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The incidence of caries and white spot lesions in orthodontically treated adolescents with a comprehensive caries prophylactic regimen—a prospective study

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SUMMARY The aim of the study was to assess the effect of a comprehensive prophylactic regimen in reducing the incidence of white spot lesions (WSL) and caries during orthodontic treatment. Eighty consecutive patients, scheduled for fixed appliance treatment in both jaws were compared with a non-orthodontic matched-control group. The oral hygiene regimen consisted of brushing two to three times daily, flossing, fluoride rinse, and plaque disclosing tablets. Patients were requested to avoid carbonated soft drinks/acidic juices and candies. The WSL index of Gorelick *et al.* (Gorelick L, Geiger A M, Gwinnett A J 1982 Incidence of white spot formation after bonding and banding. American Journal of Orthodontics 81: 93–98) was used. Caries were scored according to Amarante *et al.* (Amarante E, Raadal M, Espelid I 1998 Impact of diagnostic criteria on the prevalence of dental caries in Norwegian children aged 5, 12 and 18 years. Community Dental Oral Epidemiology 26: 87–94). We collected data from all finished cases. It comprised 40 subjects in the orthodontic group (mean age: 13.6 years, range: 12–16 years) and 40 matched controls. The average treatment time was 18 months (range: 9–25 months). The mean increase in WSL index in the orthodontic group was 1.9 and 0.4 in the control group ($P = 0.001$). The mean increase in dentine caries was 0.5 lesions and 0.7 lesions in the in the orthodontic group and control group, respectively ($P = 0.62$). Twenty-three per cent of treated patients showed good compliance, 68 per cent moderate compliance, and 9 per cent poor compliance. The mean increase in WSL was 1.0, 1.4, and 3.3 in the good, moderate, and poor compliance group, respectively ($P = 0.155$). Orthodontically treated patients have significantly higher risk for developing WSL than untreated patients, while there is no difference with respect to development of new dentinal caries lesions. This study showed that a possible relationship between compliance and WSL development existed.

Introduction

Initial caries development in the form of white spot lesions (WSLs) on the labial surfaces is a serious side effect of orthodontic treatment with fixed appliances. A recent study showed that up to 97 per cent of the patients treated with fixed appliances had WSL after therapy (Boersma *et al.*, 2005). These lesions appear to be very resistant to complete remineralization (Ogaard, 1989a). Thus, several years after debonding, orthodontic patients have a high number of these often discoloured lesions (Ogaard, 1989). Despite the high number of WSL, the incidence of filled surfaces resulting from caries development is not higher for orthodontically treated patients compared to non-treated controls when fluoride containing toothpastes and mouth rinses are used (Ogaard, 1989b). Fixed orthodontic appliances create stagnation areas for plaque and make tooth cleaning difficult. The irregular surfaces of brackets, bands, and wires limit the naturally occurring self-cleansing mechanism of the oral musculature and saliva (Mount and Hume, 2005). Over time, the colonization of acidure bacteria results in active caries lesions (Chang *et al.*, 1997).

Other important factors in the development and progression of carious lesions are the patient's modifying factors, including medical history; dental history; diet; levels of calcium, phosphate, and bicarbonate in saliva; fluoride levels; and genetic susceptibility (Chalmers, 2006; Mount and Hume, 2005). To prevent dental caries, each dentist should therefore assess each patient's risk factors before and during treatment. Suitable caries preventative agents and therapies can be fluoride products (toothpastes, gels, varnishes, and mouth rinse), antimicrobials, xylitol gum, diet counselling, and casein derivates (Derks *et al.*, 2004).

Most patients with fixed appliances experience an increased incidence of gingivitis during treatment. When good oral hygiene and careful removal of excess adhesive

around the bracket bases are performed, only mild inflammation of the gingival tissues is seen (Zachrisson and Brobakken, 1978). There is conflicting evidence whether a relationship between malocclusion and caries experience exists (Palin-Palokas and Ruokokoski-Pirkkanen, 1990; Gabris *et al.*, 2006). A recent article by Borzabadi-Farahani *et al.* (2011) found an association between orthodontic treatment need and caries experience, though not statistically significant.

In a prospective study on 220 patients scheduled for fixed appliance therapy, Øgaard *et al.* found that the level of visible plaque around the appliance, shortly after bonding was the best predictor for WSL at debonding (Ogaard *et al.*, 2001). There appears to be a synergistic effect between oral hygiene and fluoride exposure in orthodontic patients. Poor oral hygiene reduces the efficacy of fluoride therapy and may be one reason for the high prevalence of WSL. The present study was designed to test the effect of a comprehensive prophylactic regimen in reducing the incidence of WSL. In addition, we measured the increment in filled surfaces.

Subjects and methods

Ethical consideration

Additional bitewing radiographs were taken in the both the test and control groups in order to have comparable data for this study. Even though the x-ray exposure with new digital images is very low, this is a side effect of this study.

This study was a part of a quality insurance program at the Public Dental Service Competence Centre of Northern Norway (TkNN), thus did not have to be approved by the regional ethical committee. The patients were treated by two postgraduate students. Patients referred to the clinic for orthodontic treatment were included in the study based on the following criteria:

1. Patients scheduled for orthodontic treatment with fixed appliances in both jaws. Living in the county of Troms in Northern Norway.
2. Younger than 16 years old at the onset of treatment.

This group comprised 80 individuals. However, at the time of closure of this study, 40 subjects were debonded, and they made up the orthodontic group. For each member in the orthodontic group, a matched control was selected. In order of priority, the inclusion criteria were as follows:

1. Bitewings taken the same year as the orthodontic group.
2. Same dental stage.
3. Same decayed-missed-filled-tooth (DMFT) as test individual.
4. Same gender.
5. Same school.

It was sometimes impossible to find a match with an identical DMFT as the test person. In these cases, every attempt was taken in order to find the closest match and to fulfil the other criteria.

A matched control was found in the computer systems ("OPUS") of the public dental service in Troms County.

Preventative measures

Before fixed appliances were bonded/banded, all patients in the orthodontic group were given thorough oral hygiene instructions. The regimen, developed by the third author, included the following:

1. All patients were given an oral hygiene package, which included a special orthodontic toothbrush, interdental brushes, plaque disclosing tablets, fluoride toothpaste, and mouth rinse.
2. A thorough oral hygiene instruction was given, and all patients were instructed to brush their teeth three times a day.
3. Treatment was not started before the plaque index was below 10 per cent (O'leary *et al.*, 1972).
4. Patients were instructed to avoid carbonated soft drinks and acidic juices during treatment and to restrict the intake of candies to a maximum of once a week.

The control group was not given any special prophylaxis apart from that administrated at routine appointments at the general dentist or hygienist. On average, Norwegian children with low caries risk is given 7.3 minutes of preventative treatment during each recall appointment, and the mean recall interval is 15.4 months (Wang and Aspelund, 2010). The most frequently performed preventative activities are information on hygiene and diet. Children with approximal caries are given fluoride application significantly more often than caries-free children (Wang and Aspelund, 2010).

X-rays

Bitewing radiographs of the orthodontic group were taken before any fixed appliances were bonded/banded and at debonding. For the control group, bitewing radiographs were already available at the public dental service. If the available radiographs were taken more than 3 months prior to the start of the study, new radiograph were taken. Bitewings were taken of the control group at the same time as the corresponding matched individual in the orthodontic group.

Appliances and bonding

The brackets (0.018-in bracket slot, Ormco, California, USA) minidiamond with gingival offset on premolars and hooks on the canines were bonded according to standard procedure with a non-fluoride adhesive (Transbond self etching primer, Transbond XT light cure adhesive paste, 3M Unitek, Minnesota, USA). Bands were used routinely on the first molars and cemented with a glass ionomer cement (GC Fuji Ortho, Alsip, Illionis, USA). Arch wires were ligated to the brackets using steel ligatures only.

Gingivitis

The gingival bleeding index (Ainamo and Bay, 1975) was assessed by using a 0.5 mm diameter periodontal probe (WHO). The gingival margin at the mesial, distal, and buccal surfaces was evaluated. Bleeding was recorded as 1, and no bleeding as 0. The number of elicited bleeding points was summarized and divided by number of sites probed.

Assessment of plaque

Plaque was assessed using plaque disclosing tablets and rinsing to remove excess disclosing agent (O'leary *et al.*, 1972). The buccal, lingual, mesial, and distal inter-proximal surfaces of all teeth were then examined for stained plaque and the findings recorded. The index is calculated by dividing the number of plaque-containing surfaces by the total number of evaluated surfaces.

Assessment of caries

All individuals in the orthodontic group were examined for occlusal caries, buccal/lingual caries, and approximal caries prior to and after orthodontic treatment. The individuals in the control group were examined at the same time intervals as their corresponding matched control. The teeth were polished with pimpstone slurry, thoroughly rinsed with water and air-dried. Caries scores were set according to the evaluation method adopted from Amarante *et al.* (1998).

White spot lesions

The WSLs were assessed according to the WSL index of Gorelick *et al.* (1982). The labial surfaces of all bonded teeth were visually examined and registered as: 1, no white spot formation; 2, slight white spot formation (thin rim); 3, excessive white spot formation (thicker bands); 4, white spot formation with cavitations. One postgraduate student examined each subject. In order to be calibrated, the 10 first patients were evaluated by both investigators (SH and KN). The inter-observer error was estimated from 84 consecutive teeth examined. The orthodontic group were examined for WSL before bonding of orthodontic appliances and at debonding (average treatment time was 18 months). The mean increases in WSL index of the whole dentition as well as of the upper six anterior teeth were calculated.

Evaluation of the control group

The control group were evaluated for WSLs, gingival bleeding, and caries according to the same criteria's as the orthodontic group, within 6 months after the study had started and after debonding of their corresponding individual in the orthodontic group.

Table 1 Descriptive statistics for the test and control groups.

	N	Mean	SD
Test group: dentine caries	40	0.5	1.0
Control group: dentine caries	40	0.6	1.5
Test group: WSL	40	1.9	2.3
Control group: WSL	40	0.4	1.2
Test group: 13–23 WSL	40	1.0	1.4
Control group: 13–23 WSL	40	0	0

Test group: dentine caries = (test group dentine caries at end) – (test group dentine caries at start).
Control group: dentine caries = (control group dentine caries at end) – (control group dentine caries at start).
Test group: WSL = (test group WSL at end) – (test group WSL at start).
Control group: WSL = (control group WSL at end) – (control group WSL at start).
Test group: 13–23 WSL = (test group WSL on upper anterior six teeth at end) – (test group WSL on upper anterior six teeth at start).
Control group: 13–23 WSL = (control group WSL on upper anterior six teeth at end) – (control group WSL on upper anterior six teeth at start).

Compliance

In order to assess compliance in the orthodontic group, all patients were give a questionnaire including five questions regarding how they actually fulfilled their hygiene instructions after debonding. For each question, they had four alternative answers. 1 = full cooperation, 2 = good cooperation, 3 = little cooperation, 4 = no cooperation. They received a score for each question corresponding to the alternative number. An average score for all questions was calculated.

Compliance and WSL

The patients were divided in to three groups according to their average compliance score to find out whether there was any association between compliance and WSL. Group 1 (good compliance) comprised all patients with an average compliance score between 1 and 2. Group 2 (moderate compliance) comprised all patients with an average compliance score between 2.1 and 3. Group 3 (poor compliance) comprised all patients with an average compliance score between 3.1 and 4.

Statistical analysis

The mean caries index and the mean WSL index before and after treatment were compared.

Two-sample *t*-test was used to evaluate differences between the two groups. The level of significance was set at 5 per cent. Statistical analysis was performed using SPSS (15.0 version) statistical program for windows.

Results

On 1 March 2006, we collected data from all the debonded cases from the start of the trial. It comprised 40 subjects

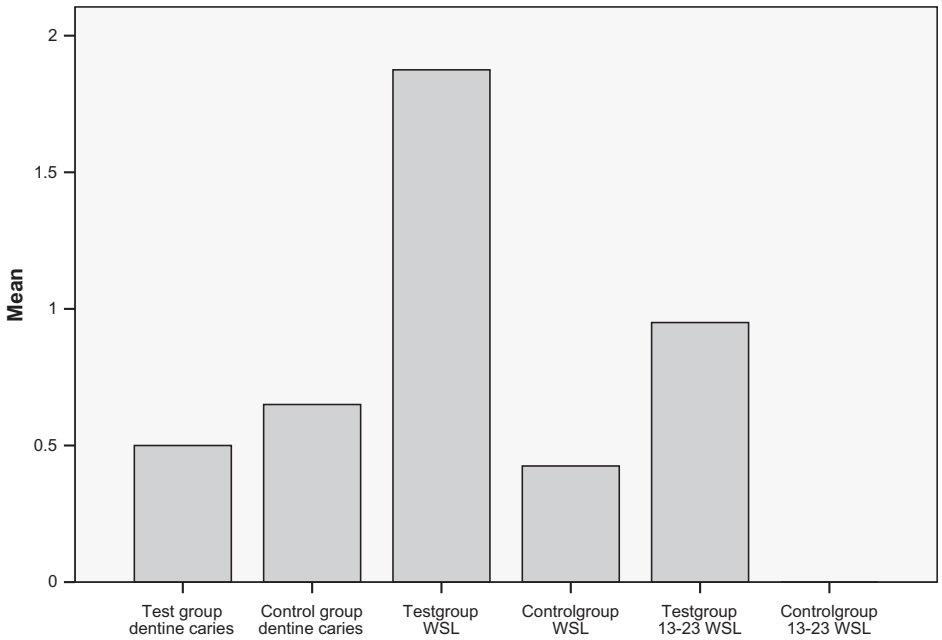

Figure 1 Mean increase in White spot lesion index (WSL) and dentine caries in the test group and control group; 13–23 refers to teeth 13–23 (upper six anterior teeth).

in the orthodontic group and 40 matched controls. The descriptive statistics are given in Table 1 and visualized in Figure 1.

Caries development

The mean treatment time in the orthodontic group was 18 months (range: 9–25 months). During this period, the mean increase in dentine caries was 0.5 lesions (range: 0–5 lesions). The control group was checked for caries at the beginning of the study and at debonding of their corresponding individual in the orthodontic group. In the control group, the increase in dentin caries was 0.7 lesions. The difference between the orthodontic group and the control group was not statistically significant ($P = 0.62$).

White spot lesion

The mean increase in WSL index was 1.9 and 0.4 in the orthodontic group and control group, respectively. This difference was statistically significant ($P = 0.001$). The newly developed WSL in both groups were all scored as 2; slight white spot formation (thin rim).

On the upper six anterior teeth, the increase in WSL index was 1.0 and 0 in the orthodontic group and the control group, respectively.

Gingivitis

The gingival bleeding index showed a mean increase of 4.4 per cent in the orthodontic group from start till the last measurement of bleeding. The control group showed a mean decrease in the gingival bleeding of 0.5 per cent during the same period. The difference in the mean changes of gingival bleeding between the groups was highly significant ($P = 0.000$).

Inter-observer error

The inter-observer error test showed a good inter-observer agreement, Kappa = 0.64 (Cohen, 1968).

Patient compliance with the hygiene regimen

The questionnaire concerning the subject's cooperation regarding the hygiene regimen in the orthodontic group showed an average score of 2.5. The scores of the two postgraduate student's groups were 2.6 and 2.4, respectively.

Compliance and WSL

The increase in WSL was 1.0 ($n = 9$, 23 per cent) in the good compliance group, 1.4 ($n = 27$, 68 per cent) in the moderate compliance group, and 3.3 ($n = 4$, 9 per cent) in the poor compliance group. There was not a statistically significant relationship between the increase in WSL and compliance with the oral hygiene regimen ($P = 0.155$).

Discussion

In the city of Tromsø, Norway, the population is ethnically homologous and highly educated. The social differences within the population are low. Various articles about caries risk predictors have considered that the past caries experience (Seppa *et al.*, 1989; Newburn and Leverett, 1990) and the

level of parents' education (Verrips *et al.*, 1993) are the most significant predictors for future caries. In order to achieve as comparable control group as possible, we matched according to the criteria we have written in the Subjects and methods section. Matching according to parent's education was not done in this study as it would be difficult to practically manage. In Norway, almost all children go to public schools in the area where they live. We matched the control and test groups according to which school the patients attended, which indirectly is likely to reflect the parents' level of education because where people live is correlated with their income and the income is correlated with their education.

Dentine caries development

The mean dentine caries development did not differ significantly between the orthodontic group and control group. This is in accordance with earlier investigation showing that the incidence of filled surfaces is not higher for orthodontically treated patients compared to non-treated controls (Wisth and Nord, 1977, Ogaard *et al.*, 1988).

Figures 2 and 3 show that the caries increase is high in a few subjects and absent or low in most of the individuals in the orthodontic and control groups. This is in accordance with the fact that some individuals are "high risk" persons in the development of caries (Skold, 2005).

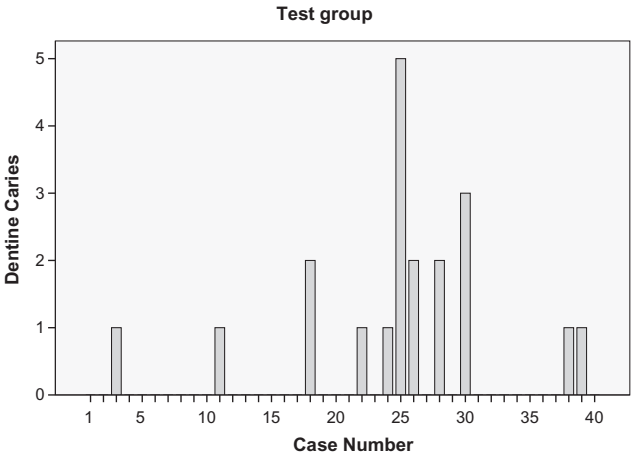

Figure 2 Increase in dentine caries in each subject in the test group.

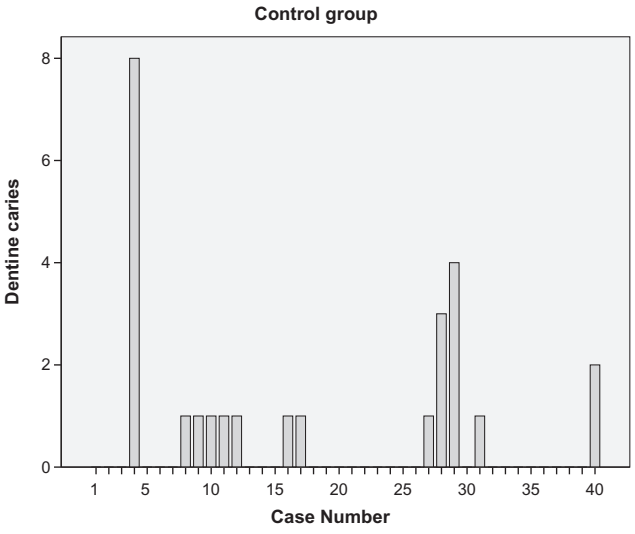

Figure 3 Increase in dentine caries in each subject in the control group.

Development of WSL

The reported prevalence of WSL in patients treated with fixed orthodontic appliances ranges form 2 to 96 per cent. The large variation may be due to the variety of methods used to assess and score the prevalence of WSL and whether idiopatic enamel lucencies where included or not (Mitchell, 1992). In our study, the differential diagnosis between developmental opacities and WSL was based on location, dimension, shape, and quality of the surface layer. We registered all WSL before treatment to assure that the lesions existing before treatment was not included in the incidence of WSL. In our study, 60 per cent of the individuals in the orthodontic group developed one or more new WSL. On average, 6.7 per cent of all the teeth had developed new WSL. In 1982, Gorelick *et al.* did a similar investigation based on the same methods (except for the fact that they only did an assessment at the end of treatment). They found that 50 per cent of the individuals and 10.8 per cent of the teeth had WSLs after fixed orthodontic treatment. This shows that the prevalence of WSL is similar in Northern Norway and New York City, USA. However, in our study, no patient had a higher WSL score than 2 (thin white rim), whereas in the study done by Gorelick *et al.* (1982), about 7 per cent of the patients developed more severe WSL in the category 3 and 4. This suggests that our prophylactic regimen reduced the severity of WSL.

In our study, we ligated the arch wires with steel ligatures only. Arch wires ligated with elastomeric rings exhibit a significant increase in the number of microorganisms in the plaque on the tooth surfaces adjacent to brackets compared to arch wires ligated with steel ligatures (Forsberg *et al.*, 1991; Sukontapatipark *et al.*, 2001). The ligation method may therefore explain some of the differences in WSL between studies.

The Gorelic Index to measure WSL is so far the most used method to registrate WSL in orthodontic patients. This index is well suited to registrate the specific area of WSL but may have limitations in measuring the extent of WSL. In this regard, the DIAGNOdent system (registered trademark of Kavo Dental, Charlotte, North Carolina, USA; www.kavousa.com) has been recommended for reliable assessment of WSL in orthodontic patients (Aljehani *et al.*, 2006)

Development of WSL on the upper anterior teeth

Generally, the upper anterior teeth have been shown to be more susceptible to WSL than other teeth (Mizrahi, 1982). The short distance between the bracket and the gingiva especially on the lateral incisors makes oral hygiene difficult. Further, it has been shown that the pH in plaque on the upper incisors is lower than in other regions of the dentition. This is probably because of low salivary clearance in the area (Arneberg *et al.*, 1997). The low pH leads to rapid loss of fluoride and a limited cariostatic effect (Ogaard *et al.*, 2006).

This study gives a confirmation to these findings. Whereas the incidence of WSL in the whole dentition was 6.7 per cent, the incidence of WSL for the upper anterior teeth was 16.7 per cent. Gorelick *et al.* (1982) found a rather similar incidence of 15.2 per cent on the upper anterior teeth. Ogaard *et al.* (2006), however, reported lower increases in WSL in the upper anterior region than our study. They found that 7.2 per cent of orthodontic patients brushing/rinsing with NaF, and only 4.3 per cent of patients using a combination of amine fluoride/stannous fluoride (Meridol) toothpaste/mouthrinse got WSL. The lower incidence of WSL in that study may be due to a better cariostatic effect of the amine fluoride/stannous fluoride compared to sodium fluoride used in the present regimen.

Patient compliance

In the present study, the caries and WSL preventive system was dependent on patient cooperation and then instruction and reinstruction. Variables such as dietary habits, oral hygiene practices, and exposure to fluorides could not be fully controlled in a clinical study. In the present study, cooperation with oral hygiene regimen was assessed on a scale from good to poor by a patient questionnaire. Using questionnaires as a method introduces the problem of whether patients gave "honest "answers of their compliance or "expected" answers.

Earlier reports have demonstrated that 79 per cent of cooperative patient had no WSL, whereas in the non-compliant group, 51 per cent had no WSL (Geiger *et al.*, 1992). In our study, only 40 per cent did not develop new WSL. This may be because fewer patients could be classified as good compliers (23 per cent) in the present study.

A possible relationship between compliance and WSL development appeared to exist. Subjects with good compliance (n = 9) developed on average one new WSL, subjects with moderate compliance (n = 27) developed 1.4 new WSL, and subjects with poor compliance (n = 4) developed 3.3 new WSL. These data were, however, not statistically significant.

In this study, 40 out of 80 patients did not finish before the closure of this trial. From clinical experience, we have the impression that the most cooperative patients also have the shortest treatment time. It is therefore likely that the 40 unfinished patients were the ones with the poorest compliance. The differences between the good and poor compliers might therefore have been greater (and hence statistically significant) if all 80 patients were included in the study.

Gingival bleeding index

In spite of good tooth cleaning, most individuals developed generalized gingivitis during the treatment period in our study. Due to the presence of the arch wires and brackets, proper probing technique was difficult. A proper assessment of the gingival bleeding index was therefore difficult. Generally, almost all patients showed gingival bleeding. Our results showing a 4.4 per cent increase in bleeding surfaces is similar to the 4.7 per cent increase reported by Ogaard *et al.* (2001).

Conclusions

Our results show that orthodontically treated persons have significantly higher risk of developing WSL during orthodontic treatment than untreated persons. The risk of developing new caries in dentine is similar. A possible relationship between compliance and WSL development appeared to exist. Subjects with good compliance developed on average fewer new WSL than subjects with moderate compliance and subjects with moderate compliance developed fewer WSL than subjects with poor compliance. However, these differences were not statistically significant. This study shows that implementing a comprehensive oral hygiene regimen in orthodontic patients appears to be difficult.

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References

Ainamo J, Bay I 1975 Problems and proposals for recording gingivitis and plaque. International Dental Journal 25: 229–235

Aljehani A, Bamzahim M, Yousif M A, Shi X Q 2006 In vivo reliability of an infrared fluorescence method for quantification of carious lesions in orthodontic patients. Oral Health and Preventitive Dentistry 4: 145–150

Amarante E, Raadal M, Espelid I 1998 Impact of diagnostic criteria on the prevalence of dental caries in Norwegian children aged 5, 12 and 18 years. Community Dental Oral Epidemiology 26: 87–94

Arneberg P, Giertsen E, Emberland H, Ogaard B 1997 Intra-oral variations in total plaque fluoride related to plaque pH. A study in orthodontic patients. Caries Research 31: 451–456

Boersma J G, van der Veen M H, Lagerweij M D, Bokhout B, Prahl-Andersen B 2005 Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: influencing factors. Caries Research 39: 41–47

Borzabadi-Farahani A, Eslamipour F, Asgari I 2011 Association between orthodontic treatment need and caries experience. Acta Odontologica Scandandinavia 69: 2–11

Chang H S, Walsh L J, Freer T J 1997 Enamel demineralization during orthodontic treatment: aetiology and prevention. Austrailian Dental Journal 42: 322–327

Chalmers J M 2006 Minimal intervention dentistry: strategies for the new caries challenge in our older patients. Journal of Canadian Association 72: 325–331

Cohen J 1968 Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychological Bulletin 70: 213–220

Derks A, Katsaros C, Frencken J E, van´t Hof M A, Kuijpers-Jagtman A M 2004 Caries-inhibiting effect of preventive measures during orthodontic treatment with fixed appliances. Caries Research 38: 413–420

Forsberg C M, Brattstrom V, Malmberg E, Nord C E 1991 Ligature wires and elastomeric rings: two methods of ligation, and their association with microbial colonization of Streptococcus mutans and lactobacilli. European Journal of Orthodontics 13: 416–420

Gabris K, Marton S, Madlena M 2006 Prevalence of malocclusions in Hungarian adolescents. European Journal of orthodontics 28: 467–470

Geiger A M, Gorelick L, Gwinnett A J, Benson B J 1992 Reducing white spot lesions in orthodontic populations with fluoride rinsing. American Journal of Orthodontics and Dentofacial Orthopedics 101: 403–407

Gorelick L, Geiger A M, Gwinnett A J 1982 Incidence of white spot formation after bonding and banding. American Journal of Orthodontics 81: 93–98

Mitchell L 1992 An investigation into the effect of a fluoride releasing adhesive on the prevalence of enamel surface changes associated with directly bonded orthodontic attachments. British Journal of Orthodontics 19: 207–214

Mizrahi E 1982 Enamel demineralization following orthodontic treatment. American Journal of Orthodontics 82: 62–67

Mount G J, Hume W R 2005 Preservation and restoration of tooth structure, 2nd edn. Knowledge Books and Software, Queensland. pp. 61–82

Newburn E, Leverett D 1990 Risk assessment dental caries working group summary statement. In: Bader J D (ed.). Risk assessment in dentistry. University of North Carolina dental Ecology, Chapel Hill, pp. 304–305

Ogaard B 1989a Prevalence of white spot lesions in 19-year-olds: a study on untreated and orthodontically treated persons 5 years after treatment. American Journal of Orthodontics and Dentofacial Orthopedics 96: 423–427

Ogaard B 1989b Incidence of filled surfaces from 10-18 years ofage in an orthodontically treated and untreated group in Norway. European Journal of Orthodontics 11: 116–119

Ogaard B, Rolla G, Arends J, ten Cate J M 1988 Orthodontic appliances and enamel demineralization. Part 2. Prevention and treatment of lesions. American Journal of Orthodontics and Dentofacial Orthopedics 94: 123–128

Ogaard B, Larsson E, Henriksson T, Birkhed D, Bishara S E 2001 Effects of combined application of antimicrobial and fluoride varnishes in orthodontic patients. American Journal of Orthodontics and Dentofacial Orthopedics 120: 28–35

Ogaard B, Alm A A, Larsson E, Adolfsson U 2006 A prospective, randomized clinical study on the effects of an amine fluoride/stannous fluoride toothpaste/mouthrinse on plaque, gingivitis and initial caries lesion development in orthodontic patients. European Journal of Orthodontics 28: 8–12

O'Leary T J, Drake R B, Naylor J E 1972 The plaque control record. Journal of Periodontology 43: 38

Palin-Palokas T, Ruokokoski-Pirkkanen S 1990 Occlusal features and caries experience. Proceedings of the Finnish Dental Society 86: 77–82

Seppa L, Hausen H, Pollanen L, Helasharju K, Karkkainen S 1989 Past caries recordings made in the public dental clinics as predictors of caries prevalence in early adolescence. Community Dental Oral Epidemiology 17: 277–281

Skold U M 2005 On caries prevalence and school-based fluoride programmes in Swedish adolescents. Swedish Dental Journal Supplement 178: 11–75

Wisth P J, Nord A 1997 Caries experience in orthodontically treated individuals. Angle Orthodontics 47: 59–64

Sukontapatipark W, El-Agroudi M A, Selliseth N J, Thunold K, Selvig K A 2001 Bacterial colonization associated with fixed orthodontic appliances. A scanning electron microscopy study. European Journal of Orthodontics 23: 475–484

Verrips G H, Kalsbeek H, Eijkman M A 1993 Ethnicity and maternal education as risk indicators for dental caries, and the role of dental behavior. Community Dental Oral Epidemiology 21: 209–214

Wang N J, Aspelund GØ 2010 Preventive care and recall intervals. Targeting of services in child dental care in Norway. Community Dental Health 27: 5–11

Zachrisson B U, Brobakken B 1978 Clinical comparison of direct and indirect bonding with different bracket types and adhesives. American Journal of Orthodontics and Dentofacial Orthopedics 74: 62–78