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White spot reduction when using glass ionomer cement for bonding in orthodontics: a longitudinal and comparative study

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SUMMARY The aim of this clinical study was to test the benefit from using glass ionomer cement (GIC) instead of a conventional diacrylate in bracket bonding for the prevention of white spot formation. Before treatment 7.2 per cent of all examined surfaces ($n = 222$) were classified as having white spots. No additional fluoride treatment other than fluoride toothpaste was prescribed. At debonding 8–39 months later, white spots were found in 24 per cent of the surfaces bonded with the cement, significantly lower than the 40.5 per cent bonded with the diacrylate ($P < 0.01$). At recall 12 months after debonding (examined surfaces $n = 214$) the frequency of surfaces with white spots was reduced to 22 and 24 per cent respectively. Re-examination after a further 12 months ($n = 160$) showed that white spot surfaces were less frequent with the cement (16 per cent compared with the diacrylate 29 per cent), but still significantly more frequent in both groups than before treatment. With longer treatment time (17 months) teeth bonded with diacrylate were more frequently affected with white spots ($P < 0.05$). Neither sex nor age affected the results.

It is concluded that the use of a GIC for orthodontic bonding will result in a significant reduction in the number of white spot surfaces at debonding compared with the use of conventional diacrylate. Although markedly reduced in both groups, the number of affected surfaces was still higher 2 years after debonding than before treatment.

Introduction

Demineralization of the enamel surface close to bonded orthodontic brackets after treatment isacurrent problem, especially in the form ofwhite spot formation. Prevalence of decalcification of enamel in patients after fixedappliance treatment varies between 15 and85 per cent (reviewed by Mitchell, 1992). Accumulation of bacterial plaque and a supply of fermentable sugars are the prerequisites for decalcification to occur. Orthodontic attachmentsandbondingmaterials may retain plaque andtherebypromote enamel surface changes (Zachrissonand Brobakken, 1978; O'Reilly and Featherstone, 1985; Årtun and Brobakken, 1986).

The ability of fluoride to reduce demineralization and enhance remineralization is well established. With additional oral hygiene treatment (instruction) and combined with daily use of a sodium fluoride rinse during orthodontic treatment, incipient caries lesions have been reduced by 30 per cent (Gorelick *et al.*, 1982). Although topical fluoride administration during treatment may minimize net decalcification of dental enamel, the patient's compliance to adequate oral hygiene and the use of fluoride at home is often poor (Zachrisson and Zachrisson, 1971; Shannon, 1981; Geiger *et al.*, 1988). Over the last few years, several studies have focused on the application of fluoride in the oral cavity independent of patient cooperation during orthodontic treatment. For example, fluoride-releasing adhesives have been extensively tested for the reduction of the frequency and severity of

decalcification (Fox, 1990; Bishara *et al.*, 1991; Ghani *et al.*, 1994). Although a significant difference in white spot formation after bracket bonding was found between fluoride-releasing and conventional light-activated bonding systems (Sonis and Snell, 1989), other studies comparing fluoride-containing and non-fluoridated composites have failed to demonstrate a statistically significant difference (Mitchell, 1992; Turner, 1993).

In recent years glass ionomer cement (GIC) has been proposed as an alternative to the more commonly used composite material for bracket bonding (White, 1986; Klockowski *et al.*, 1989; Norevall *et al.*, 1990). Earlier reports on fluoride-releasing cements in orthodontic bonding have supported the view that such cements have a cariostatic effect. As the two materials adhere in different ways to the enamel surface, they may also differ with regard to the potential risk for enamel surface changes. Firstly, when using GIC there is no need for pretreating the enamel with acid to create conditions for mechanical bonding as there is in conventional bonding (Fajen *et al.*, 1990). Secondly, a major advantage with GIC would be the release of fluoride over several months, as has been similary shown when used as a filling material (Forsten, 1977; Swartz *et al.*, 1984; Hatibovi´c-Kofman and Koch, 1991), resulting in significantly increased fluoride levels in plaque adjacent to brackets retained with GIC compared with composite controls (Hallgren *et al.*, 1993). Thirdly, it has been found that a less caries-inducing microflora may develop as well as a lower acid production in the plaque when GIC is used (Hallgren *et al.*, 1992, 1994).

The purpose of this study, was to test the long-term benefits of GIC compared with a conventional diacrylate for the prevention of white spot formation in patients receiving orthodontic treatment with fixed bonded appliances, when no fluoride mouth rinse was used.

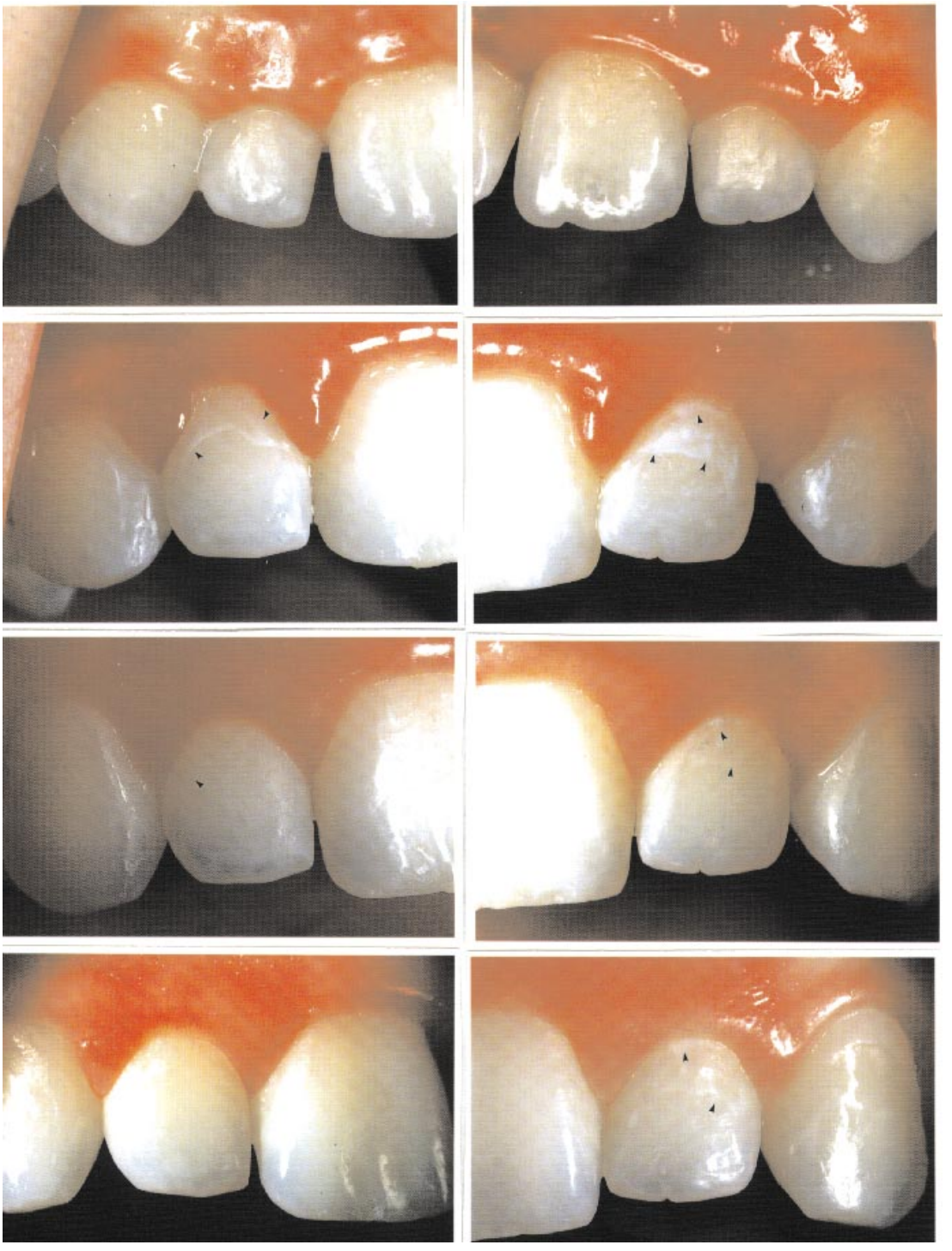
Subjects and methods

Patients referred to the Department of Orthodontics, Umeå University Clinic, were examined and therapy plans were proposed. From those patients assigned to the post-graduate programme, requiring a fixed appliance therapy according to a straight-wire technique and having a normal number of permanent teeth, 60 consecutive patients (21 boys, 39 girls) were selected for the study. The mean age of the subjects was 13 years 7 months (Table 1). The study was limited to four teeth: the upper lateral incisors and the lower canines. Initially each tooth was photographed for colour slides in two projections according to a standardized, macro-photographic procedure to minimize reflections

Table 1 Number of subjects and the distribution of gender and age at the four examinations.

Examination	No. of subjects	Boys	Girls	Median age (decimal years)	Range (decimal years)
Before treatment	60	21	39	13.7	10.8–19.1
At debonding	60	21	39	15.3	12.3–20.9
1 year follow-up	58	20	38	16.4	13.7–21.9
2 year follow-up	44	16	28	17.3	14.7–20.9

Figure 1 Photographs of the maxillary laterals from one patient who was present at all four examinations. The patient's right lateral was cemented with AquaCem® and the left lateral bonded with Unite®. (a) Maxillary right lateral; before treatment score = 0. (b) Maxillary left lateral; before treatment score = 0. (c) Maxillary right lateral; after debonding score = 1; see arrows. (d) Maxillary left lateral; after debonding score = 2; see arrows. (e) Maxillary right lateral; 1 year follow-up score = 1; see arrows. (f) Maxillary left lateral; 1 year follow-up score = 1; see arrows. (g) Maxillary right lateral; 2 year follow-up score = 0. (h) Maxillary left lateral; 2 year follow-up score = 1; see arrows.



on the tooth surface masking enamel surface features (Figure 1). Furthermore, occurrence and extension of colour shades or opacities were recorded after visual inspection.

Brackets were cemented with a GIC (AquaCem®, De Trey, Div., Dentsply Ltd, Weybridge, Surrey, UK) or bonded with a no-mix diacrylate (Unite®, Unitek Corp., Monrovia, CA). For each jaw the two bonding materials were selected according to random procedure and a split-mouth technique. Before bonding, all tooth surfaces were gently cleaned with a fluoride-free pumice in a rubber cup, sprayed with water and dried with an airstream for approximately 15 seconds. The buccal surfaces to be bonded with diacrylate were etched for 30 seconds with 37 per cent phosphoric acid (Etching Liquid®, 3M, Dental Products Div., St Paul, MN), rinsed with water and dried in an airstream for a further 30 seconds. After application of primer on the conditioned enamel surface and the bracket base, bonding material (Unite®) was applied to the bracket. The bracket was then placed in the correct position and pressed firmly towards theenamel surface; excess bonding material was removed later with a scaler. The GIC chosen for cementation was mixed according to the manufacturer's instructions and applied with a toothpick to the bracket base. The bracket was then positioned on the tooth and pressed towards the enamel surface in the same way as for the bracket bonded with diacrylate. Excess cement was removed with a scaler.

Instructions concerning the importance of good oral hygiene, good dietary habits and correct tooth brushing technique were given by the assisting nurse. The information was reinforced by giving all patients a locally produced booklet, 'Being an Orthodontic Patient' (in Swedish). All patients were instructed to use a toothpaste containing fluoride and to contact us immediately if the bracket failed. Because of naturally occurring fluorides in drinking water (0.3 ppm) and the daily use of fluoride-containing toothpaste, no additional fluoride treatment was prescribed. Dislodged brackets during active treatment were replaced with new brackets and bonded/cemented according to the orginal schedule. All bonding and debonding was carried out by two of the authors (A.M., L.I.N.) to ensure a high degree of standardization throughout the study. At the debonding session brackets were removed using a Unitek Debracketing Instrument with a pull-wire for full-size brackets (Unitek Corp., Monrovia, CA). Any bonding material remaining on the enamel surface was removed with a tungsten-carbide burr (Jet-burr, 5LA, 1172; Beavers, Morrisburg, Ontario, Canada) at a low speed and without water cooling according to Zachrisson and Årtun (1979). All teeth were also polished with a non-fluoridated pumice and paste. At debonding and after 1 and 2 years tooth surface conditions were recorded photographically and visually inspected as before. Charts were designed to provide the following information: patient's age and sex, method of bonding and rebonding, bonding and debonding date, and the presence and severity of white spot formation before bonding, at debonding, and 1 and 2 years after debonding.

Assessment of demineralization

The pre- and post-treatment photographic slides, as well as those 1 and 2 years after debonding, were mounted and the enamel surface changes were classified at a magnification of ×20 by three observers. The observers were unaware of which teeth had been cemented with AquaCem® and which teeth had been bonded with Unite®. Classification was made according to a modification of a scoring by Geiger *et al.* (1988) as follows: 0 = no white spot formation; 1 = slight white spot formation; 2 = severe white spot formation; 3 = excessive white spot formation (cavitation).

In case of disagreement between the observers, the concordant classification between the three observers holds good. Inter-examiner reproducibility was calculated using κ statistics (Fleiss and Chilton, 1983).

Statistical analysis

To test the accuracy of the joint classification a reproducibility study was carried out on 186 photographs of recorded teeth. Statistical comparisons were made by testing for differences

Table 2 Occurrence of white spots (in per cent) at the four examinations for the two samples, AquaCem® and Unite®, and *P*-values for differences between the two samples.

Examination	No.	AquaCem®	Unite®	*P*-value
Before treatment	111	8	6	0.6037
At debonding	111	24	40.5	0.0099**
1 year follow-up	107	22	24	0.7466
2 year follow-up	80	16	29	0.0583

No. = the numbers of surfaces in each sample.
** $P < 0.01$.

between scores for enamel surface appearance before and after debonding, after 1 and 2 years, and between as well as within groups of bonding materials. To eliminate a possible effect of contributory patient factors on white spot formation, analyses were made of differences between the two bonding materials in individuals tested with the Wilcoxon matched-pairs signed-ranks test. Changes in scores between various recordings and teeth within the two groups, AquaCem® and Unite®, were tested with the χ^2 test. $P < 0.05$ was chosen for significant difference.

Results

A total of 222 teeth in 60 patients were examined from the time of bracket bonding to debonding, 214 teeth were examined 1 year after debonding and 160 teeth 2 years after debonding (Table 2). Of the 60 patients 25 per cent were bonded forless than 16.7 months, 50 per cent for 16.7–27.0 months and 25 per cent for 27.0–39.7 months (mean 22.0 months). A total of 1636 photographs were evaluated. The reproducibility study on 186 teeth showed 95.4 per cent agreement on the index scores (Table 3). Cohen's κ value was 0.88 (values in the range 0.75–1.0 represent excellent agreement beyond chance).

Demineralization

Before treatment 7.2 per cent of the examined surfaces were classified as having white spots. Of these surfaces 8.1 and 6.3 per cent were later

Table 3 Examiner agreement on classification of decalcification.

		Decalcification score (1st examination)				
		0	1	2	3	Total
Decalcification score (2nd examination)	0	124 (88.08)				128
	1	4	47 (14.25)	1		52
	2			3 (0.064)		3
	3				3 (0.048)	3
	Total	128	51	4	3	186

Score 0 to 3 for 186 teeth of two examinations. Figures in brackets are expected frequencies of agreement by chance.

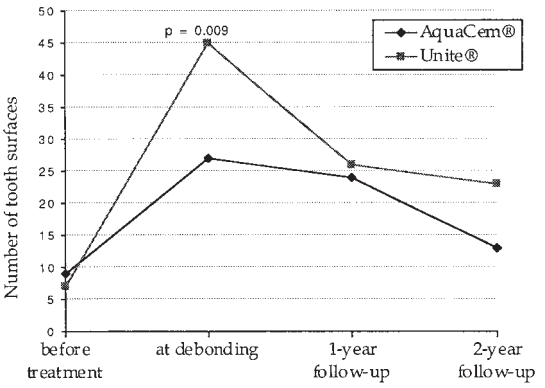


Figure 2 Changes in scores 1, 2 and 3 (white spots) from the time of bonding to the re-examination 2 years after debonding. Where the scores are significantly different, corresponding *P*-values are indicated.

bonded with AquaCem® and Unite® respectively; there were no significant differences between the samples (Table 2, Figure 2). After debonding 8–39 months later (mean 22 months) white spots were found in 24 per cent of the surfaces bonded with the cement, a significantly lower number than the 40.5 per cent found for the diacrylate ($P < 0.01$) (Table 2, Figure 2).

At recall 12 months after debonding the frequency of surfaces with white spots was reduced to 22 and 24 per cent respectively (Table

Table 4 *P*-values for differences between various registrations in the number of white spot affected teeth and for each recorded tooth in the two samples.

Registration		AquaCem®					Unite®				
	No.	12	22	33	43	all	12	22	33	43	all
bt-ad	111	0.09	0.03*	0.46	0.06	0.002**	0.01*	0.01*	0.05	0.12	0.00***
bt-y1	107	0.30	0.16	0.17	0.04*	0.005**	0.03*	0.12	0.09	0.08	0.00***
bt-y2	80	0.30	0.30	0.18	0.07	0.04*	0.04	0.17	0.17	0.007**	0.00***
ad-y1	107	0.46	0.23	0.22	0.68	0.48	0.04*	0.01*	0.68	0.59	0.006**
ad-y2	80	0.10	0.10	0.32	1.00	0.09	0.11	0.01*	0.59	0.36	0.03*
yl-y2	80	0.31	0.68	0.18	1.00	0.58	0.59	1.00	0.59	0.36	0.34

bt = before treatment; ad = at debonding; y1 = 1 year follow-up; y2 = 2 year follow-up.
*** $P < 0.001$; ** $P < 0.001$; * $P < 0.05$.

2, Figure 2). In a subgroup ($n = 160$) re-examined after a further 12 months, white spot surfaces were less frequent with the cement (16 per cent compared with 29 per cent) but still significantly more frequent in both groups than before treatment (Table 4). The distribution of white spot surface changes for the 160 teeth followed for the entire 2 year period after debonding is given in Table 5. When testing for the differences between the various registrations for each tooth, the right upper lateral bonded with diacrylate showed a significant difference throughout the study (Table 4). The group of teeth bonded with Unite® showed a significant difference for all registrations except between the 1 and 2 year follow-ups. Teeth bonded with AquaCem® showed a significant difference between the registrations taken before treatment and after debonding, and the tooth most frequently involved was the left lateral. For the time period before treatment to the 2 year follow-up, all teeth bonded with AquaCem® showed a significant difference.

Patients treated for more than 17 months showed an increased frequency of white spots in both groups. When subsamples were formed according to the length of treatment time, teeth bonded with diacrylate showed a tendency to be more affected ($P < 0.05$) (Table 6). Neither sex nor age affected any of the results of group differences. When eliminating the effect of the two materials in the analysis, there were no significant differences on the individual level before and after treatment, or before treatment and after 1 or 2 years post-treatment.

Table 5 Occurrence of white spot (in per cent) at the four examinations for teeth followed through the entire 2 year period after debonding in the two samples, AquaCem® and Unite®, and *P*-values for differences between the samples.

Examination	No.	AquaCem®	Unite®	*P*-value
Before treatment	80	7.5	5	0.5136
At debonding	80	20	43	0.0025**
1 year follow-up	80	19	24	0.4395
2 year follow-up	80	16	29	0.0583

No. = the number of surfaces in each sample.
** $P < 0.01$.

Discussion

The general findings in this study reinforce earlier reports that white spot formation remains a problem during orthodontic treatment with fixed appliances, despite careful patient selection and prophylactic programmes. Only one-quarter of the recorded surfaces were considered unaffected by the treatment. The large variation between earlier incidence reports may be partly explained by the method of bonding, including polymerization of the sealant layer (Joseph *et al.*,1994). Nevertheless, the advantages of an orthodontic bonding adhesive capable of sustained fluoride release and with good adhesive

Table 6 Number of teeth in each of the two samples, AquaCem® and Unite®, distributed by white spot score 0–3 at debonding for short, medium and long treatment periods. *P*-value for differences between the two samples.

Treatment period	No.	AquaCem®				Unite®				*P*-value
		0	1	2	3	0	1	2	3	
7.7–16.7 months	26	22	3	0	1	23	3	0	0	0.6845
16.7–27.0 months	57	41	11	3	2	31	20	2	4	0.0522
27.0–39.7 months	28	21	6	0	1	14	13	1	0	0.0533
Total	111	84	20	3	4	68	36	3	4	0.0533

Not significant: $P \geq 0.05$.

properties are many since the dependence on patient cooperation and dietary habits is reduced. Alternatively, fluoride may be topically administered as a daily mouth rinse, or around the brackets at every appointment or at scheduled intervals (Büyükilmaz *et al.*, 1994).

The reported disadvantage of GIC is an increased risk of bracket failure during fixed appliance treatment, as an inferior bond strength has been reported in both laboratory studies (Cook and Youngson, 1988; Klockowski *et al.*, 1989; Norevall *et al.*, 1990; Øen *et al.*, 1991) andclinical studies (Cook, 1990; Fricker, 1992; Norevall *et al.*, 1996). Pretreatment with acids for establishing mechanical retention do not significantly alter GIC bond strength (Fajen *et al.*, 1990), although a favourable influence by preconditioning the enamel surface with aromatic carbon-acids has been observed (Fischer-Brandies *et al.*, 1991).

In order to test the efficacy of AquaCem®, a GIC containing fluoride, it was necessary to find an objective and preferably quantitative method of assessing decalcification. The photographic method used in this study gives an enlarged permanent record which can be rescored as manytimes as required. Allowing a longitudinal comparison, we are aware, however, that lesions appearing clinically as white spot lesions may also comprise microcavities (Thylstrup and Fejerskov, 1994).

The teeth chosen for documentation were the maxillary laterals and mandibular canines. Earlier studies have shown that banded or bonded teeth especially affected with white spots are maxillary laterals, mandibular canines and premolars (Zachrisson and Zachrisson, 1971; Gorelick *et al.*, 1982; Årtun and Brobakken, 1986). The premolars were excluded because of extraction treatment or aplasia.

The split-mouth design, allowing an analysis of intra-individual differences between the materials, was adopted as topically applied fluoride will mainly act locally (Primosch *et al.*, 1986). A recent study by Hallgren *et al.* (1993), however, indicates that a slight crossover distribution may occur via the saliva.

White spot lesions before treatment

Before treatment 5.8 per cent of the maxillary laterals and 7.5 per cent of the mandibular canines in our study were classified as having white spots. Our observations are in agreement with the findings of Årtun and Brobakken (1986), who found white spots on 6.5 per cent of the maxillary laterals and 4.2 per cent of the mandibular canines in an untreated group, while Gorelick *et al.*(1982) reported a frequency of 7 and 1 per cent respectively for the same teeth. Turner (1993) found white spots in a total of 6.7 per cent of the examined teeth before treatment.

White spot lesions at debonding

The findings in this study demonstrate that use of a GIC for bracket bonding will result in a significant reduction in the number of white spot surfaces at debonding compared with the use ofa conventional diacrylate (Tables 2 and 4, Figures 1 and 2). This difference, 17 and 34 per cent respectively, is mainly caused by teeth affected

with slight white spots (score 1). We found higher incidences than those reported by Gorelick *et al.* (1982), 23 per cent for the maxillary laterals and 18 for the mandibular canines in a composite group.

When eliminating the effect of the two materials in the statistical analysis, there was no significant difference on an individual level. This indicates that teeth bonded with GIC in our study were less affected with white spots. It supports earlier suggestions of a local cariostatic effect of glass ionomer when used for orthodontic bracket bonding (Hallgren *et al.*, 1992, 1993) although a high incidence of white spots was still recorded in our study.

Treatment time and white spot lesions

In agreement with Geiger *et al.* (1988), who reported that the incidence and severity of white spot formation after debonding was related to treatment time, we found an increase in white spot formation with longer treatment periods. Both studies thus contradict an earlier report (Gorelick *et al.*, 1982). However, we found an increase in white spot occurrence in both groups, with no significant differences between the materials. Although there may be a tendency for teeth to be less affected when using GIC in the midrange and long treatment periods, our results, similar to those observed in orthodontic band cementation, show that GIC does not provide the desired caries protection when access is difficult (Rezk-Lega *et al.*, 1991), despite the high level of fluoride accumulated in the plaque adjacent to the orthodontic bracket (Hallgren *et al.*, 1993).

White spot lesions 1 and 2 years after treatment

At recall 1 year after debonding the 50% reduction in white spots (score 1) in the diacrylate group convincingly demonstrates that slight white spots may 'heal'. White spot features and repair may, however, be significantly affected by attrition caused by surface treatment at debonding and also by mechanical oral hygiene. It is not unlikely that the difference between the two samples in the frequency of white spot lesions at debonding may have already been reduced by the more abrasive measures required for the removal of excess composite than of glass ionomer (Östman-Andersson *et al.*, 1993). Long-term SEM recordings have also indicated that surface wear rather than repair is responsible for the clinical improvement seen in arrested white spot lesions (Årtun and Thylstrup, 1989).

After a further 12 months the frequency of surfaces with white spots was 16 and 29 per cent respectively, with no differences between the two groups. This shows a continuing reduction of white spots in the group cemented with AquaCem®. It may also be that the scoring system was too insensitive to record possible differences in the severity of the lesions, some of which may include microcavities, between the two groups.

Conclusions

The results of the present study demonstrate that use of GIC for bracket bonding will result in a significant reduction in the number of white spot surfaces at debonding compared with the use of conventional diacrylate. However, although markedly reduced with time, the number of affected surfaces will still be higher 2 years after debonding than before treatment for both materials.

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