A 5-year clinical review of bond failure with a light-cured resin adhesive

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The introduction of acid etching of enamel by Buonocore[1] in 1955 heralded the possibility of direct bonding of orthodontic brackets to teeth,[2] a technique that has now become a routine part of fixed appliance therapy.[3-6] Developments in dental material science over the past 30 years have led to improvements in orthodontic adhesive formulations, resulting in the current availability of two-paste systems,[7] no-mix adhesives,[8] and light-activated direct bonding materials.[9,10] Fluoride-releasing visible-light-activated bonding agents,[11,12] and more recently, adhesive precoated brackets[13] have also been used for bracket bonding. All these bonding materials are based on acrylic or diacrylic resins, the latter founded on a resin bisphenol A glycidyl dimethacrylate (Bis-GMA) developed by Bowen.[14] Bis-GMA creates an extremely rigid polymer with less shrinkage, greater strength, and less water absorption than acrylic resins.

Diacrylate polymerization may be accomplished by an autopolymerizing chemical reaction, by energy derived from ultraviolet light, or by a visible-light-activated catalyst system. Ultraviolet-light-cured or visible-light-cured adhesives were a particular refinement of orthodontic bonding systems, combining greater time for accurate bracket positioning with the facility for command-setting of the resin.[15] However, the long exposure times required with ultraviolet-light-cured products together with poor transillumination through the tooth substance and the potential health risk imposed by prolonged exposure to ultraviolet light make these systems

Abstract

The purpose of this study was to investigate the time to first failure of stainless steel orthodontic brackets (Ormco Corp, Glendora, Calif) bonded with a light-cured resin adhesive (Transbond, 3M Unitek, Monrovia, Calif) and assess whether time to failure was related to the patient's age at the start of treatment or sex, the proficiency of the individual placing the brackets, or the presenting malocclusion. Data on 548 patients with 7118 bonded brackets were analyzed. Survival analysis was carried out on a single bracket per patient. In each patient, the first bracket to fail was studied. In cases where no brackets failed, the bracket with the shortest follow-up time was analyzed and handled as a censored observation in the formal analysis. Median time until first bracket failure was 442 days, and an overall failure rate of 6% was recorded. There were no significant differences in time to first failure of brackets with respect to the sex or age of the patient at the start of treatment (p=0.168, and p=0.261, respectively), operator proficiency in placing brackets (p=0.189), or presenting malocclusion (p=0.052). Performance of brackets bonded with Transbond does not appear to vary significantly according to the variables examined.

Key Words

Clinical review • Bond failure • Survival analysis

Submitted: March 1997 **Revised and accepted:** July 1997 Angle Orthod 1998;68(4):351-356.

unsuitable for routine clinical use.[16]

Following successful bonding of orthodontic brackets by transillumination of a visible-light-activated composite resin[17] and improvements in their adhesive properties, these materials are now widely used for bracket bonding.[18] However, laboratory studies comparing the bond strengths obtained with light-cured systems with those obtained with chemically cured systems have been equivocal.[19-21] Nonetheless, a recent study by Chamda and Stein[15] showed there was no significant difference between the bond strengths achieved by the chemically cured and light-cured systems at 10-minute, 60-minute, and 24-hour intervals.

Ideally, a bonded bracket should remain attached to the tooth surface throughout treatment, the bond strength of the bonding material being sufficient to resist tensile, shear, torque, and peel functional stresses.[22] Bond failure, however, is encountered frequently during treatment and may be influenced by etching time,[6] concentration of the etch,[23] bonding agent employed,[7-10,24] bonding technique used,[25,26] or characteristics of the bracket base.[27,28] In addition, factors related to the operator[8,9] and patient[8] are likely to influence the failure rate of any bonding system. Care in the clinical technique, moisture control, choice of bonding material, and the appliance fitted, along with the instructions given the patient are all controlled by the operator, whereas the sex and age of the patient, the presenting malocclusion, and care taken of the appliance are patient variables. With the increasing use of light-curing for bonding over the past 6 years[18] and the advent of brackets precoated with Transbond (3M Unitek, Monrovia, Calif) light-cured resin adhesive,[13] there is a need to evaluate clinically the effectiveness of this material for routine bracket bonding. To date, the clinical performance of brackets bonded with Transbond does not appear to have been assessed thoroughly over a substantial time period.

The purpose of this study was to assess the time to first failure of stainless steel orthodontic brackets bonded with Transbond. The effect of the patient's sex and age at start of treatment, the proficiency of the operator in placing brackets, and the impact of the presenting malocclusion on bracket survival time were assessed as well.

Materials and methods

Transbond has been used in the Orthodontic Department, County Hospital, Halmstad, Sweden since 1988 for routine bonding of orthodontic brackets in patients undergoing fixed appliance therapy. The files of patients completing fixed appliance orthodontic treatment at this unit between January 1, 1991, and December 31, 1995, were examined. All the patients included in the study had orthodontic treatment with brackets bonded with Transbond. All bonding procedures were carried out by trained orthodontic auxiliaries with at least 2 years postqualification experience or by orthodontists with many years experience. Prior to bonding, teeth were cleaned with a nonabrasive liquid (Tubilicid, Dental Therapeutics, Nacka, Sweden), washed with water, and dried with an air syringe. The buccal or labial enamel surface was then etched for 15 seconds with 37% orthophosphoric acid gel, washed for 60 seconds, and dried with compressed air. Transbond primer was applied to the tooth surface and light-cured for 10 seconds. Transbond composite was then placed on the bracket base (Ormco Corp, Glendora, Calif) and the bracket positioned firmly on the tooth. Excess composite material was removed from around the bracket with a sharp probe before curing the material for 40 seconds (20 seconds each for the incisal and gingival aspects of the bracket).

An 0.018 inch preadjusted edgewise system (Ormco Mini Diamond brackets, Ormco Corp, Glendora, Calif) was used in all cases. Initial aligning archwires were tied into the bracket slots immediately following completion of bracket bonding. These were either 0.010 or 0.012 stainless steel wires (TP, Australia) or 0.0155 Dentaflex wires (Dentaurum, Pforzheim). Patients were given both verbal and written instructions in relation to appliance care. They were instructed specifically to return if a bracket became loose or if they had any other problems with the appliance. Patients were seen at 4- to 6-week intervals throughout treatment, and bond failures were accurately recorded in the patient's case notes. The time of bond failure was recorded as the date of the appointment at which bond failure was discovered.

The following information was recorded for each patient: date of birth and sex of the patient; operator; class of presenting malocclusion according to incisor classification; date of placement of bonded orthodontic brackets; the fate of each bracket up to December 31, 1995.

In order to carry out survival analysis, a code was allocated to each bonded bracket to indicate if the bracket had not failed (censored, code 1), the patient had moved away (withdrawn, code 2) or the bracket had debonded (failed, code 3). Using SAS for Windows, Version 6.08, formal

analyses were carried out on a single bracket per patient. In each case, the bracket chosen was the one that was the first to fail. In cases where no brackets failed, the bracket with the shortest follow-up time was analyzed and handled as a censored observation in the formal analyses. It was necessary to include only one bracket per patient, as the analyses assume the observations were all independent of each other. The impact of sex of the patient, age at the start of treatment, operator, and starting malocclusion on bonded bracket survival was assessed by producing Kaplan-Meier estimates of survival curves stratified by the factor and using the log rank test to compare the various levels of the factor, e.g., to assess whether the survival profile differed for males and females. In addition, relative hazards were calculated based on a Cox proportional hazards model to compare various subgroupings. The relative hazard compares the failure rates for one subgroup relative to another. A relative hazard of 1 indicates that there is no difference in rate between two subgroups. A relative hazard of 2, for example, would indicate that the failure rate in one group was twice as high as in the other.

Table 1
Sample characteristics for 7118 brackets bonded with Transbond

No. of patients (218 males; 330 females)	548
No. of bonded brackets	7118
Median age at start of treatment (years) (lower quartile 12.2 years; upper quartile 15.5 years)	13.5
No. of patients per malocclusion type	
Class I	275
Class II Division I	219
Class II Division 2	23
Class III	31
No. of patients bonded per operator	
Operator I	122
Operator II	6
Operator III	119
Operator IV	156
Operator V	133
Operator VI	12

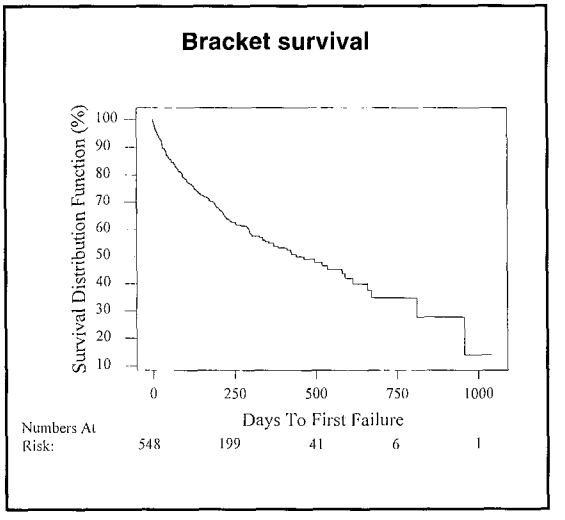

Figure 1

Results

Overall analysis

The sample characteristics of the study population are given in Table 1. Three hundred twenty-five patients had no bracket failures, and 223 patients had at least one. Overall, 426 brackets failed (6%), and the failure rates were the same in the upper and lower arches. Two hundred sixty-six brackets failed in the upper arch and 160 failed in the lower arch. Nine percent (223 brackets) of the brackets bonded to premolars failed, while 4% (60 brackets) and 5% (143 brackets) of brackets bonded to canines and incisors, respectively, failed.

The Kaplan Meier estimate of the overall survival curve is given in Figure 1. The numbers at risk are the number of people whose brackets had not failed at that time. Median survival time was 442 days, with lower and upper quartile survival times of 130 and 959 days, respectively.

Survival analyses for various factors

Effect of patient sex (Figure 2)

No evidence was found of a difference in bracket survival for males and females (log rank test $p = 0.168$, relative hazard for males compared with females: point estimate 1.21, 95% confidence interval 0.92 to 1.57).

Effect of patient age at start of treatment (Figure 3)

Age at start of treatment, a continuous measurement, was divided into categories to allow survival curves to be drawn. The data were arbitrarily split at quartiles, ensuring four equally sized groups (n = 137 each) for comparison. No significant difference was found among subgroups (log rank test $p = 0.261$, relative hazard per 1 year advance in age at the start of treatment: point estimate 0.97, 95% confidence interval 0.94 to 1.00).

Effect of operator (Figure 4)

Six operators were involved in the study and no evidence was found of a difference in bracket survival between operators (log rank test $p = 0.189$). Operators 2 and 6 treated 6 and 12 patients, respectively. Any apparent "patterns" in such small groups must be interpreted with caution.

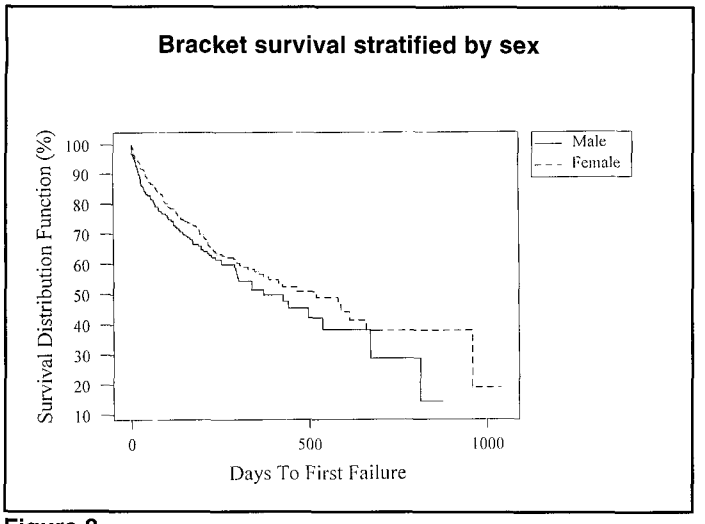

Figure 2

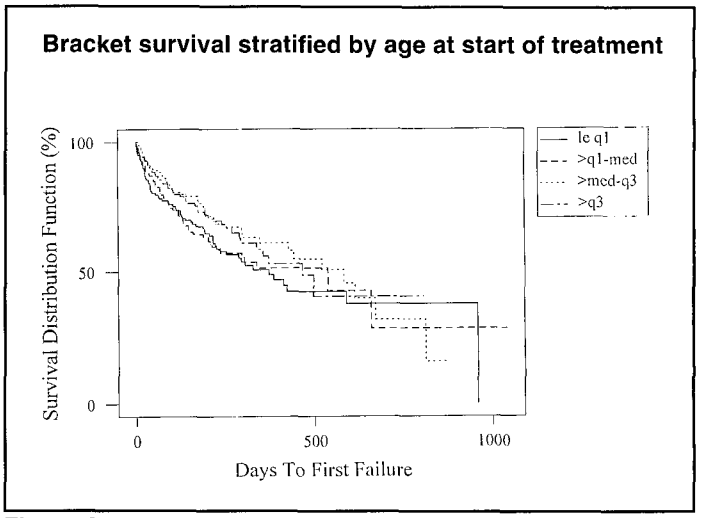

Figure 3

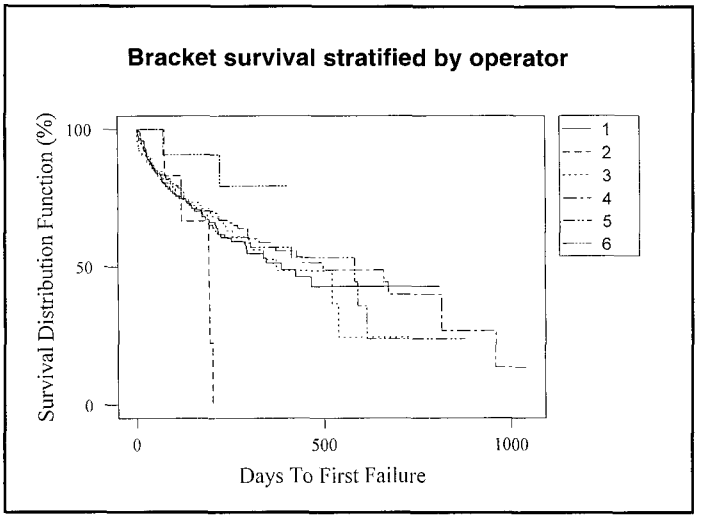

Figure 4

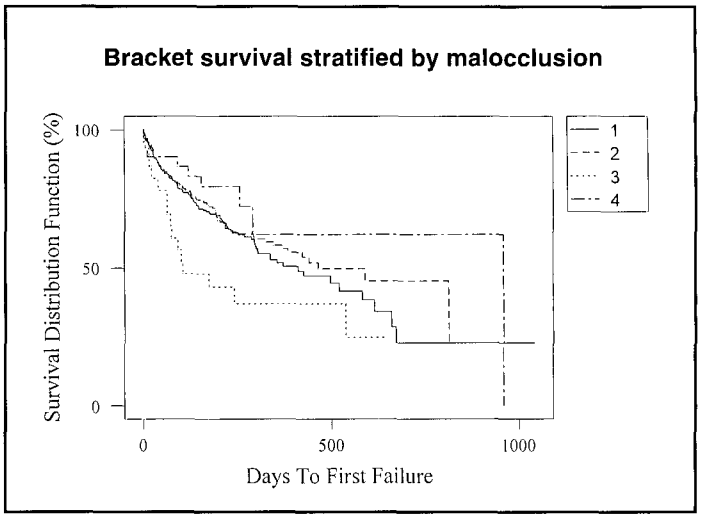

Figure 5

Effect of presenting malocclusion (Figure 5)

Four malocclusion categories were included in the study. The analysis produced a result of borderline statistical significance (log rank test p = 0.052, relative hazards: Class II Division 1 versus Class I malocclusion: point estimate 0.89, 95% confidence interval 0.61 to 1.29; Class II Division 2 malocclusion versus Class I malocclusion: point estimate 1.32, 95% confidence interval 0.92 to 1.90; Class III malocclusion versus Class I malocclusion: point estimate 0.87, 95% confidence interval 0.64 to 1.58; Class II Division 2 malocclusion versus Class II Division 1 malocclusion: point estimate 1.97, 95% confidence interval 0.94 to 4.12; Class III malocclusion versus Class II Division 1 malocclusion: point estimate 0.81, 95% confidence interval 0.50 to 1.32 and Class III malocclusion versus Class II Division 2 malocclusion: point estimate 0.34, 95% confidence interval 0.11 to 1.08). Although there was no significant difference between any of the malocclusion categories with respect to bracket survival, it is clear that if there were any difference it would appear to be between Class II Division 2 malocclusion and the other groups, although it should be noted that there were only 23 patients in the Class II Division 2 group.

Discussion

The performance of 7118 orthodontic brackets bonded with a light-cured resin adhesive (Transbond) in 548 patients has been examined over a 5-year period. Reports on the clinical performance of orthodontic bonding agents have concentrated primarily on the effect of position in the dental arch of the bracket [3,4,6,7,10] and the bracket base design[4,28] on the failure rate recorded. The effects of patient sex and age at start of treatment, operator, and presenting malocclusion on bracket failure rate have received less attention.[8,9] In addition, statistical handling of results has been limited and few trials have applied survival analysis to the collated data.[6,8,9,29]

Although recording the failure rate of brackets

is the most common way of reporting the performance of a particular bonding adhesive, it has certain shortcomings in that no indication is given of the time to failure.[8] For this reason, survival analysis was used to examine the data recorded in this study and to assess the impact of certain variables on bond survival. Treating each patient as a unit, the time to first bracket failure was recorded, thus identifying the worst-case scenario for each individual. It is incorrect statistically to assume that observations on each bracket are independent of the patient and for that reason each patient, rather than each bracket, was considered an independent unit.

In the present study, the median survival time of brackets bonded with Transbond was 442 days, or almost 15 months. Most fixed appliance orthodontic treatment lasts about 18 months, and the nearer the median survival time is to this, the lower the bond failure rate would be expected to be. With a median survival time of 442 days, one would expect to record a low failure rate with Transbond, and this is confirmed by the 6% failure rate recorded in this investigation.

The failure rate of brackets bonded to premolars (9%) was almost twice that of brackets bonded to canines or incisors, confirming the findings of other studies.[3,4,6,7,10] The higher failure rate recorded for premolars may be related to difficulty with moisture control at bonding or the larger amounts of aprismatic enamel, which may affect the quality of the micromechanical bond.[8,30]

No significant difference in time to first bracket failure was recorded between male and female patients or when patients were stratified into four groups according to age at the start of treatment. Kinch et al.[6] found no significant difference in survival time of brackets bonded with Concise orthodontic resin using different etch times in either male or female patients or in those 20 years old or younger at the start of treatment.

Although some previous studies have recorded a significant difference between operators with respect to bond failure[8,9] or bracket survival times,[8,9] no such difference was recorded in this study. The considerable expertise of the orthodontic auxiliaries or orthodontic clinicians who bonded all the brackets in the present investigation and the similarities in treatment mechanics adopted by operators are likely to account for the lack of difference between operators.

With respect to the presenting malocclusion and bracket survival, no significant difference was recorded here either. However, it appears that if a significant difference were to exist, it would be between the Class II Division 2 malocclusion group and the other malocclusion groups. The deep overbite present initially in the Class II Division 2 malocclusion group is often difficult to control, and bond failure, particularly on the lower incisors, can result from occlusal loading by the opposing maxillary teeth. A larger sample of patients in this malocclusion category would be required, however, to gather meaningful data on this possibility.

This retrospective study set out to analyze time to first failure (median survival time) of brackets bonded with a light-cured resin adhesive (Transbond). As such, the study contains certain shortcomings. No direct comparison was made to bracket survival with a chemically-cured adhesive over the same time period. A randomized prospective clinical study would be the only way of obtaining the most accurate data in this regard. However, the 6% failure rate recorded in this study for brackets bonded with Transbond compares very favorably with the 8% failure rate recorded in a retrospective study for a no-mix adhesive, Right-On[8] (TP, La Porte, Ind). Additionally, results of a recent short-term clinical study[31] comparing failure rates of brackets precoated with Transbond and those bonded with a no-mix adhesive (Unite, "A"-Company Inc, San Diego, Calif) found a 2.7% failure rate with the precoated system and a 7.5% failure rate with the no-mix adhesive. It would appear, therefore, that the light-cured resin adhesive, Transbond, is a reliable resin for bonding.

The study reported here details the clinical outcome of the largest sample to date of bonded brackets using a single adhesive system and would appear to be the first study to provide substantial data on the clinical performance of brackets bonded with the light-cured resin adhesive Transbond. As such, it gives comparative data for all clinicians using this adhesive as a bonding material.

Conclusions

1. For 7118 brackets bonded with a light-cured resin adhesive (Transbond) in 548 patients, the median time until first bracket failure was 442 days. The overall failure rate of brackets was 6%.
2. Neither the patient's sex, age at the start of treatment, the operator, nor the presenting malocclusion had any significant effect on the time to first failure of each bonded attachment.

Acknowledgment

The authors would like to thank Ms. A-C Fornell for her invaluable assistance with data collection.

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