

# The effect of enamel bleaching on the shear bond strengths of metal and ceramic brackets

E. Öztaş\*, G. Bağdelen\*, H. Kılıçoğlu\*, H. Ulukapı\*\* and İ. Aydın\*\*\*

Departments of, \*Orthodontics, \*\*Operative Dentistry, Faculty of Dentistry, Istanbul University, Istanbul, Turkey and \*\*\*Department of Chemical Engineering, Faculty of Engineering, Istanbul University, Istanbul, Turkey

Correspondence to: Dr Evren Öztaş, Department of Orthodontics, Faculty of Dentistry, Istanbul University, Capa 34093 Istanbul, Turkey. E-mail: evrenoztas@yahoo.com

**SUMMARY** The aim of this study was to evaluate the effects of bleaching and delayed bonding on the shear bond strengths of metal and ceramic brackets bonded with light and chemically cure composite resin to human enamel. One hundred and twenty extracted human premolar teeth were randomly divided into three groups of 40 each. The first two groups were bleached with 20 per cent carbamide peroxide (CP) at-home bleaching agent. No bleaching procedures were applied to the third group and served as control. The first two and control groups were divided into equal subgroups according to different adhesive–bracket combinations. Specimens in group 1 ( $n = 40$ ) were bonded 24 hours after bleaching process was completed while the specimens in group 2 ( $n = 40$ ) were bonded 14 days after. The specimens in all groups were debonded with a Universal testing machine while the modified adhesive remnant index was used to evaluate fracture properties. No statistically significant differences were found between the shear bond strengths of metal and ceramic brackets bonded to bleached enamel after 24 hours, 14 days, and unbleached enamel with light or chemical cure adhesives ( $P > 0.05$ ). The mode of failure was mostly at the bracket/adhesive interface and cohesive failures within the resin were also observed. Our findings indicated that at-home bleaching agents that contain 20 per cent CP did not significantly affect the shear bond strength of metal and ceramic orthodontic brackets to enamel when bonding is performed 24 hours or 14 days after bleaching.

## Introduction

There are a number of methods and approaches that have been described in the literature for bleaching vital teeth. Materials such as hydrogen peroxide (HP), sodium perborate, and carbamide peroxide (CP) are generally used for the bleaching processes. Some of the external bleaching systems are applied by the clinician as an in-office procedure, using a high concentration of HP subjected to either heat or light to speed up the reaction (Kugel *et al.*, 1997; Tavares *et al.*, 2003). HP in the form of CP is widely used for tooth bleaching, both in professionally and in self-administered current at-home bleaching products. The basic difference between the materials of the in-office and at-home products is that the CP in the latter contains carbopal, an additive that thickens the bleaching material, improves adhesion, and prolongs the oxygen release of the peroxide (Tse *et al.*, 1991). The first at-home ‘night-guard’ bleaching system using CP was introduced by Haywood and Heymann (1989). Since then, manufacturers have introduced commercially numerous at-home bleaching systems containing different concentrations of CP. Many of these systems use between 5 and 30 per cent CP as the active bleaching agent (Tse *et al.*, 1991; Turkun and Kaya, 2004).

Bleaching products can be used before or after orthodontic treatment. The effect of bleaching on the enamel surface morphology and on the bond strength between composite resins and the bleached enamel and the effect of post-

bleaching period is still a controversial subject. Some studies have shown that the bond strength of adhesive restorations and resin-bonded brackets is reduced when the tooth has been bleached with an in-office or at-home technique (Titley *et al.*, 1991; Stokes *et al.*, 1992; Garcia-Godoy *et al.*, 1993; Miles *et al.*, 1994) and several authors have reported a significant decrease in the bond strength of composite resin to CP-bleached enamel when compared with unbleached enamel (Stokes *et al.*, 1992; Titley *et al.*, 1992; Garcia-Godoy *et al.*, 1993; Miles *et al.*, 1994; Sung *et al.*, 1999; Turkun *et al.*, 2002; Turkun and Kaya, 2004). Some research results have shown that the enamel layer and structure are affected by CP (Bishara *et al.*, 1987; Titley *et al.*, 1988; McCracken and Haywood, 1996; Turkun *et al.*, 2002) while others concluded that CP had minimal effects on the surface morphology of enamel (Haywood *et al.*, 1990; Leonard *et al.*, 2001).

According to previous studies, post-bleaching period for bonding procedures varied from 24 hours to 4 weeks and up to 3 months (Titley *et al.*, 1992; Miles *et al.*, 1994; van der Vyder *et al.*, 1997; Uysal *et al.*, 2003), before resin–enamel bond strengths return to values obtained for unbleached enamel, which could depend on the brand of the bleaching agent, type of the solvent in the adhesive, and the duration of application (Sung *et al.*, 1999; Turkun *et al.*, 2002). This debate in reduction in enamel bond strength has become a concern in orthodontics, where vital bleaching is often

considered a first step to improve the appearance of teeth prior to bonding orthodontic brackets.

The aim of this study was to determine the effect of a 20 per cent CP at-home bleaching agent on the shear debonding strengths of metal and ceramic brackets bonded with light and chemically cure composite resin to human enamel, 24 hours and 14 days after the bleaching process, respectively.

### Material and methods

One hundred and twenty freshly extracted human first premolars for orthodontic purposes were collected, debrided and washed in tap water, and stored at room temperature in a solution of 0.9 per cent NaCl, which had been renewed systematically, until required. The criteria for tooth selection were intact buccal enamel; no pretreatment of chemical agents, such as derivatives of peroxide, acid, or alcohol; no cracks from forceps; no caries; and no restorations. The extracted premolars were randomly divided into an experimental group ( $n = 80$ ), which was bleached with 20 per cent CP, and a control group ( $n = 40$ ), which was not bleached. The experimental group was further divided into two main groups. Specimens in group 1 ( $n = 40$ ) were bonded 24 hours after bleaching and in group 2 ( $n = 40$ ) 14 days after bleaching. Twelve subgroups ( $n = 10$  per subgroup) were created in each group with the combination of metal and ceramic brackets, which were bonded with self- and light-cure composite adhesives, respectively, to perform the shear tests (Table 1).

#### Preparation of the specimens

Before the experiment, the roots of the teeth were embedded until their cemento-enamel junctions, in standardized  $15 \times 18.5 \times 29$  mm<sup>3</sup> stainless steel molds containing auto-polymerized acrylic resin (Meliodent; Herause Kulzer, Hanau, Germany) and which were covered with petroleum jelly from the inside for easy removal of the acrylic resin blocks after polymerization and for the reuse of the molds. A mounting jig was used to align the facial surfaces of the teeth perpendicular to the bottom of the mold so that the labial surfaces would be parallel to the applied force during the shear test. Just before bleaching, the enamel surfaces were polished with oil- and fluoride-free fine pumice and

water by using a brush and a slow-speed handpiece, rinsed again, and dried with an air syringe. At-home bleaching agent which contains 20 per cent CP (Opalescence; Ultradent Products, South Jordan, Utah, USA) was applied with a microbrush, at room temperature on the enamel surfaces of the embedded teeth and left for 6 hours a day for a period of 2 weeks according to the manufacturer's instructions. The specimens were partially immersed in water at room temperature in a glass laboratory beaker so that the enamel surfaces coated with bleaching gel did not contact the water. After the daily bleaching procedure, the specimens were thoroughly rinsed with water and compressed air for 30 seconds and air-dried. For the rest of the day, they were stored in a moisturized environment at room temperature. Subsequently, the procedure specified for each experimental group was followed. Before bonding, all control and experimental teeth were stored in a moisturized environment at 37°C in Memmert 600 stove (GmbH Co. KG, Schwabach, Germany) for 24 hours for the control group and group 1 and for 14 days for group 2.

Two types of brackets were used in the study. The first type of brackets was 0.018 inch, mesh-based stainless steel premolar brackets (Gemini bracket; 3M Unitek, Monrovia, California, USA) and the mean area of each bracket base was 10.6 mm<sup>2</sup>. The second type of brackets was 0.018 inch, metal-reinforced, polycrystalline alumina, mechanical lock-based ceramic premolar brackets (Clarity bracket; 3M Unitek) and the average surface area for the bracket base was 11.3 mm<sup>2</sup> (area for the bracket bases was provided by 3M Unitek).

The preparations for bonding the brackets in all groups were essentially similar: the enamel surfaces were polished with fluoride-free fine pumice by using a brush and a slow-speed handpiece, thoroughly rinsed, and dried with an air syringe, conditioned with 38 per cent gel form orthophosphoric acid (Etch-Rite; Pulpdent Corporation, Watertown, MA, USA) solution for 20 seconds, and followed by immediate rinsing for 15 seconds. Air was applied for 20 seconds to dry the teeth until their buccal surfaces appeared to be chalky white. Transbond XT sealant (3M Unitek) was then applied according to manufacturer's instructions by the same operator. The adhesive was then light cured with a visible curing light unit (XL 3000; 3M Unitek) for a total of 40 seconds from mesial, distal,

**Table 1** Shear bond strengths of subgroups ( $n = 10$  per subgroup).

Adhesive type	Bracket type	Control group (Mpa)	Group 1 (Mpa)	Group 2 (Mpa)	P
Unite	Metal bracket	12.459 ± 2.648	14.552 ± 4.622	13.359 ± 2.845	N.S.
Unite	Ceramic bracket	12.217 ± 3.676	13.794 ± 2.157	12.131 ± 5.422	N.S.
Transbond XT	Metal bracket	9.587 ± 0.779	11.494 ± 4.461	9.423 ± 2.702	N.S.
Transbond XT	Ceramic bracket	13.594 ± 3.88	15.367 ± 3.513	14.735 ± 4.556	N.S.

The statistical analysis of the shear bond strength (Kruskal–Wallis test).  
N.S.:  $P > 0.05$ .

gingival, and occlusal sides of the metal and ceramic brackets (10 seconds per side). The same preparation procedures were applied to half of the specimens, which were bonded with chemically cured bisphenol A glycidyl methacrylate (Bis-GMA) no-mix composite resin Unite (3M Unitek) at 24°C room temperature according to manufacturer's instructions by the same operator. When placing the brackets, a force of 300 g was applied for 5 seconds using a spring balance (Correx Tension Gauge; Haag-Streit AG, Koeniz, Switzerland) and ensuring a uniform thickness of the adhesive. Excess adhesive was removed with a scaler. After bonding, all control and experimental teeth were stored in a moisturized environment at 37°C in Memmert 600 stove for 24 hours.

### Mechanical tests

The shear bond strengths were measured with an universal testing machine (H10KS, Hounsfield, England) at the Experimental Test Laboratory, Engineering Faculty, Istanbul University, at a crosshead speed of 1 mm/minute, using a 100 g load cell. An incisal-to-cervical shear force was applied as close to the bracket-tooth interface as possible by a chisel-shaped rod attached to the crosshead of the universal testing machine. The load at failure was monitored and continuously recorded by a software system. The data of applied load to specimens were standardized by dividing the force-to-failure value by the area of the bracket base (bracket base dimensions were provided by 3M Unitek) and expressed in megapascals (MPa).

### Analysis of fractured surfaces

Fracture analysis of the debonded enamel surfaces and bracket bases was done with a stereomicroscope (Olympus Co, Tokyo, Japan) at  $\times 25$  magnification. The adhesive remnant index (ARI) scores were used as a more comprehensive means of defining the sites of bond failure between the enamel, the adhesive, and the bracket base (Årtun and Bergland, 1984). Any adhesive remaining after debonding was assessed, scored, and classified according to the modified ARI (Olsen *et al.*, 1997) because of the use of ceramic brackets in the study. The scoring criteria of the index were as follows: a score of 0 was assigned when no adhesive left on tooth surface and failure was between adhesive and enamel; 1, when less than half of adhesive left on tooth surface; 2, when half or more adhesive was left on tooth; 3, when all adhesive left on tooth surface, failure was between adhesive and bracket base, and a clear imprint of the bracket was evident; 4, when there was enamel fracture; and 5, when there was bracket fracture.

Five randomly specimens selected from each main group were examined under a scanning electron microscope (SEM; JEOL JSM-5600, Tokyo, Japan) at between  $\times 250$  and  $\times 1000$  magnification to show the characteristics of the enamel surfaces.

### Statistical analysis

Descriptive statistics including mean, standard deviation, and minimum and maximum values were calculated for each test group. Kruskal–Wallis test for nonparametric means was used to determine whether significant differences existed between the groups (Table 1), Dunn's multiple comparison test for the subgroups and Mann–Whitney *U*-test for pairwise comparisons of the groups. Significance for all statistical tests was predetermined at  $P < 0.05$  level. Kruskal–Wallis test for the groups and Dunn's multiple comparison test for the subgroups were used to determine any difference in the ARI scores (Tables 2 and 3). All statistical analyses were processed with the Graph Pad Prisma V.3 software system (GraphPad Software, San Diego, California, USA).

### Results

No statistically significant differences were found between the control and experimental groups even the results of 24 hours delay group in all bracket–adhesive combinations were found higher than the control and 14 day delay group ( $P > 0.05$ ; Table 1). No statistically significant differences were found between pairwise comparison of the control and experimental groups according to Dunn's Multiple Comparison test for Unite and Transbond XT ( $P > 0.05$ ). No statistically significant differences were found between the frequency distribution of the subgroups according to the modified ARI scores of metal and ceramic brackets ( $P > 0.05$ ; Tables 2 and 3). In all ceramic bracket groups, except one (bonded with Unite in group 2), bracket fracture was observed (Table 3). In group 1, one metal bracket bonded with Unite and two ceramic brackets bonded with Transbond XT showed

**Table 2** Distribution of adhesive remnant index (ARI) scores for metal brackets ( $n = 10$  per subgroup).

ARI scores		0	1	2	3	4	5
Control group	Unite	0	2	3	5	0	0
	Transbond XT	0	0	2	8	0	0
Group 1	Unite	0	2	6	1	1	0
	Transbond XT	0	3	0	7	0	0
Group 2	Unite	0	1	6	3	0	0
	Transbond XT	0	2	2	6	0	0

**Table 3** Distribution of adhesive remnant index (ARI) scores for ceramic brackets ( $n = 10$  per subgroup).

ARI scores		0	1	2	3	4	5
Control group	Unite	0	2	2	5	0	1
	Transbond XT	0	0	2	7	0	1
Group 1	Unite	0	0	2	6	0	2
	Transbond XT	0	0	1	6	2	1
Group 2	Unite	0	1	2	7	0	0
	Transbond XT	0	0	3	5	0	2



enamel fracture during the shear tests (Tables 2 and 3). The mode of failure was mostly at the bracket/adhesive interface and cohesive failures within the resin were also observed. SEM analysis of specimens in the shearing test showed that bleaching had a mild etching effect on the enamel surface as indicated by partial loss of the perichymata layer and the appearance of a rudimentary honeycomb typically seen during acid etching of the enamel surface in the control and experimental groups. In all groups, the SEM findings of the enamel surfaces had similar changes (Figure 1a–1c).

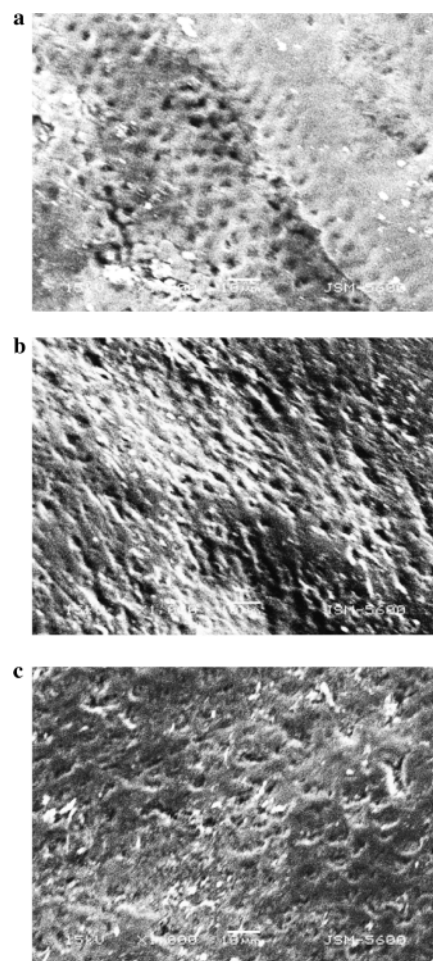
## Discussion

Bonding of brackets has been a critical issue since the introduction of direct bonding because of the biomechanical importance of a stable bracket–adhesive interference to transfer the loads generated from the engagement of an activated archwire to the tooth. *In vitro* investigation of bond strength plays an important role in evaluating the bonding efficiency of orthodontic systems to guide the clinician in the selection of new adhesive and bracket combinations. With an increasing demand for adult treatment, orthodontists often face patients who are not satisfied only with well-aligned dentitions but also want whiter looking teeth. Many bleaching products and techniques are now available to the clinician that have a controversial effect on the bonding of orthodontic brackets to the bleached enamel according to the literature (Bishara *et al.*, 1993; Miles *et al.*, 1994; Hintz *et al.*, 2001; Homewood *et al.*, 2001; Uysal *et al.*, 2003; Bishara *et al.*, 2005; Bulut *et al.*, 2006).

It is well known that the bond strength of brackets is affected by the type of adhesive. Two adhesives with different polymerization types were used in the study: a light-cure adhesive, Transbond XT (Arnold *et al.*, 2002; Schanveltd and Foley, 2002; Verstryngge *et al.*, 2004; Cozza *et al.*, 2006; Klocke and Kahi-Nieke, 2006; Santos *et al.*, 2006), and a self-cure adhesive, Unite (Adolfsson *et al.*, 2002). The testing of ceramic brackets was included to address potential aesthetical concerns of the patients who often also demand bleaching procedures.

Results from comparative bond strength studies show large variations because of the lack of standardized bond strength measurement tests. Considering that the minimal bond strength required to withstand orthodontic forces is 6–8 Mpa (Reynolds 1975), all groups displayed clinically acceptable mean bond strengths in our study (Table 1).

The interaction between bleaching agent and bond strength of composite resin to enamel was investigated in many previous studies. Several authors have reported a significant decrease in the bond strength of composite resin to CP-bleached enamel when compared with unbleached enamel (Stokes *et al.*, 1992; Titley *et al.*, 1992; Garcia-Godoy *et al.*, 1993; Miles *et al.*, 1994; Sung *et al.*, 1999; Turkun and Kaya, 2004; Bulut and Turkan, 2006). Miles *et al.* (1994) reported a significant reduction in bond strength



**Figure 1** (a) Normal enamel morphology in control group ( $\times 1000$ ). (b) Enamel morphology immediately after bleaching with 20 per cent carbamide peroxide (CP;  $\times 1000$ ). (c) Enamel morphology after bleaching with 20 per cent CP and 14 days of storage ( $\times 1000$ ).

of ceramic brackets after 72 hours of bleaching with 10 per cent CP. They suggested discontinuing tooth whitening product usage at least 1 week before the bonding of orthodontic attachments. In contrast to these findings, Bishara *et al.* (1993, 2005) evaluated the effect of enamel bleaching on the bonding strength of orthodontic brackets and stated that the use of 10 per cent CP did not result in significant changes in the shear bond strength of orthodontic brackets. The results of this study also demonstrated no reduction in the shear bond strength of brackets bonded 24 hours after bleaching and no significant differences ( $P > 0.05$ ) were found when compared with the control group.

Some authors have suggested that residual bleaching agents affected the bonding process and were responsible for decreased bond strengths and recommended pumicing before bonding to reduce any residual CP or HP on the tooth surface. Sung *et al.* (1999) recommended use of alcohol-based dental bonding agents to reduce or eliminate the detrimental effects of residual oxygen to the composite bonding process. In our study, the specimens were

thoroughly rinsed with water and compressed air for 30 seconds after the daily bleaching procedure, air-dried, and then kept in a moisturized environment.

Some authors have suggested that a delay of at least 1–2 weeks is needed after bleaching for the tooth structure to regain its prebleaching adhesive properties. The results of our study demonstrated that 14 days of delayed bonding after bleaching the shear bond strength values showed no significant differences with the control and 24 hours delay group. These results are in accordance with the results of Murchison *et al.* (1992), Homewood *et al.* (2001), and Bishara *et al.* (2005), which also used 10 per cent CP as the active bleaching agent.

The failure patterns were associated with the geometry of the bracket and the debonding techniques. The high incidence of enamel fracture usually observed in shear bond strength tests (Rix *et al.*, 2001; Kitayama *et al.*, 2003) and other debonding procedures (Zachrisson and Årtun, 1979; Yapel and Quick, 1994; Stratmann *et al.*, 1996; Katona, 1997) was not observed in this study. Ceramic brackets with mechanically retained bases had significantly lower bond strengths and show less enamel fracture than those with chemically retained brackets (Liu *et al.* 2005). In this study, enamel fractures were noted in 2 of 60 brackets with the ceramic brackets bonded with Transbond XT and 1 of 60 for the metal brackets bonded with Unite after shear bond strength testing both in 24 hour delay groups (group 1). These could be attributed to the increase in bond strength in this group, which was found non-significant. The results indicated that debonding of ceramic or metal brackets is safe in both bleached and unbleached teeth but individual differences in enamel structure or the adhesive curing process and type of bracket may have played a role in the fracture of enamel. It is also well known that the morphology of the tooth surface and fluoride content of the tooth, disinfection and storage media of the tooth before bonding, type of loading, configuration of specimen testing jig, crosshead speed of mechanical testing machine, and bonding area of the bracket can affect the measured bond strength. According to Fujisawa and Kadoma (1992), thymol solution could have an inhibitory effect on the polymerization of composite. In this study, all the teeth were stored at room temperature in a solution of 0.9 per cent NaCl which was renewed systematically to overcome this problem.

The ARI score is of clinical importance because the greater the incidence of failure at the enamel–adhesive interface, the greater the stresses applied to the enamel surface. Higher ARI scores mean that the mode of failure is closer to the bracket/adhesive interface, and the risk of enamel fracture is decreased. Earlier reports (Cozza *et al.*, 2006; Bulut and Turkun, 2006; Klocke and Kahi-Nieke, 2006) on the bond failure site showed that metal brackets consistently failed at the resin/bracket base interface and ceramic brackets with mechanically retained bases, the bracket/adhesive interface. On average, more than 50% of the adhesive remained on the teeth after debonding

(Theodorakopoulou *et al.*, 2004). In our study, because of the significantly increased ARI scores of 2 and 3, for metal and ceramic brackets in all subgroups, the most common failure site was the bracket/adhesive interface and the within the adhesive and the probability of bond failure at the enamel–adhesive interface was reduced which would minimize the risk of enamel damage. ARI scores differences between the subgroups were not found statistically significant ( $P > 0.05$ ).

Loss of calcium, decrease in microhardness, and alterations in the organic substance of the enamel have been associated with reduced bond strengths. It has been shown that CP bleaches create slight morphological changes in the enamel surface at various pH levels (Bitter and Sanders, 1993; Shannon *et al.*, 1993) and these changes are minimal in comparison to the severe morphological changes that occur when the enamel surface is subjected to phosphoric acid. On the other hand, Haywood *et al.* (1990), Scherer *et al.* (1992), and Gultz *et al.* (1999) concluded that CP solutions did not cause any significant surface morphologic changes in enamel surface structure. SEM results were obtained from unbleached and bleached enamel to help interpret our findings (Figure 1a–1c) showed that in all cases, the enamel surfaces have similar changes that could also explain the non-significant shear bond strengths between the groups. Scherer *et al.* (1991) demonstrated that the use of a brush-on CP gel system (up to 30 days) was found to have no effect on surface structure under SEM examination. Our findings support previous studies showing that minimal changes occurred in the enamel surface after CP bleaching and the damage was less than that seen after phosphoric acid etching.

## Conclusions

The results of this *in vitro* study indicated that 20 per cent CP bleaching did not significantly affect the shear bond strength of metal and ceramic orthodontic brackets bonded with chemically or light-cure composite resin to enamel when bonding occurred 24 hours or 14 days after bleaching.

## Funding

The study was supported by the Reseach Fund of Istanbul University. T-548/21102004.

## References

- Adolfsson U, Larsson E, Ögaard B 2002 Bond failure of a no-mix adhesive during orthodontic treatment. *American Journal of Orthodontics and Dentofacial Orthopedics* 122: 277–281
- Arnold W R, Combe E C, Warford J H 2002 Bonding of stainless steel brackets to enamel with a new self etching primer. *American Journal of Orthodontics and Dentofacial Orthopedics* 122: 274–276
- Årtun J, Bergland S 1984 Clinical trials with crystal growth conditioning as an alternative to acid-etch pretreatment. *American Journal of Orthodontics* 85: 333–340
- Bishara S E, Denehy G E, Goepferd S G 1987 A conservative post-orthodontic treatment of enamel stains. *American Journal of Orthodontics and Dentofacial Orthopedics* 92: 2–7

- Bishara S E, Oonsombat C, Soliman M M A, Ajlouni R 2005 The effect of tooth bleaching on the shear bond strength of orthodontic brackets. *American Journal of Orthodontics and Dentofacial Orthopedics* 128: 755–760
- Bishara S E, Sulieman A, Olson M 1993 Effect of enamel bleaching on the bonding strength of orthodontic brackets. *American Journal of Orthodontics and Dentofacial Orthopedics* 104: 444–1407
- Bitter N C, Sanders J L 1993 The effect of four bleaching agents on the enamel surface: a scanning electron microscopic study. *Quintessence International* 24: 817–824
- Bulut H, Turkun M, Demirbaş Kaya A 2006 Effect of an antioxidantizing agent on the shear bond strength of brackets bonded to bleached human enamel. *American Journal of Orthodontics and Dentofacial Orthopedics* 129: 266–272
- Cozza P, Martucci L, De Toffol L, Penco S I 2006 Shear bond strength of metal brackets on enamel. *Angle Orthodontist* 76: 851–856
- Fujisawa S, Kadoma Y 1992 Effect of phenolic compounds on the polymerization of methyl methacrylate. *Dental Materials* 8: 324–326
- Garcia-Godoy F, Dodge W W, Donohue M, O'Quinn J A 1993 Composite resin bond strength after enamel bleaching. *Operative Dentistry* 18: 144–147
- Gultz J, Kaim J, Scherer W, Gupta H 1999 Two in-office bleaching systems: a scanning electron microscope study. *Compendium of Continuing Education in Dentistry* 20: 965–968
- Haywood V B, Heymann H O 1989 Nightguard vital bleaching. *Quintessence International* 20: 173–176
- Haywood V B, Leech T, Heymann H O, Crumpler D, Bruggers K 1990 Nightguard vital bleaching: effects on enamel surface texture and diffusion. *Quintessence International* 21: 801–804
- Hintz J K, Bradley T G, Eliades T 2001 Enamel colour changes following whitening with 10 per cent carbamide peroxide: a comparison of orthodontically-bonded/debonded and untreated teeth. *European Journal of Orthodontics* 23: 411–415
- Homewood C, Tyas M, Woods M 2001 Bonding to previously bleached teeth. *Australian Orthodontic Journal* 17: 27–34
- Katona T R 1997 Stresses developed during clinical debonding of stainless steel orthodontic brackets. *Angle Orthodontist* 67: 39–46
- Kitayama Y, Komori A, Nakahara R 2003 Tensile and shear bond strength of resin-reinforced glass ionomer cement to glazed porcelain. *Angle Orthodontist* 73: 451–456
- Klocke A, Kahi-Nieke B 2006 Effect of debonding force direction on orthodontic shear bond strength. *American Journal of Orthodontics and Dentofacial Orthopedics* 129: 261–265
- Kugel G, Perry R D, Hoang E, Scherer W 1997 Effective tooth bleaching in 5 days: using a combined in-office and at-home bleaching system. *Compendium of Continuing Education in Dentistry* 18: 380–383
- Leonard R H, Eagle J C, Garland G E, Matthews K P, Rudd A L, Phillip C 2001 Night-guard vital bleaching and its effect on enamel surface morphology. *Journal of Esthetic and Restorative Dentistry* 13: 132–139
- Liu J K, Chung C H, Chang C Y, Shieh D B 2005 Bond strength and debonding characteristics of a new ceramic bracket. *American Journal of Orthodontics and Dentofacial Orthopedics* 128: 761–765
- McCracken M S, Haywood V B 1996 Demineralization effects of 10 percent carbamide peroxide. *Journal of Dentistry* 24: 395–398
- Miles P, Pontier J, Bahiraei D, Close J 1994 The effect of carbamide peroxide bleach on the tensile bond strength of ceramic brackets: an in vitro study. *American Journal of Orthodontics and Dentofacial Orthopedics* 106: 371–375
- Murchison D F, Charlton D G, Moore B K 1992 Carbamide peroxide bleaching: effects on enamel surface hardness and bonding. *Operative Dentistry* 17: 181–185
- Olsen M E, Bishara S E, Damon P, Jakobsen J R 1997 Evaluation of Scotchbond multi-purpose and maleic acid as alternative methods of bonding orthodontic brackets. *American Journal of Orthodontics and Dentofacial Orthopedics* 111: 498–501
- Reynolds J R 1975 A review of direct orthodontic bonding. *British Journal of Orthodontics* 2: 171–178
- Rix D, Foley T F, Mamandras A 2001 Comparison of bond strength of three adhesives: composite resin, hybrid GIC, and glass-filled GIC. *American Journal of Orthodontics and Dentofacial Orthopedics* 119: 36–42
- Santos J E, Quioca J, Loguercio A D, Reis A 2006 Six-month bracket survival with a self-etch adhesive. *Angle Orthodontist* 76: 863–868
- Schaneveldt S, Foley T F 2002 Bond strength comparison of moisture-insensitive primers. *American Journal of Orthodontics and Dentofacial Orthopedics* 122: 267–273
- Scherer W, Cooper H, Ziegler B, Vijayaraghavan T V 1991 At-home bleaching system: effects on enamel and cementum. *Journal of Esthetic Dentistry* 3: 54–56
- Scherer W, Penugonda B, Styner D, Georgescu M 1992 At-home vital bleaching: effects on stained enamel and dentin. *Practical Periodontics and Aesthetic Dentistry* 4: 11–15
- Shannon H, Spencer P, Gross K, Tira D 1993 Characterization of enamel exposed to 10% carbamide peroxide bleaching agents. *Quintessence International* 24: 39–44
- Stokes A N, Hood J A, Dhariwal D, Patel K 1992 Effect of peroxide bleaches on resin-enamel bonds. *Quintessence International* 23: 769–771
- Stratmann U, Schaarschmidt K, Wegener H, Ehmer U 1996 The extent of enamel surface fractures. A quantitative comparison of thermally debonded ceramic and mechanically debonded metal brackets by energy dispersive micro- and image-analysis. *European Journal of Orthodontics* 18: 655–662
- Sung E C, Chan S M, Mito R, Caputo AA 1999 Effect of carbamide peroxide bleaching on the shear bond strength of composite to dental bonding agent enhanced enamel. *Journal of Prosthetic Dentistry* 82: 595–599
- Tavares M, Stultz J, Newman M, Smith V, Kent R, Carpino E 2003 Light augments tooth whitening with peroxide. *Journal of American Dental Association* 134: 167–175
- Theodorakopoulou L P, Sadowsky P L, Jacobson A, Lacefield W Jr 2004 Evaluation of the debonding characteristics of 2 ceramic brackets: an in vitro study. *American Journal of Orthodontics and Dentofacial Orthopedics* 125: 329–336
- Titely K C, Torneck C D, Ruse N D 1992 The effect of carbamide-peroxide gel on the shear bond strength of a microfil resin to bovine enamel. *Journal of Dental Research* 71: 20–24
- Titely K, Torneck C D, Smith D C 1988 Effect of concentrated hydrogen peroxide solution on the surface morphology of cut human dentin. *Endodontics and Dental Traumatology* 4: 32–36
- Titely K C, Torneck C D, Smith D C, Chernecky R, Adibfar A 1991 Scanning electron microscopy observations on the penetration and structure of resin tags in bleached and unbleached bovine enamel. *Journal of Endodontics* 17: 72–75
- Tse C S, Lynch E, Blake D R, Williams D M 1991 Is home tooth bleaching gel cytotoxic. *Journal of Esthetic Dentistry* 3: 162–168
- Turkun M, Kaya A D 2004 Effect of 10% sodium ascorbate on the shear bond strength of composite resin to bleached bovine enamel. *Journal of Oral Rehabilitation* 31: 1184–1191
- Turkun M, Sevgican F, Pehlivan Y, Aktener B O 2002 Effects of 10% carbamide peroxide on the enamel surface morphology: a scanning electron microscopy study. *Journal of Esthetic and Restorative Dentistry* 14: 238–244
- Uysal T, Basciftci F A, Usumez S, Sari Z, Buyukerkmen A 2003 Can previously bleached teeth be bonded safely? *American Journal of Orthodontics and Dentofacial Orthopedics* 123: 628–632
- van der Vyder P J, Lewis S B, Marais J T 1997 The effect of bleaching agent on composite/enamel bonding. *Journal of the Dental Association of South Africa* 52: 601–603
- Verstrynge A, Ghesquiere A, Willems G 2004 Clinical comparison of an adhesive precoated vs. an uncoated ceramic bracket system. *Orthodontics and Craniofacial Research* 7: 15–20
- Yapel M J, Quick D C 1994 Experimental traumatic debonding of orthodontic brackets. *Angle Orthodontist* 64: 131–136
- Zachrisson B U, Årtun J 1979 Enamel surface appearance after various debonding techniques. *American Journal of Orthodontics* 75: 121–127