

# A post-treatment evaluation of multibonded ceramic brackets in orthodontics

Jon Årtun

Department of Orthodontics, University of Washington, Seattle, WA, USA

**SUMMARY** The purpose of this study was to perform a clinical evaluation of ceramic brackets with silane-coated bases for chemical (Transcend) and microcrystalline bases for mechanical (Transcend 2000) retention. The sample consisted of 49 consecutive patients; the first 30 were treated with brackets with chemical retention and the following 19 with brackets with mechanical retention. For each patient the brackets on one side of the mouth were assigned at random to be bonded with Concise and the other with Transbond as recommended by the manufacturers. Levelling and alignment of severely displaced roots was initiated with superelastic wires and completed with stainless steel wires. Any space closure or correction of interarch discrepancy was performed with rectangular stainless steel wires. The brackets with chemical retention were removed with a torsional rotation debonding wrench, and those with mechanical retention with a tensile debonding plier. The bond failure rate was low, with no difference between the two bracket types or between brackets bonded with Concise and Transbond. Bracket fracture was a significant clinical problem, both during active treatment and at the time of appliance removal. New teeth with formation of pronounced enamel cracks were seen in 20.6 and 10.5 per cent of the teeth treated with brackets with chemical and mechanical retention, respectively ( $P < 0.001$ ), with no difference between teeth bonded with Concise and Transbond. Enamel tear-outs were seen in 3 of the 544 and in 1 of the 344 teeth treated with the respective types of bracket. These teeth were bonded with Concise.

## Introduction

Ceramic orthodontic brackets are machined from monocrystalline or polycrystalline aluminium oxide (Swartz, 1988; Birnie, 1990). Their unrivalled clinical appearance is due to the translucency and the resistance to discoloration of aluminium oxide. However, indirect discoloration from adhesives, elastic ligatures and chains may reduce the aesthetic benefits. For that reason meticulous flash removal and use of adhesives with low discoloration potential, such as light- or chemically-cured composites with low amine concentration, are critical (Swartz, 1988).

Aluminium oxide is chemically inert, necessitating fabrication of undercuts in the bracket bases for mechanical retention or preparation of the bases with a silane coupling agent for chemical retention of the adhesive (Swartz, 1988). *In vitro* machine tests indicate that both methods produce a shear bond

strength similar to or higher than that of mesh-backed metal brackets (Gwinnett, 1988; Britton *et al.*, 1990; Joseph and Rossouw, 1990; Viazis *et al.*, 1990; Eliades *et al.*, 1991; Forsberg and Hagberg, 1992), and that the type of adhesive is of minor significance for shear strength (Ødegaard, 1990; Viazis *et al.*, 1990; Chaconas *et al.*, 1991; Eliades *et al.*, 1991). The majority of the *in vitro* tests conclude a predominance of failure within the bond material or in the adhesive/bracket interface on removing brackets with mechanical retention (Gwinnett, 1988; Forsberg and Hagberg, 1990; Viazis *et al.*, 1990; Eliades *et al.*, 1991). However, for brackets with chemical retention, failure modes both in the adhesive/enamel (Gwinnett, 1988; Ødegaard, 1990; Eliades *et al.*, 1991) and the adhesive/bracket (Britton *et al.*, 1990; Viazis *et al.*, 1990; Chaconas *et al.*, 1991; Forsberg and Hagberg, 1992) interfaces have been reported.

The tensile strength of aluminium oxide is

high, approximately 260,000 psi for monocrystalline and 55,000 psi for polycrystalline materials, compared with 40,000 psi for stainless steel (Birnie, 1990). However, tensile strength is a bulk material measure of stress and therefore does not reflect the clinical performance of ceramic versus metal brackets (Scott, 1988). A more important comparison is that stainless steel deforms approximately 20 per cent prior to failure, as opposed to less than 1 per cent for aluminium oxide. That difference in strain reflects how easily a ceramic bracket will fail compared with a metal bracket (Scott, 1988; Birnie, 1990). *In vitro* studies have confirmed the potential for wing fracture of ceramic brackets when simulating archwire deflections that may occur in the clinic (Rhodes *et al.*, 1992). Any material imperfection or minor scratch on an aluminium oxide surface will further reduce the load required for fracture (Scott, 1988; Swartz, 1988; Birnie, 1990), while a similar scratch on a stainless steel surface is insignificant (Scott, 1988). For that reason, use of elastic ligatures has been recommended with ceramic brackets, to avoid bracket wing fracture due to pressure from the steel ligatures (Birnie, 1990) and scratches associated with tying and cutting of the ligatures (Swartz, 1988; Birnie, 1990).

The aetiology of enamel cracks is unclear and probably multifactorial. However, one form is a fracture of the enamel cap induced by stresses at the tooth surface (Atkinson and Prophet, 1953; Tyldesley, 1970). The capacity of metal brackets to be deformed allows formation of a peel force in the bracket/adhesive interface on removal. This may facilitate bond failure in that interface and reduce the potential for stress build-up in the enamel, minimizing the risk of enamel crack formation. A clinical comparison of two large patient groups treated either with cemented bands or bonded brackets to untreated matched controls detected only minor intergroup differences in prevalence of enamel cracks (Zachrisson *et al.*, 1980). However, the resistance to deformation of ceramic brackets, and any tendency for increased bond strength, may cause stress build-up in the enamel/adhesive interface on bracket removal, increasing the risk of enamel cracks. There may also be a potential risk for

enamel tear-out on bracket removal in situations with failure in the enamel/adhesive interface (Joseph and Rossouw, 1990; Eliades *et al.*, 1991; Forsberg and Hagberg, 1992). Another problem with the brittleness of the aluminum oxide material is the potential risk for bracket fracture during debonding (Bishara and Trulove, 1990; Joseph and Rossouw, 1990; Chaconas *et al.*, 1991), necessitating grinding to remove the remaining part of the ceramic bracket.

Case reports (Machen, 1990; Jeiroudi, 1991) and surveys (Lindquist, 1989) indicate that ceramic brackets are associated with an occasional risk of iatrogenic enamel tear-out on removal. Also, clinical recommendations have been made to avoid bracket wing fracture during active treatment (Carter, 1989). However, comprehensive clinical reports are lacking. The purpose of this study was therefore to perform an evaluation of the clinical performance of ceramic brackets with chemical and mechanical retention in groups of consecutively treated patients. The specific aims were to analyse the frequency of bond failure and wing fracture during active treatment, to evaluate the failure mode on removal, and to test the hypothesis that mechanical removal of ceramic brackets is associated with formation of enamel cracks.

## Materials and methods

### Sample

The sample consisted of 49 consecutively treated patients, 26 adults and 23 adolescents. The patients presented with various types of malocclusion and were treated with multibonded appliances in both arches by the author.

### Brackets and adhesives

The first 30 patients were treated with ceramic brackets with silane-coated bases for chemical retention (Transcend; Unitek/3M, Monrovia, CA). The remaining 19 patients were treated with ceramic brackets with microcrystalline bases for mechanical retention (Transcend 2000; Unitek/3M). For each patient the brackets on one side of the mouth were assigned at random to be bonded with a heavily (approximately 80 per cent) filled, chemically-cured composite material with medium (approximately 8  $\mu$ m)

particle size (Concise; Unitek/3M). The brackets on the contralateral side were bonded with a heavily (approximately 80 per cent) filled, light-cured composite with small (approximately 1.5  $\mu\text{m}$ ) particle size (Transbond; Unitek/3M).

### *Orthodontic treatment*

Non-extraction as well as a variety of extraction approaches were selected, and the patients were treated with an edgewise light-wire technique. Levelling was initiated with thin, round superelastic wires, and completed with round stainless steel wires. In occasional situations with severe discrepancy superelastic rectangular wires were used in the initial phases of vestibulo-lingual alignment of the roots. Any interarch corrections or space closure were performed with stainless steel wires. Spaces were typically closed in a friction-free manner, using contraction arches with loops. Extraoral forces were used whenever necessary for anchorage purposes, growth adaptation or movement of maxillary molars distally to their correct position.

Brackets were direct-bonded to all premolars, incisors and canines. Particular emphasis was made to avoid any occlusal contact with the mandibular brackets. Prior to bonding, etching was performed with 37 per cent phosphoric acid for approximately 15 seconds (Nordenvall *et al.*, 1980). The Concise pastes were prediluted with the corresponding unfilled resins and used according to previous recommendations (Årtun and Zachrisson, 1982). Similar routines were followed with Transbond. Upon setting of the adhesive, any excess was carefully trimmed with tungsten carbide burs at low speed without water coolant. The archwires were tied in with prefabricated 0.012 inch stainless steel ligatures. Whenever necessary for untying, the ties were loosened prior to cutting the ligatures.

### *Bracket removal*

The Transcend brackets were removed with a torsional rotation debonding wrench (#800-804; Unitek/3M). The instrument was seated firmly against the enamel at the mesial and distal aspects of the brackets, and a quick, circular motion was used. The Transcend 2000 brackets were removed with a tensile debonding plier (#444-770; Unitek/3M). The metal extensions

from the beak were seated under the bracket wings at the occlusal and gingival aspects before the handles were squeezed together. With either method the teeth were supported by having the patient bite firmly on a cotton roll. If bracket fracture precluded appropriate fit of the debonding instrument, a diamond bur was used at high speed with water coolant for complete removal of all ceramic material from the tooth. Residual adhesive was removed with a tungsten carbide bur at low speed without water coolant (Zachrisson and Årtun, 1979).

### *Clinical examination*

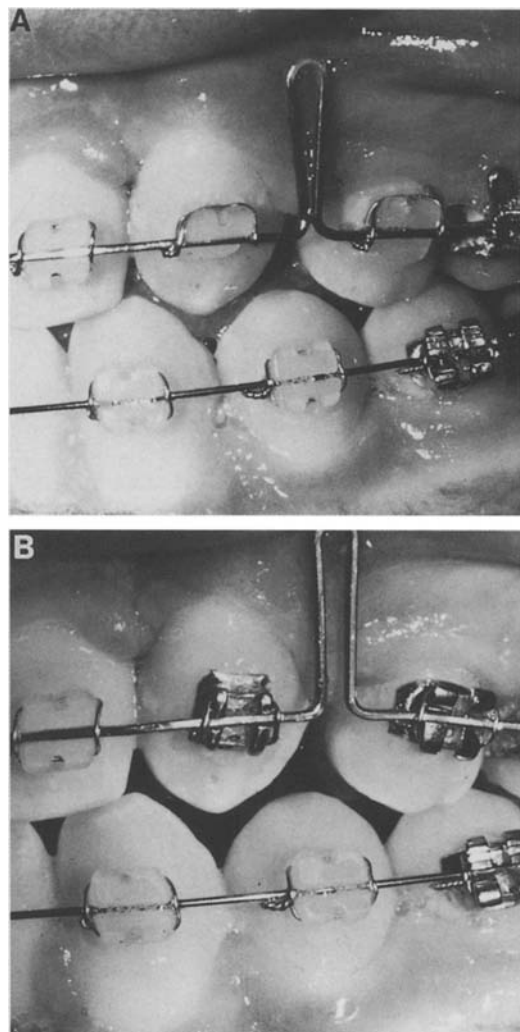
Any bracket loosening (bond failure) or bracket wing fracture (bracket failure) during treatment was recorded whenever they occurred. At time of bracket removal the failure mode was recorded as bond failure if the bracket was completely removed with the instrument in question, and bracket failure if the procedure was associated with a bracket failure to the extent that the instrument did not fit, necessitating use of a diamond bur to remove the remaining ceramic material. Following bond failure the amount of adhesive left on the tooth was scored according to the Adhesive Remnant Index (ARI) system (Årtun and Bergland, 1984), with score 0 indicating no adhesive left on the tooth, score 1 and 2 less and more than half of the adhesive left on the tooth respectively, and score 3 all adhesive left on the tooth. The presence of enamel cracks was scored before treatment and again after appliance removal. Only 'pronounced' cracks were recorded, and defined as those that could be detected by direct inspection under normal office illumination without the use of fibre optics or a dental light source (Zachrisson *et al.*, 1980). According to direction on the teeth, the cracks were classified as vertical, horizontal or oblique. Occurrence of enamel tear-outs was also recorded.

### *Data analysis*

The number of new teeth with the presence of any type of crack from before to after treatment, and the number of teeth with any occurrence of each of the other variables or scores were calculated separately for the two groups of patients treated with brackets with mechanical

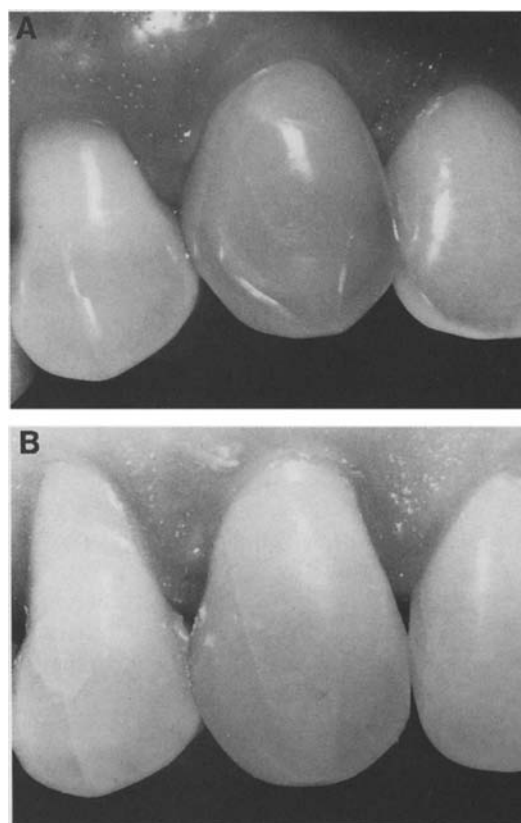
**Table 1** Percentage occurrence of bracket wing fracture (bracket failure) during treatment (tx) and bracket removal (rx), tooth surfaces within each score group of adhesive remnants following bracket removal according to the ARI system, and new teeth with formation of pronounced enamel cracks in 544 teeth of 30 patients treated with ceramic brackets with silylated bases (C) and in 344 teeth of 19 patients treated with ceramic brackets with microcrystalline bases (M), bonded with Concise on one side of the mouth and Transbond on the other.

	Central incisor			Lateral incisor			Canine			First premolar			Second premolar			Total		
	Concise			Concise			Concise			Concise			Concise			Transbond		
	Max	Mand	Max	Mand	Max	Max	Mand	Max	Max	Mand	Max	Max	Mand	Max	Max	Mand	Max	Mand
Bracket failure tx: C	3.3	3.3	13.3	10.0	3.3	6.7	6.7	6.7	3.3	13.3	10.0	0.0	30.0	6.3	13.3	6.3	3.3	6.3
Bracket failure tx: M	10.5	0.0	10.5	10.5	10.5	0.0	0.0	0.0	5.3	5.3	0.0	10.0	10.5	10.0	10.5	20.0	5.3	20.0
Bracket failure rx: C	16.7	3.3	20.0	10.0	13.3	0.0	16.7	3.3	0.0	6.7	3.3	0.0	3.3	0.0	3.3	6.3	6.3	7.2
Bracket failure rx: M	5.3	10.5	10.5	5.3	10.5	15.8	15.8	10.5	21.1	0.0	36.8	5.3	10.0	0.0	0.0	5.3	0.0	0.0
ARI score 0: C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARI score 0: M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARI score 1: C	4.0	0.0	4.2	0.0	3.8	0.0	0.0	0.0	6.7	0.0	0.0	6.3	3.4	12.5	6.9	7.4	0.0	6.7
ARI score 1: M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARI score 2: C	0.0	3.4	0.0	0.0	11.5	0.0	0.0	3.4	13.3	3.6	13.8	0.0	12.5	6.9	18.8	3.4	7.4	0.0
ARI score 2: M	5.6	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
ARI score 3: C	92.0	96.6	95.8	100	84.6	100	100	96.6	80.0	96.4	86.2	100	81.3	89.7	68.8	89.7	85.2	100
ARI score 3: M	94.4	100	94.1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
New cracks: C	10.0	10.0	13.3	6.7	33.3	3.3	30.0	6.7	36.7	30.0	30.0	13.3	18.8	20.0	12.5	26.7	33.3	30.0
New cracks: M	21.1	10.5	15.8	10.5	26.3	0.0	15.8	0.0	21.1	5.3	10.5	5.3	0.0	5.3	21.1	5.3	0.0	0.0



**Figure 1** Intraoral photographs taken during orthodontic treatment using multibonded ceramic brackets with silylated bases for chemical retention. (A) Note fracture of both occlusal wings of maxillary left canine and second premolar brackets. (B) Note that fractured brackets are replaced with stainless steel brackets.

and chemical retention, and for the quadrants bonded with Concise or Transbond. A robust log rank test (Lin, 1994) was used to test for any statistically significant differences in bond and bracket failure during treatment. A Chi square test was used to test for any statistically significant differences in ARI score and formation of enamel cracks.



**Figure 2** Intraoral photographs before (A) and after (B) orthodontic treatment using multibonded ceramic brackets with silylated bases for chemical retention. Note the formation of a horizontal crack on the maxillary left canine and oblique cracks on the maxillary left premolar.

## Results

### *Failures during treatment*

The bond failure rate was 1.7 and 3.2 per cent for the brackets with chemical and mechanical retention respectively. This difference was not statistically significant ( $P = 0.20$ ), and there was no difference in failures between brackets bonded with Concise and Transbond.

The bracket failure rate was not significantly different for the two bracket types ( $P = 0.43$ ), and occurred in 48 of the 544 brackets with chemical retention and 27 of the 344 with mechanical retention (8.8 and 7.8 per cent respectively; see Table 1). No differences were observed for maxillary and mandibular brackets, or for brackets in anterior and posterior segments.



Fracture of both occlusal or both gingival wings occurred in 21 of the fractured brackets with chemical retention and 12 of the fractured brackets with mechanical retention (Figure 1).

#### *Failure mode during bracket removal*

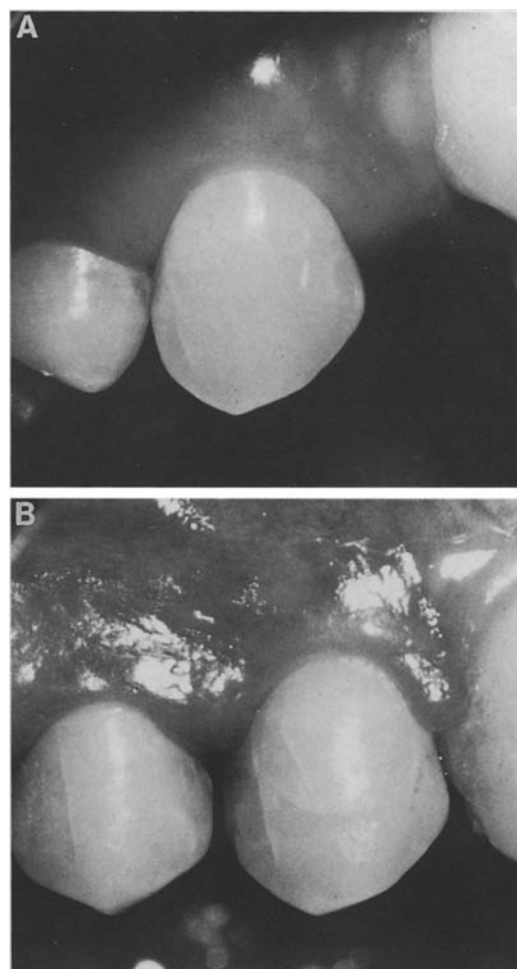
A total of 39 (7.2 per cent) and 31 (9.0 per cent) of the brackets with chemical and mechanical retention respectively, had to be ground off due to fracture either during treatment or at the time of attempted bracket removal. Wing fracture had occurred during treatment in 25 and 17 of these brackets respectively. Following removal of brackets with chemical retention, the ARI score of the 505 teeth with bond failure was 1 in 16 teeth (3.1 per cent), 2 in 29 teeth (5.7 per cent) and 3 in 460 teeth (91.1 per cent). Similar scores of 313 surfaces under brackets with mechanical retention were 2 in 2 teeth (0.6 per cent) and 3 in 311 teeth (99.4 per cent). The difference in the frequency of ARI score 3 was statistically significant ( $P < 0.001$ ; Table 1). No difference in the ARI score was seen following removal of brackets bonded with Concise and Transbond.

#### *Enamel cracks*

The number of new teeth with the presence of pronounced cracks of any type from before to after treatment was 112 among the 544 teeth treated with brackets with chemical retention (20.6 per cent, Figures 2 and 3) as opposed to 36 among the 344 teeth treated with brackets with mechanical retention (10.5 per cent; Figure 4) ( $P < 0.001$ ; Table 1). Only 12 and 4 new teeth with horizontal or oblique cracks were seen in the two groups respectively. No difference in crack formation was seen between teeth bonded with Concise and Transbond.

#### *Enamel tear-outs*

Enamel tear-outs were observed in one maxillary canine, one maxillary first premolar and one mandibular second premolar of the 544 teeth bonded with brackets with chemical retention. These three teeth were bonded with Concise, and two were given an ARI score of 1 and one was given an ARI score of 2 upon bracket removal. Only one mandibular second premolar of the 344 teeth bonded with brackets with mechanical retention developed enamel tear-out. The tooth was bonded with Concise, and the incidence

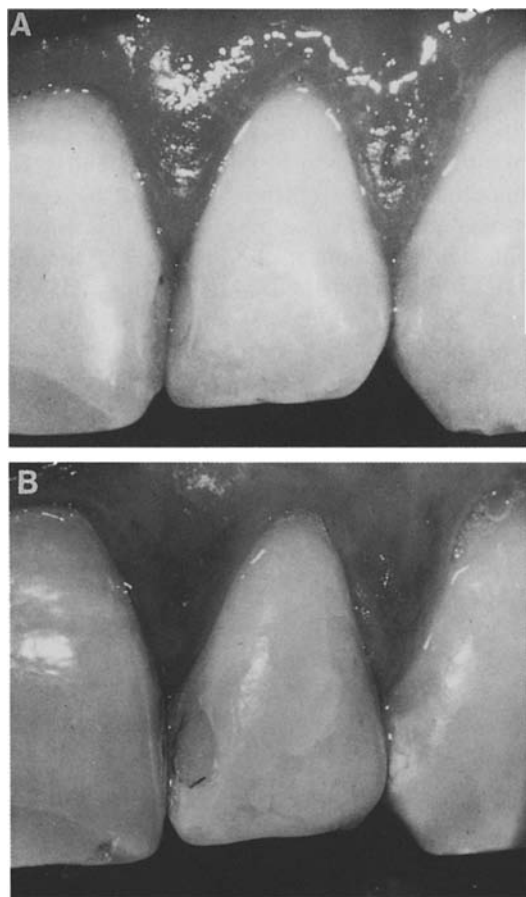


**Figure 3** Intraoral photographs before (A) and after (B) orthodontic treatment using multibonded ceramic brackets with silylated bases for chemical retention. Note the formation of multiple cracks on the maxillary left first premolar.

occurred during treatment in association with a bond failure (Figure 5). No composite remained on the tooth after the failure. The ARI score following removal of the rebonded bracket was 3.

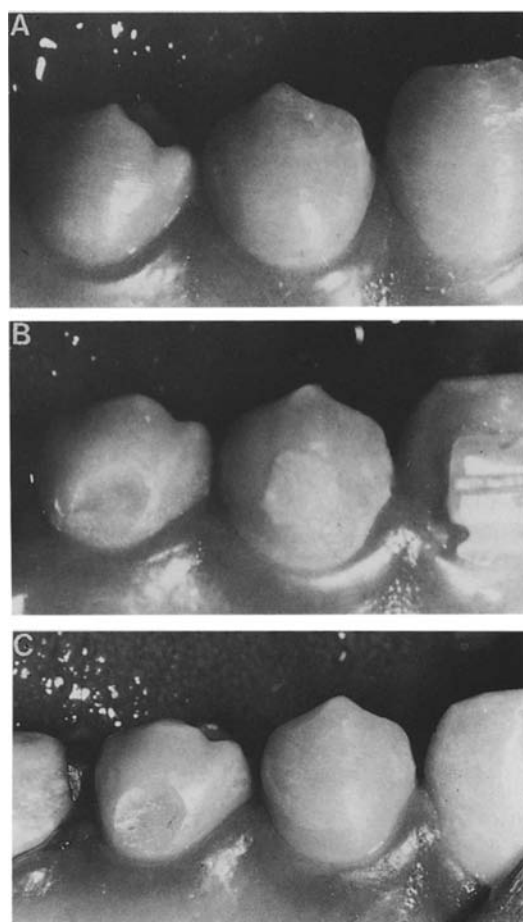
#### **Discussion**

The hypothesis that removal of ceramic brackets is associated with formation of enamel cracks can be confirmed. Any differences in bond properties between adhesives with medium-sized



**Figure 4** Intraoral photographs before (A) and after (B) treatment using multibonded ceramic brackets with microcrystalline bases for mechanical retention. Note the formation of an oblique crack on the maxillary left lateral incisor.

and small filler particles were not found to be consequential in this regard. A previous follow-up evaluation detected only minor differences in prevalence of cracks between subjects treated with bonded metal brackets and untreated matched controls (Zachrisson *et al.*, 1980). The reason for the present finding may therefore be due to properties inherent in the brackets. The most likely explanation is that the lack of ductility of the ceramic material prevents formation of a peel force in the bracket/adhesive interface on removal. Instead, the applied forces for bracket removal may generate stress build-up



**Figure 5** Intraoral photographs before (A), during (B) and after (C) treatment using multibonded ceramic brackets with microcrystalline bases for mechanical retention. Note the bracket failure during treatment on the mandibular right first and second premolars, and the formation of an enamel tear-out on the second premolar.

in the adhesive/enamel interface. Previous studies suggest that such stresses may produce enamel cracks (Atkinson and Prophet, 1953; Tyldesley, 1970). As many as 25 of the 30 patients treated with brackets with chemical retention and 15 of the 19 patients treated with brackets with mechanical retention experienced one or more new teeth with the presence of pronounced cracks. These cracks were horizontal or oblique in eight and two of the patients of the respective groups. Such cracks are seen only rarely in patients treated with metal brackets (Zachrisson *et al.*, 1980), suggesting

that the stress build-up during mechanical removal of ceramic brackets is considerable.

The clinical significance of enamel cracks is poorly documented. The cracks seen following bracket removal are unlikely predilection sites for caries, since they occur on easy-to-clean, smooth vestibular surfaces. Also, the stress build-up that may have caused the cracks is not likely to be associated with trauma to the pulp. When asked, no patients in this sample reported discomfort or hypersensitivity to hot or cold. However, cracks as pronounced as those seen in this study may represent an aesthetic problem (Figures 2–4), particularly following any discoloration of organic filling-in material from saliva.

In agreement with results of *in vitro* tests (Gwinnett, 1988; Eliades *et al.*, 1991), a higher frequency of failure in the enamel/adhesive interface upon removal of brackets with chemical than with mechanical retention was found in this study. This may indicate stronger bonds using silane-coated bracket bases, and is supported by the observation that such brackets demonstrated only about half as many bond failures as those with microcrystalline bases. Although this difference may be considered clinically significant, it should be stressed that the survival analysis test failed to demonstrate statistical significance, probably due to reduced power. Results of *in vitro* tests also suggest increased bond strength utilizing brackets with chemical rather than mechanical retention (Viazis *et al.*, 1990). Any relative increase in force for removal of brackets with chemical retention may therefore explain my finding of higher frequency of crack formation using such brackets. However, the difference in ARI score following removal of the two bracket types was small, suggesting a contribution of other factors to the almost 100 per cent difference in crack formation. It cannot be ruled out that the bracket removal technique *per se* may be a variable of importance. In several situations more than one attempt with the torsional rotation debonding wrench was necessary to remove the bracket, and on several occasions crack formation was observed during the first unsuccessful attempt. Use of a tensile debonding plier may represent a gentler technique.

Formation of enamel tear-outs occurred rarely

relative to the number of teeth examined in this study, with less than 0.6 and 0.3 per cent of teeth affected in the two groups. However, the fact that 10 per cent of the patients treated with brackets with silane-coated bases experienced a tooth with enamel tear-out should be a cause for concern. The occurrence was invariably associated with a bond failure in the enamel/adhesive interface. Accordingly, the fact that only two of the 344 teeth bonded with brackets with microcrystalline bases showed small areas with denuded enamel following bracket removal suggests that the risk of enamel tear-outs is very rare with such brackets. In this study the only occurrence was associated with the presumably very unusual combination of a bond failure during treatment and a break in the enamel/adhesive interface (Fig. 5).

The potential for formation of enamel cracks and tear-outs may be minimized using a thermodynamic debonding technique. In short, the technique implies application of a heat element of several hundred degrees Celsius to the bracket surface. The heat penetrates the ceramic bracket bulk and melts the resin component of the adhesive in the bracket/adhesive interface, allowing bracket removal without any mechanical trauma (Sheridan *et al.*, 1986). One major disadvantage of the technique is the potential for iatrogenic pulp damage due to migration of heat through the enamel and dentine (Jost-Brinkmann *et al.*, 1992). However, recent experiments indicate that a heat application of only 3–5 seconds may be sufficient for atraumatic removal of ceramic brackets, and that such short application periods are unlikely to be associated with a measurable temperature increase in the pulp (Jost-Brinkmann *et al.*, 1994). A laser-aided debonding technique has also been suggested to minimize the potential for enamel damage during removal of ceramic brackets (Strobl *et al.*, 1992). However, the clinical feasibility of the technique has not been described in any detail.

The hypothesis and the results from previous case reports (Birnie, 1990) and *in vitro* tests (Rhodes *et al.*, 1992) that bracket failure is a significant problem during treatment with ceramic brackets could be confirmed. Fracture of one occlusal or gingival wing does not



represent a clinical problem, since control in all three planes of space may be maintained and the debonding instrument may still fit the bracket. However, fracture of both occlusal or gingival wings compromises the ability to perform vestibulo-lingual root movements, necessitating rebonding when active torque is required (Fig. 1). In such cases the rebonding procedure is time-consuming because the remaining ceramic material typically has to be ground off due to lack of fit between debonding instrument and bracket. Admittedly, the occurrence of bracket failure is technique-sensitive. Pressure from the stainless steel ligatures may have caused wing fractures in this study. However, fracture never occurred during the ligation process, and any pressure from the ligatures may be considered necessary to maintain archwire engagement. Also, every effort was made in this study to partially untie the ligatures before cutting, to avoid contact between ligature cutter and bracket. Wing fractures of ceramic brackets may therefore be very difficult to avoid during treatment, and the fact that fracture of both occlusal or both gingival wings occurred in almost 4 per cent of the brackets in this investigation may be considered a significant clinical problem.

Bracket failure at the time of debonding is also technique-sensitive. In every case any adhesive flash was carefully removed to secure optimal seating of the respective debonding instruments, and the instruments were used according to the manufacturers' recommendations. Despite that, grinding was necessary for complete removal of ceramic material in ~8 per cent of the brackets, which for two major reasons may be considered a significant clinical problem. One is the increase in debonding time. The other is associated with the fact that water coolant is necessary to avoid heat generation and pulp damage (Machen, 1990). Use of water complicates the distinction between ceramic, adhesive and enamel during grinding, with the potential for iatrogenic enamel damage where there is contact between the diamond bur and the enamel (Zachrisson and Årtun, 1979).

Case reports (Douglas, 1989; Viazis *et al.*, 1989) and *in vitro* tests (Viazis *et al.*, 1990) suggest that enamel abrasion of teeth in the

opposing arch is a potential clinical problem associated with the use of ceramic brackets. However, the occurrence requires direct occlusal contact between enamel and ceramic. Such iatrogenic damage may be minimized through careful bracket positioning and selective bracket grinding during treatment, and was not a significant problem in the present study.

In attempts to reduce the risk of bracket failure, ceramic brackets are typically made bulkier than metal brackets, with higher profiles and shorter wing projections. In this sample, the high profile was occasionally associated with patient discomfort in the initial stages of treatment, and the short wing projections made it difficult to place both a ligature tie and an elastic chain, or to place Kobayashi hooks for attachment of elastics.

It should be stressed that only two brands of polycrystalline ceramic brackets and two types of adhesive were evaluated in this study. However, despite improvements in shape and structure of the brackets, and use of modified adhesive mixtures, the problems associated with the basic properties of ceramic materials may be difficult to overcome. It may therefore be concluded that failure and mechanical removal of ceramic brackets is associated with a clinically significant formation of enamel cracks. On the other hand, formation of enamel tear-outs may be rare using brackets with mechanical retention. The brittleness of the ceramic material causes a clinically significant occurrence of bracket fractures, both during active treatment and at time of mechanical removal.

#### Address for correspondence

Professor Dr Odont. Jon Årtun  
Department of Orthodontics SM-46  
University of Washington  
Seattle, WA 98195  
USA

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