

Factors Affecting the Formation, Severity and Location of White Spot Lesions during Orthodontic Treatment with Fixed Appliances

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ABSTRACT

Objectives: The purpose of the present study was to investigate factors affecting the formation, severity and location of white spot lesions in patients completing fixed appliance therapy.

Material and Methods: A total of 45 patients (19 males and 26 females, mean age 15.81 years, standard deviation 2.89 years) attending consecutively Aberdeen Dental Hospital (ADH) between January and June 2013 to have their fixed appliances removed were given a questionnaire to elicit information regarding their dental care and diet. They were then examined clinically as well as their pre-treatment photographs to record treatment data and white spot lesion (WSL) location and severity using a modified version of Universal Visual Scale for Smooth Surfaces (UniViSS Smooth). Absolute risk (AR) and risk ratios (RR) were also calculated.

Results: The incidence of at least one WSL observed in patients was 42%, with males displaying a higher incidence than females. The highest incidence of WSLs was recorded on the maxillary canines and lateral incisors, and on the maxillary and mandibular premolars and first molars. The gingival areas of the maxillary and mandibular teeth were the most affected surfaces. Significant ($P < 0.05$) relationships were found between the presence of WSLs and the following factors: poor oral hygiene (OH), males, increased treatment length, lack of use of fluoride supplements, use of carbonated soft drinks and/or fruit juices and the use of sugary foods. Poor OH posed the highest risk of developing WSL (RR = 8.55).

Conclusions: 42% of patients have developed white spot lesions during fixed appliance therapy. Various contributing risk factors were identified with the greatest risk posed by a poor oral hygiene.

Keywords: dental white spot; fluoride; orthodontic wires; orthodontic brackets; risk factors; teeth.

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INTRODUCTION

A white spot lesion (WSL) is a mark of decalcification or demineralization of enamel, which appears as a white spot on tooth surfaces eluding to their name [1]. WSLs can affect any tooth in the dentition and occur on any area of the tooth surface. They signify the initial stage of tooth caries and are caused by the activity of bacterial plaque [2,3]. WSLs are particularly common problem during orthodontic treatment, and a continuous challenge faced by clinicians to prevent their occurrence [4]. The presence of fixed appliances on tooth surfaces such as brackets and bands creates difficulties in keeping teeth clean, leading to the build-up of plaque and WSL formation [5]. WSLs can interfere with orthodontic treatment and affect patients as a cosmetic problem post-orthodontic treatment [6]. Under normal circumstances, the balance of demineralization and remineralisation of enamel determines the formation of dental caries. Dental caries is caused by the activity of oral bacteria that forms as plaque on tooth surfaces, also known as dental biofilm, and are responsible for producing organic acids by metabolism of carbohydrates in the mouth [1,7,8]. The metabolism of carbohydrates, notably sugars from food result in the production of an acidic, low pH environment [9,10]. These acids diffuse into tooth enamel and dissolve the layers of calcium and phosphate hydroxyapatite crystals [2,9], leading to lesions on the enamel surface. Furthermore, plaque itself acts as a barrier that prevents acids from diffusing away from the local environment [1]. The lesions created by demineralization can be arrested from progressing and reversed by calcium, phosphate and fluoride minerals present in saliva, which diffuse back into the porous subsurface region of the carious lesion, which form new layers in the enamel, termed remineralisation [1,2,11,12]. This balance of damage and repair occurs naturally, constantly on-going and occurs numerous times daily in the mouth [2]. If a disruption of this balance has occurred in favour of demineralization, this would lead to the permanent formation of white spot lesions that can progress into cavities and can no longer be reversed [3]. Tipping the balance back toward remineralisation would arrest the progression of WSLs [11], although they remain as cosmetic scars [6]. Various risk factors can contribute to the development of WSLs. These are poor oral hygiene, low salivary volume and a sugary diet, which all promote the proliferation and activity of bacterial plaque [1,13]. Although WSLs occur in caries development irrespective of orthodontic treatment, it is during

orthodontic treatment that they are extremely common [4]. The brackets, bands, archwires and elastomeric modules of fixed orthodontic appliances provide additional surface area for bacteria to develop and thus accelerate the accumulation of plaque and the formation of lesions in areas that would normally have a low risk of caries [13]. This is especially so when combined with a poor oral hygiene (OH) [12,14]. The levels of oral bacteria have been reported to increase five folds upon the application of fixed bonds [1]. The increased time and difficulty of maintaining good oral hygiene during orthodontic treatment are challenges faced by patients, as the use of dental floss, interdental brushes and good tooth brushing techniques requires greater effort.

There have been many studies into the incidence of WSLs with varying results. Studies have reported incidence from 23% to 97% of patients present at least with one white spot lesion when assessed immediately after fixed appliance debonding at completion of treatment [1,13,15-20]. This high variation seen may be due to differences in the methods of lesion quantification (visual scale or imaging analysis), local attitudes toward dental health, treatment length and individual risk factors of patients, such as OH and diet in the studied groups. The anterior maxillary teeth were found to be the most affected, with studies reporting the highest incidence of WSLs on the maxillary lateral incisors, located on the gingival margin [14,15,20]. In a 5-year follow-up study by Ogaard, 1989 [16], WSLs were still observed as a cosmetic problem for orthodontic patients. Similar findings were published in a 12-year follow-up study by Shungin et al. [6] examining patients who had incidences of WSLs during orthodontic treatment. They found that although the size of the lesions were reduced over time, they still presented a cosmetic problem for many orthodontic patients as scars on their teeth even 12 years after treatment.

Although WSLs are a common problem in orthodontic patients, they can be prevented by addressing their risk factors including diet restriction and good OH [2,12], and use of fluoride. The benefits of fluoride come from its ability to reduce the solubility of enamel once incorporated into its surface [22], slow the progression of any carious lesion by promoting remineralisation of the region and reducing the rate of transport of soluble minerals out of tooth enamel in an acidic environment, by forming fluoridated hydroxyapatite crystals on the enamel surface [23]. Fluoridated hydroxyapatite also hardens tooth enamel, making it more resistant to caries formation [24]. However, fluoride alone cannot overcome a high bacterial challenge [2]. The delivery of fluoride can occur through commercially

available products such as toothpaste, mouthwash and dissolving tablets, while other fluoride sources include varnishes, and fluoridation of public water supply [25]. The use of fluoride supplements is regularly recommended by multiple studies to prevent WSLs and tooth decay due to the overwhelming beneficial evidence. Fluoride prescription has been shown to lower the prevalence of WSLs in patients undergoing orthodontic treatment compared to patients that did not use fluoride or only used it sparingly [15,24,26,27]. An in-depth systematic review by Benson et al. [4] on the use of fluoride to counteract demineralization during orthodontic treatment concluded that there were links between supplementary exposure to fluoride and the lower occurrence and severity of white spot lesions, and recommended daily use of fluoride mouthwash to lower the risk of WSLs development, although noted more research was needed into the effectiveness of different fluoride delivery methods.

A few studies have reported some risk factors of the formation of WSLs, but none to date have evaluated all the factors contributing to the incidence, severity and location of WSLs. Therefore, the purpose of the present study was to investigate factors affecting the formation, severity and location of white spot lesions in patients completing fixed appliance therapy.

MATERIAL AND METHODS

Study sample

This is a cross-sectional analytical study of a sample of forty five patients who attended Aberdeen Dental Hospital consecutively to have their fixed appliances removed between January and June 2013. Inclusion criteria were: patients who were treated orthodontically. Non-Caucasian patients, patients who have had previous orthodontic treatment, patients with congenital abnormalities or systematic medical conditions were excluded from the study. Consent was sought and obtained from all patients on the day of their fixed appliances removal.

Study design

Patient's data collection was made using a data sheet that was developed to record the incidence of WSLs and contributing factors. The collection sheet was designed to collect data anonymously in two parts, first to survey patients before their admission into the surgery regarding their contributing factors to WSLs i.e. dental care and diet, including use of fluoride supplements, use of carbonated soft drinks and/or fruit juices and use of sugary foods. Once in the surgery, the second part

of the data collection sheet commenced by examining patients for the presence, location and severity of WSLs using the initial patient photographs as pre-treatment comparison record. Additional treatment data was recorded from the patient's dental notes.

WSL examination took place by an experienced and trained clinician, where the tooth surfaces were pumiced, cleaned with water to remove any adhesive residue and debris and dried with compressed air before inspection under a dental lamp. Examination of the buccal/labial tooth surfaces occurred in a systematic manner, starting with the maxillary left first molar, and continuing until the maxillary right first molar followed by the same pattern in the mandibular arch.

Following WSL inspection and recording, additional treatment data was obtained from the patient's dental record including age, genders, treatment length and state of the OH. The state of OH was recorded as either adequate or inadequate. Inadequate OH was recorded if the patient failed to achieve an adequate OH in 4 or more occasions when seen to adjust their fixed appliances.

WSL severity and location was recorded on a schematic diagram representing the maxillary and mandibular buccal/labial surfaces of the first molars, first and second premolars, canines, lateral incisors and central incisors. The schematic diagram contained reference lines illustrating the surface aspects of each tooth: central, mesial, distal and gingival margin. The central aspect was located where the orthodontic bracket was bonded, mesial and distal sides were located to either side of the central surface, and the gingival aspect was located toward the gingival margin.

If WSLs were observed, the location was drawn onto the diagram and its corresponding severity (1, 2, 3 or 4) was noted beside it. A caries severity scale was kept on hand as a reference for classifying WSLs. The severity scale was modified from Universal Visual Scoring System (UniViSS); a visual analogue scale developed by Kuhnisch et al. [28]. The scale was developed with influences from key publications, International Caries Detection and Assessment System (ICDAS) and the World Health Organization (WHO) to potentially standardize the development of carious lesions for accurate classification, in order to address current issues with many other visual diagnostic scales such as validity and reproducibility [28]. Two variants exist, one for occlusal surfaces and another for smooth surfaces. As orthodontic appliances are fixed onto the smooth labial and buccal surfaces of teeth, UniViSS for smooth surfaces was chosen, as importantly, it was a clear and simple visual analogue scale with image references to classify WSLs from their early development to the formation of cavities and tooth

Table 1. Modified Universal Visual Scoring System for smooth surfaces (UniViSS smooth)

Discoloration	Lesion detection and severity assessment			
	First visible signs of a caries lesion	Established caries lesion	Microcavity and/or localised enamel breakdown	Dentin exposure
	Score 1	Score 2	Score 3	Score 4
Sound surface	No cavitations and/or discolorations are detectable.			
White spot	First white spot lesions are unobtrusive and will be detected after prolonged air drying (~5 seconds).	White spot lesions are detectable without prolonged air drying. Air drying improves the assessment of the surface texture (smooth versus rough)	Pathological enlargements are detectable with or without enamel breakdowns - visible as interruption of the surface continuity. No dentin exposure is evident. Enlargements > 0.5mm (use the ball point of the CPI probe) may indicate a microcavity.	Dentin exposure is detectable.
White-brown	White-(caramel-) brown lesions will be detected with prolonged air drying (~5 seconds). Brown areas are in most cases visible without air-drying.	White-(caramel-) brown lesions are detectable without prolonged air drying. Air drying improves the assessment of the surface texture, which indicates in most cases a rough lesion. The brown spot is surrounded by white demineralisations.		
Brown (dark)	Small brown spot lesions will be detected even without air drying.	Brown discoloured lesions are always detectable without prolonged air drying.		
Greyish translucency	Not detectable			

decay. The scale was then modified by simplifying the severity scale for use in this study (Table 1). The scale used in the study was as follows:

1. Class 1 - First visible signs of a caries lesion;
2. Class 2 - Established caries lesion;
3. Class 3 - Microcavity and/or localised enamel breakdown;
4. Class 4 - Dentin Exposure.

Statistical analysis

Cohen’s kappa statistics was used to assess the agreement between two examiners recording the presence/absence of WSL of 20 randomly selected patients. Pearson Chi-Square test was used to assess the statistical significance of the differences of the presence/absence of WSLs between different risk groups. When > 20% of the expected cells has frequencies less than 5 the Fisher-Freeman-Halton Test was used. The absolute risk (AR) and risk ratio (RR) of developing WSL was also calculated.

RESULTS

The study sample consisted of 26 females (mean age ± standard deviation (SD) = 15.69 ± SD 2.88 years) and 19 males (mean age ± SD = 15.97 ± SD 2.98 years). Sixty five percent of females (17 patients) were < 18 years old and the remaining (9 patients) were ≥ 18 years whereas in males 63% (12 patients) were < 18 years old and the remaining (7 patients) were ≥ 18 years.

The inter-rater agreement for the presence/absence of WSLs was found to be near perfect (Kappa = 0.82 [P < 0.001]). The incidence of WSLs at Aberdeen Dental Hospital was 42%, where 19 out of 45 patients were observed with at least one WSL. For further analysis of possible contributing factors, the patients were divided into gender and age groups. The incidence of WSLs in males was significantly higher than females (P < 0.001). In females, 23% (6 out of 26 patients) were observed with at least 1 WSL compared to males at 68% (13 out of 19 patients) (Table 2). The RR of developing WSL in males compared with females was 2.96 indicating that males were almost 3 times more likely to form WSLs compared with females. The incidence of WSLs was twice in teenagers (age under 18 years) compared to adults (age 18 years and over) with corresponding incidences of 52% and 25% respectively (Table 2). However, the differences were not statistically significant (P > 0.05). The RR of developing WSL in teenagers compared with adults was 2.08 indicating that teenagers were twice at risk of developing WSL more than adults.

Ninety seven percent of the WSLs were of grade 1 severity and the remaining 3% were of grade 2 severity and none of the WSLs scored grade 3 or 4 severity.

There was a symmetry in the incidence of WSLs. The maxillary anterior teeth were statistically significantly (P < 0.05) more affected than the mandibular anterior teeth. The range of the number of WSLs for the maxillary anterior teeth was 9 - 14 whereas for the mandibular anterior teeth was 2 - 4. The maxillary lateral incisors and canines are the most affected teeth

Table 2. Distribution of patients with and without white spot lesion (WSL) depending on the associated risk factors

Factor		In group number (%) with WSL	Total number (%) of group	Test and P-value
Gender	Female	6 (23)	26 (100)	Pearson Chi-Square (12.583), P < 0.001 ^a
	Male	13 (68)	19 (100)	
Age	< 18 years	15 (52)	29 (100)	Pearson Chi-Square (3.019), P > 0.05
	≥ 18 years	4 (25)	16 (100)	
Treatment length	< 24 years	3 (20)	15 (100)	Fisher-Freeman-Halton Test (9.13), P < 0.05 ^b
	24 - 36 months	5 (33)	15 (100)	
	> 36 months	11 (73)	15 (100)	
OH level	Adequate	3 (11)	28 (100)	Pearson Chi-Square = 30.16, P < 0.001 ^a
	Inadequate	16 (94)	17 (100)	
Use of fluoride supplements (with regards to treatment)	None	13 (93)	14 (100)	Fisher-Freeman-Halton Test (33.32), P < 0.001 ^b
	Before	4 (80)	5 (100)	
	During	2 (17)	12 (100)	
	Both	0 (0)	14 (100)	
Use of carbonated soft drinks and/ or fruit juices (times per week)	1	3 (20)	15 (100)	Fisher-Freeman-Halton Test (13.72), P < 0.005 ^b
	2	3 (25)	12 (100)	
	3	7 (58)	12 (100)	
	≥ 4	6 (100)	6 (100)	
Use of sugary foods (times per week)	1	4 (27)	15 (100)	Fisher-Freeman-Halton Test (13.57), P < 0.005 ^b
	2	4 (33)	12 (100)	
	3	3 (30)	10 (100)	
	≥ 4	8 (100)	8 (100)	

OH = oral hygiene.

^aStatistically significant, Pearson Chi-Square test.

^bStatistically significant, Fisher-Freeman-Halton test.

followed in descending order by the maxillary and mandibular premolars and first molars, the maxillary central incisors, mandibular canines and mandibular incisor teeth.

With regards to the location of WSLs on tooth surfaces, it was found that the most affected location in both dental arches was the gingival margin. However, WSLs were located in all areas of the maxillary teeth, but almost all WSLs were exclusively recorded on the gingival margin of the mandibular teeth.

When assessing the impact of treatment length on the formation of WSLs there were statistically significant differences between the 3 treatment length groups compared: < 24 months, 24 - 36 months and > 36 months (P < 0.05). The RR of forming WSLs in the treatment length groups 24 - 36 months and > 36 months compared with the < 24 months group was 1.65 and 3.65 respectively. This means that the 24 - 36 months group was 1.65 times and the > 36 months group was 3.65 times more likely to form WSLs than the < 24 months group (Table 2).

Comparison of the incidence of WSLs between those who had adequate and inadequate OH level revealed a statistically significant difference (P < 0.001)

with those who had inadequate OH were 8.55 times more likely to have WSLs than those with adequate OH. The AR for the adequate OH group was 0.11 whereas the corresponding figure for the inadequate OH group was 0.94 (Table 2).

Statistically significant (P < 0.001) differences in the occurrences of WSLs were found between those who had fluoride supplements during the orthodontic treatment and those who either never had it or had it only before the start of orthodontic treatment (Table 2). Patients who never had fluoride supplements or only had it before the orthodontic treatment were 5.47 and 4.71 times respectively more likely to form WSLs than those who regularly had fluoride supplements during the orthodontic treatment. The corresponding ARs for those who never had fluoride supplements, those who had them only before the orthodontic treatment and those who had them during the orthodontic treatment were 0.93, 0.80 and 0.17.

Statistically significant (P < 0.005) differences in the formation of WSLs were found between those who used carbonated soft drinks and/or fruit juices once or twice a week and those who used them 3 and 4 times or more a week (Table 2). The ARs for those who used

carbonated soft drinks and/or fruit juices once, twice, three times, four times or more a week were 0.20, 0.25, 0.58 and 100 respectively.

Statistically significant ($P < 0.005$) differences in the formation of WSLs were also found among patients depending on the frequencies of their usage of sugary foods (Table 2), with the differences found mainly between those who used sugary foods 4 or more times and the remaining groups. The ARs for those who used sugary foods once, twice, three times, four times or more a week were 0.27, 0.33, 0.3 and 100 respectively.

DISCUSSION

The incidence of WSL found in the present study was 42% which falls in the mid-range of the reported figures in the previous literature. This figure compares well with the figures reported by Tufekci et al. [18] and Lucchese and Gherlone [20]. Tufekci et al. [18] reported a prevalence of 46% in a similar sample size of patients (37 patients), and Lucchese and Gherlone [20] reported a prevalence of 40% among patients who had been treated for 6 months, a figure which was increased to 43% among those who had been treated for 12 months. However, authors of the latter two studies have assessed the presence of WSLs using direct visual assessment method during orthodontic treatment, thus probably underestimating the reported incidence due to the difficulty of ascertaining the presence of a WSL. Some previous studies that reported lower incidence than that in the current study have evaluated either only the maxillary anterior teeth [13] or only the maxillary and mandibular anterior teeth [27], or used only photographic evaluation to assess the presence of WSL [30]. The highest incidence of WSLs reported in the previous literature (97%) [19] was probably due to the early identification of the presence of WSLs that were not clinically visible as this study used quantitative light-induced fluorescence (QLF) to evaluate the presence of WSLs.

The present study found a symmetry in the incidence of WSLs as in many previous studies [13,15,16,19,29]. The maxillary anterior teeth were statistically significantly ($P < 0.005$) more affected than the mandibular anterior teeth, a finding which agrees with previous investigations [29-31]. With regards to the most affected teeth, it was found in the present study that the maxillary canines were the most affected teeth followed by the maxillary lateral incisors. Similar findings were found by several previous investigators who have reported the most affected teeth to be either the maxillary canines [16,19] or the maxillary lateral incisors [13,14,15,29]. However, some studies

have reported different results, where the greatest number of WSLs was recorded on the maxillary first molars [16]. Only one study has found no differences in the incidence of WSLs between tooth types [18]. This may be attributed to the small sample size, relatively short follow-up period (12 months) and the evaluation of the WSLs while the fixed appliances were still present which would have made it more difficult to identify the mild forms of WSLs.

In contrast to the maxillary arch, posterior teeth (the first molars and premolars) were the most affected teeth in the mandibular arch. A study by Artun and Brobakken [14] found mandibular canines and premolars to be the most affected teeth instead. The distribution pattern of WSLs observed in the maxillary and mandibular teeth may be explained by different amounts of exposure of saliva to the maxillary anterior teeth in contrast to other areas of the dentition, or simply by poor tooth brushing techniques resulting in the ineffective cleaning of certain teeth.

Another contrast in the distribution of WSLs between the maxillary and mandibular arches was found in regards to the location of WSLs on tooth surfaces, where WSLs were found in all areas of the maxillary teeth, but almost all WSLs were exclusively recorded on the gingival margins of the mandibular teeth. However, the gingival margin was the most frequently recorded surface location of WSLs on both the maxillary and mandibular teeth. The gingival margin, located on the cervical third of the tooth where the tooth and gingiva meet is a common area for bacterial growth [1], and was the area where the most WSLs were seen. Accordingly, studies have also reported that WSLs commonly affect the gingival areas [14,15,31]. The predominant location of WSLs on the gingival margins of the posterior mandibular teeth found in this study was interesting and unexpected. A possible explanation may primarily be due to the natural positioning of the posterior mandibular teeth with their clinical crowns are lingually inclined, unlike the maxillary teeth which have clinical crowns that sit centrally on their roots. This incline may mean that the lower, gingival areas of the mandibular teeth may be missed while brushing, which may be exacerbated by the presence of a large orthodontic bracket fixed on the buccal tooth surface, leading to bacterial build up and the formation of WSLs.

With regards to differences between genders it was found in the current study that males had significantly greater incidence of WSLs than females. There were discrepancies between previous studies in the reported incidence of WSLs with regards to genders. Some studies have reported similar findings to our investigation [13,18,19] and others reported

no statistically significant ($P > 0.005$) differences between genders although males tended to have greater incidence than females [16,17,20,29,30,32]. This gender difference may be due to the commonly reported better OH standards in females than in males [33-35].

Adolescent patients in the current study were found to be as twice as more likely to develop WSLs as adult patients, but the differences between the 2 age groups were not statistically significant P , a finding which was also reported by Chapman et al. [13].

In the current study treatment length did impact on the formation of WSLs and it was found as the treatment length increased from < 24 months to > 36 months the likelihood of formation of WSLs did increase by 3.65 times. Tufekci et al. [18] and Lucchese and Gherlone [20] showed that WSLs can be prevalent in patients undergoing orthodontic treatment for as early as 6 months (38% and 40% respectively), which increases with longer treatment duration at 12 months (46% and 43% respectively), supporting the idea that the presence of fixed orthodontic appliances and greater treatment lengths serve as a risk factor for WSLs formation [5]. Similar finding was also reported by Chapman et al. [13] and Julien et al. [29], but Lovrov et al. [30] were unable to find an impact of the treatment length on the prevalence of WSLs.

OH level was found to have a significant correlation with the formation of WSLs whereby those who had inadequate OH were 8.5 times more likely to develop WSLs than those with adequate OH. This has also been reported by several previous investigators who used different methods of assessing the OH level [13,19,29,30]. Furthermore, Julien et al. [29] evaluated the impact of the change in the OH level during treatment on the development of new WSLs and found that 59% of those whose OH have worsened during treatment have developed WSLs during treatment compared with only 20% of those whose OH stayed the same or got better during treatment developed new WSLs during treatment.

Fluoride supplements investigated in this study included fluoride mouthwash, fluoride tablets, fluoride varnishes and the intake of fluoridated water. The water supply in Aberdeenshire and Scotland in general are not fluoridated, with only rural Morayshire in Scotland receiving natural water fluoridation [25]. Additionally, all patients were unaware of water fluoridation during their childhood, regardless of where they lived during their childhood. No patients used fluoride tablets or varnishes, therefore only the use of normal anti-bacterial mouthwash containing fluoride was examined as a source of fluoride use.

As might be expected regular use of fluoride

mouthwash during the orthodontic treatment did significantly reduce the risk of developing WSLs. Strateman and Shannon [36] reached the same conclusion following their study of 209 patients divided into 2 groups, the first (110 patients) who used fluoride gel regularly and the second group (99 patients) have used no fluoride and found corresponding incidence of WSLs of 27% and 59% respectively. It was also found that the daily use of 0.05 sodium fluoride mouthrinse reduced the incidence of decalcification during orthodontic treatment [37]. A study by Hadler-Olsen et al. [27] found that patients who received fluoride supplements and good patient compliance displayed a lower incidence of WSLs after orthodontic treatment than a control group that did not receive any fluoride supplements. Similarly, O'Reilly and Featherstone [24] illustrated that patients who used a combination of commercially available fluoride products had hardened enamel and inhibition of demineralization, compared to those that used little or no fluoride products at all.

However the incidence of WSLs reported in previous studies on patients who used daily fluoride rinse ranges from 11% to 89% [14,16,30-32]. This reported wide range and discrepancies between those studies can be explained by the fact that previous research into the use of fluoride involved only asking patients about the use of mouthwash before and during treatment, or both limiting the responses to yes/no answers. Due to the wide time span covered, an important factor such as the regularity and frequency of fluoride use was not determined in those studies. Furthermore there may well have been significant discrepancies between those studies in terms of patient's compliances with the use of regular fluoride. A systematic review into the benefits of fluoride use during orthodontic treatment by Benson et al. [4] recommended the use of fluoride mouthwash, but stressed that beneficial effects would only be seen if used regularly, not sparingly.

Diet is a strong contributing factor to the development of WSLs and tooth decay, with a poor diet high in sugar increases the activity of bacterial plaque, raising the risk of WSLs formation [12]. It is also complex to study, due to different diets and the variety of food available, thus, has not been studied extensively in relation to orthodontic treatment. Thus, only sugary foods were investigated.

The use of carbonated soft drinks and/or fruit juices 4 times or more a week has significantly increased the risk of developing new WSLs compared with less frequent usages of such beverages. It has been shown that soft drinks adhere to enamel more readily and for a longer period than saliva, thus allowing plaque accumulation and growth and sugar metabolism resulting in enamel decalcification [38]. Furthermore, it was also shown

that the frequency of consumption of soft drinks and especially between meals was correlated with greater decayed/missing/filled teeth (DMFT) scores [39] and was considered to be a high risk factor of dental caries [40]. It would have been more useful to analyse the effects of carbonated soft drinks and fruit juices separately as it has been reported that the effect of fruit juices on enamel demineralization was more pronounced than that of carbonated soft drinks due to their resistance to the buffering capacity of neutralising factors [41] and its organic acid content [42]. This was not possible to analyse statistically due to the small number of subjects who consumed either carbonated soft drinks alone or fruit juices alone.

Similar pattern to the impact of the use of carbonated soft drinks and/or fruit juices on the development of WSLs and reported above was also found for the use of sugary foods. It has been reported that the consumption of carbohydrate alone does not necessarily increase the risk of caries [1]. Therefore the effect of the carbohydrates in foods on WSLs found in the present study was due to the presence of other factors such as an inadequate OH, increased consumption of carbonated soft drinks and/or fruit juices as well as the increased consumption of the carbohydrates in foods.

However the findings of this study in terms of the impact of sugary foods on the incidence of WSLs should be interpreted with caution. Patients were asked to quantify the frequency of consumption of sugary foods on average per week throughout their entire course of treatment, which may not be accurate. In addition, patients may or may not have been entirely truthful when asked about their dieting habits in relation to high sugar 'junk' foods. Furthermore, an important factor was not determined, the time of consumption, which may be as important as the diet itself. Eating high sugar foods regularly throughout the day places the tooth surfaces under continuing sugar challenge for a longer period of time compared to those who may consume high sugar foods only at mealtimes, raising the risk of WSLs formation [9,10]. Lastly, since WSLs

are multifactorial in their development, it may have been better to study patient diet as a whole combining together high risk food groups, rather than studying the effect of each high risk food on the incidence of WSLs as was done in this study.

CONCLUSIONS

The incidence of WSLs at Aberdeen Dental Hospital was 42%.

The incidence of WSLs in males was significantly higher than in females with males were almost 3 times more likely to form WSLs compared with females. However, ideally a larger sample would be required to make a firm conclusion with regards to the difference in the incidence of WSL between sexes.

There was a symmetry in the incidence of WSLs. The maxillary anterior teeth were statistically significantly more affected than the mandibular anterior teeth. The maxillary lateral incisors and canines were the most affected teeth. The most affected tooth surface location in both dental arches was the gingival margin.

The following risk factors were found to have statistically significant effect on the development of new WSLs: treatment length > 36 months, inadequate oral hygiene during orthodontic treatment, lack of regular use of fluoride mouthwash during orthodontic treatment, the use of carbonated soft drinks/fruit juices and/or sugary foods four times or more a week.

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