% of the patients had WSLs after orthodontic treatment with fixed appliances, which is in accordance with the 2001 study by Hu[15] (59. 4%). Amongst all 5612 permanent teeth examined, a post-orthodontic white spot lesion was found on 972 (17.3%). Notably, this prevalence is much lower than reported by Mizrahi et al[16], who found that 84% of teeth had WSLs, which was measured after post-treatment. However, their results may have been affected by the patient group, which had a greater number of demineralised white lesions caused by local environmental effects. Recently Chapman et al[17], using digital photographs, reported that the incidence of WSLs was just 36%. The result was significantly lower than the findings of the current study. Future studies are needed to assess the incidence and severity of WSLs during treatment with fixed orthodontic appliances.

White spot lesions can occur on any type of tooth, but are most frequently observed on the facial surfaces of maxillary lateral incisors and mandibular canines[4,18], consistent with our study. Due to the short crown of maxillary lateral incisors, brackets are close to the gum line, facilitating the collection of food debris and bacterial plaque. In extraction cases, a closing loop or hook is often placed between the maxillary lateral incisor and canine, explaining the high prevalence. In addition, orthodontic bands may deflect salivary flow. Furthermore, secretions from minor mucous glands in

the upper lip are very low in buffering ability and mineral content. Thus, the maxillary anterior teeth are more susceptible to WSLs[19].

Age, orthodontic therapy time, consumption of foods with sugar, and change in unhealthy dietary habits during orthodontic treatment are related to the formation of WSLs as determined by multivariate logistic regression analysis. In the present study, many participants did not know whether their toothpaste contained fluoride, a possible symptom of the generally poor oral hygiene practices in China[20]. The present study demonstrates that factors associated with higher risk of WSLs include age at the start of treatment (11 to 15 year olds) and longer treatment duration (17 months or longer), findings consistent with the result of Chapman[17]. The results support the hypothesis of a higher risk of WSLs in regions adjacent to brackets in younger patients. This is a direct consequence of the lower resistance of dental tissues and the poorer cooperation from younger patients in the orthodontic treatment process[21]. Undoubtedly, the longer the orthodontic therapy time required, the larger the number of WSLs per patient. There is abundant epidemiological evidence that dietary sugars, especially sucrose, affect the prevalence and progression of dental caries[22]. Higher sugar consumption enables repetitive acid production by cariogenic bacteria adherent to the teeth, resulting in white spot lesions[23]. In the present study, the occurrence of WSLs was significantly associated with the consumption of food with sugar. Furthermore, if a healthy dietary habit during orthodontic treatment was established, the number of WSLs was reduced.

Most orthodontic toothbrushes have a V-shaped groove along the long axis of the toothbrush head. The shorter nylon bristles in the V-shaped groove are progressively firmer and more efficient at removing food debris from the midbracket region, whereas the longer, softer filaments are positioned in the bracket-wing region. In the present study, orthodontic toothbrushes did not prevent the formation of WSLs compared to classical toothbrushes. There is little evidence to support the notion that brushing reduces dental caries even if orthodontic toothbrushes are effective in improving the tooth plaque index, the bracket plaque index, and the gingival index[23-25]. The relationship between individual oral hygiene status and caries experience is also weak, and instructional programs designed to reduce caries incidence by promoting oral hygiene have failed[21].

In the current study, the gender distribution is unequal; the number of females with orthodontic treatment is significantly higher than that of males. This could be due to the fact that females were generally more dissatisfied with the appearance of their teeth than males[13]. It was consistent with the findings of Deli[26], who showed that females were more likely to undergo orthodontic treatment.

A limitation of this study arises from the cross-sectional study design that exhibits difficulty in distinguishing idiopathic white spots and demineralisation. In the current study, all WSLs were considered to form after orthodontic treatment, which may increase the prevalence cited. In addition, for participants, who were unable to accurately recall changes in diet over the course of the study, this might have lead to recall bias. Finally, after debonding of brackets, the mechanical removal of residual bonding material with rotary instruments may damage the enamel. Removal of outer enamel may also remove WSLs.

In conclusion, the prevalence of WSLs after orthodontic treatment with fixed appliances was found to be relatively high in China. This study also found that the aetiology of WSLs could be multifactorial. Age, orthodontic therapy time, consumption of food with sugar, and change in unhealthy dietary habits during orthodontic treatment were considered factors associated with the presence of WSLs. To prevent, minimise, and manage the possible adverse effects of orthodontic appliances, the clinician should be aware of the risk factors of WSLs. Oral health education and regular use of professionally applied topical fluoride treatment should be recommended for orthodontic patients.

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