British Journal of Orthodontics/Vol. 25/1998/283–287

Clinical Performance of Orthodontic Brackets and Adhesive Systems: A Randomized Clinical Trial

S. SUNNA, B.D.S., M.DENT.SC., M.ORTH., R.C.S.(ENG.)
W. P. ROCK, B.D.S., D.D.S., F.D.S.R.C.S., D.ORTH.(ENG)
School of Dentistry, The University of Birmingham, St Chads Queensway, Birmingham, B4 6NN, UK

Abstract. *The aim of the study was to evaluate and compare the clinical performance of adhesive precoated brackets (APC) with that of two types of uncoated bracket bases, Straight-Wire and Dyna-Lock, bonded using two types of orthodontic adhesives, Transbond XT, and Right-On. Forty consecutive orthodontic patients entered the trial and 607 brackets were bonded. The incidence and site of first time bond failures were recorded over a period of 1 year. The time required for bonding was also recorded.*

The overall bond failure rate was 6·6 per cent. There were no significant differences between the failure rates of the five groups, or between the upper and lower arch. However, significantly more brackets failed on the left side than on the right. Premolar brackets were lost most often, whilst incisor brackets failed least. No association was found between bond failure and time elapsed since bonding. Bonding time was least with Right-On adhesive. There were no significant differences between bonding times using APC or Transbond.

Results of the present study conflict with those of a previous ex vivo *study by the authors, using the same materials and bonding technique. Suggested reasons for this are discussed.*

Index Words: Adhesive precoated brackets, bracket bonding, clinical failure rate, chair side time.

Refereed Paper

Introduction

Bonding of orthodontic attachments to enamel has been in use for over 40 years, although the exact date of the first use of the technique is disputed (Cueto, 1990; Mitchell 1992; Newman 1992).

The success of fixed appliance therapy depends on attachments having adequate bond strengths and a low failure rate. The overall time required to place an appliance is an important factor in the cost of treatment, whilst the need to replace brackets frequently may severely impair the progress of fixed appliances, and can be costly in terms of materials and time.

Orthodontic attachments are subjected to a large number of forces in the mouth, resulting in a complex distribution of stresses within the adhesive and at its junctions with the enamel and the bracket base. Bond strength to enamel will depend on a large number of factors including the nature of the enamel surface, enamel conditioning procedures, the types of adhesive used, and the shape and design of the bracket base.

Adhesive Precoated Brackets (APC; 3M Unitek, P.O. Box 1, Bradford, BD5 9UY, UK) have been introduced recently. The composite used to precoat the brackets is a version of Transbond XT (3M Unitek, P.O. Box 1, Bradford, BD5 9UY, UK), modified by an increased viscosity (Bergstrand, 1996, personal communication). Cooper *et al.* (1992) listed the following advantages of APC over other systems:

- Consistent quality and quantity of adhesive.
- Easier clean-up following bonding.
- Reduced waste during bonding.
- Improved asepsis.
- Better inventory control.

In addition, improved control of both the bracket and adhesive associated with the use of APC is claimed to improve bond strength and clinical failure rate (3M Unitek product literature, 1995).

A previous study by the authors (Sunna and Rock, in press) compared the *ex vivo* shear bond strength of APC with that of two types of uncoated bracket bases, Straight-Wire (Orthologic, Summit House, Summit Road, Potters Bar, EN6 3EE, UK) and Dyna-Lock (3M Unitek, P.O. Box 1, Bradford BD5 9UY, UK), bonded using two types of adhesives, Transbond XT and Right-On (TP Orthodontics, 2 Bruntcliffe Way, Morley, Leeds LS27 0JG, UK). The APC system did not produce a significant increase in bond strength over applied Transbond XT, but did give a higher strength than Right-On used in association with Dyna-Lock brackets.

The retention rate of APC brackets has been found to be superior to that of similar brackets bonded using adhesive applied by the clinician (Ash and Hay, 1996). The failure rate of Mini Unitwin APC brackets was less than that of similar brackets bonded with Unite, a no-mix chemically-cured composite resin.

Objectives of the Present Study

- To compare the clinical failure rate of Dyna-Lock APC brackets with uncoated Dyna-Lock and also with mesh-backed Straight-Wire brackets.

0301-228X/98/003000+00$02.00

- To compare the clinical failure rate of two orthodontic adhesives systems, Transbond XT and Right-On.
- To compare the clinical chair-side time required for bonding APC brackets with that required for bonding brackets to which adhesive was applied.
- To identify the time interval following bonding during which orthodontic brackets are at highest risk of bond failure.
- To assess the clinical applicability of *ex vivo* studies on bond strength.

TABLE 1 *Quadrant allocation of bracket/adhesive combinations*

Patient no.	Upper right and lower left	Upper left and lower right
1	APC	Dyna-Lock/Transbond
2	APC	Dyna-Lock/Right-On
3	APC	Straight-Wire/Transbond
4	APC	Straight-Wire/Right-On
5	Dyna-Lock/Transbond	Dyna-Lock/Right-On
6	Dyna-Lock/Transbond	Straight-Wire/Transbond
7	Dyna-Lock/Transbond	Straight-Wire/Right-On
8	Dyna-Lock/Right-On	Straight-Wire/Transbond
9	Dyna-Lock/Right-On	Straight-Wire/Right-On
10	Straight-Wire/Right-On	Straight-Wire/Transbond

Subjects, Materials, and Methods

Forty successive patients from the waiting list, presenting with various malocclusions and requiring orthodontic treatment formed the study group. The approval of the Local Ethical Committee and of parents was obtained. Subjects were treated with upper and lower straightwire appliances by one clinician (SS).

Three types of brackets were used: Metallic Dyna-Lock Torque-in-Base brackets, available in standard and adhesive precoated (APC) versions, and Straight-Wire Twin brackets (Fig. 1). Dyna-Lock brackets incorporate integral bases which utilize horizontal undercut channels and serrated ridges for adhesive retention. Straight-Wire brackets, on the other hand, utilize a foil mesh base for retention.

Three types of adhesive systems were used: Right-On chemically-cured adhesive paste, Transbond XT light-cured adhesive paste, and a modified version of Transbond XT, precoated onto the bases of the APC brackets by the manufacturer. Light curing was achieved using an Ortholux XT light unit (3M Unitek, P.O. Box 1, Bradford BD5 9UY, UK). Prior to each bonding session, the unit was tested for adequate light intensity via a built-in light meter.

Patients selected were successively allocated into groups representing the quadrant distribution of bracket/adhesive combinations (Table 1). To ensure an equal distribution of bracket/adhesive combinations between right and left sides, allocation of materials per quadrant was reversed after every tenth subject.

A standardized protocol of tooth preparation and bracket bonding was adopted for all groups. All teeth, with the exception of molars, were bonded, brackets being positioned on the LA point of each tooth (Andrews, 1976). Where overcorrection was required, this was achieved through archwire adjustments or through the use of rotation wedges.

The time required for bonding each quadrant was registered using a stop watch. Time spent in the preparation of teeth for bonding (prophylaxis, acid etching, washing, and drying) was not registered as this was similar for all bracket/adhesive combinations.

Right-On is a no-mix primer/paste adhesive system, in which the primer is applied to the etched tooth surface and the bracket base followed by adhesive paste which is applied to the bracket only. After seating the bracket with firm pressure excess adhesive was removed with a probe. Light curing of Transbond XT and APC brackets followed the recommendation of Cooper *et al.* (1992) who suggested partly curing each bracket adhesive for 1–2 seconds prior to proceeding to the next tooth. This ensured that bracket drift did not occur. Once all brackets were in position, complete light curing was performed for 20 seconds according to the manufacturer's instructions, 10 seconds distally and then 10 seconds mesially on each tooth.

Every effort was made to minimize variation in the magnitude of orthodontic forces applied to brackets and teeth. The usual choice of aligning archwires was either an 0·012-inch NiTi or 0·014-inch NiTi wire depending on the initial level of alignment and crowding. Overbite reduction

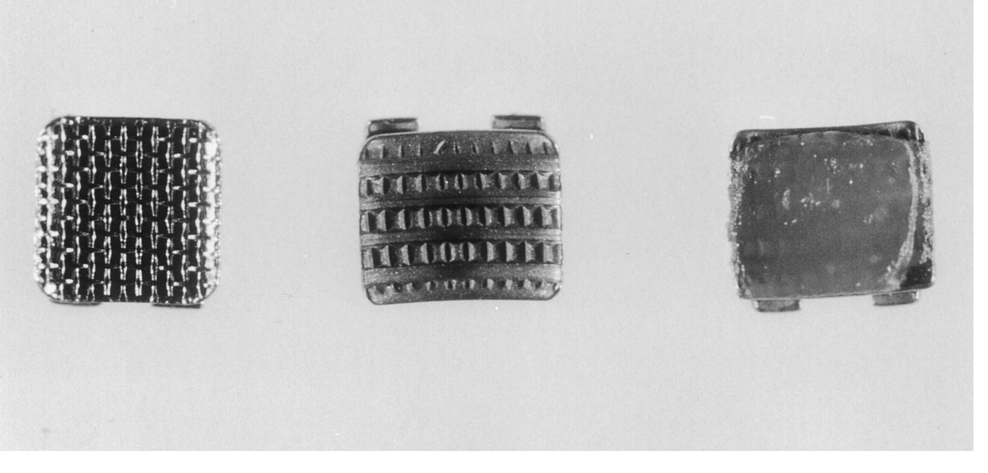

FIG. 1 The fitting surfaces of Dyna-Lock precoated and non coated brackets and a mesh base.

was achieved using a removable appliance with an anterior bite plane, particularly where occlusal interferences were anticipated following a full bond-up.

The number, site, and date of first time bond failures were recorded over a period of 1 year. Patients were seen at intervals of 6–8 weeks, but were requested to attend as soon as possible once a bond failure was detected.

Results and Statistical Analysis

Assessment of bond failure

Results for bond failure rates by the various bracket/adhesive combinations can be seen in Table 2. Six-hundred-and-seven brackets were bonded and there were 40 failures (6·6 per cent). A Chi-Square test showed no statistically significant differences between groups.

Bond failures are presented in Table 3 according to the site of the failed bracket. Comparisons were made between the upper and lower arches, and between the right and left sides. Almost twice as many brackets failed in the lower arch as in the upper. However, a Chi-Square test with Yates' correction showed no statistically significant difference. Bracket failure rate on the left side was almost three times as much as that on the right side ($P<0{\cdot}001$). Because of the small numbers of bracket failures, results were combined into three groups of teeth, incisors, canines, and premolars, in order to allow meaningful statistical analysis. Premolars had the highest failure rate (10·7 per cent), while incisors had the lowest (3·9 per cent). A Chi-Square test showed significant differences between the three groups ($P<0{\cdot}05$). To determine the locations of the differences further Chi-Square tests of subsets were performed using the Bonferroni correction which allows for multiple comparisons. This showed that significantly more premolar bonds failed than did those on incisors ($P<0{\cdot}05$).

Bond failure rates were also evaluated in relation to the time interval following bonding in three-monthly intervals (Table 4). Sixty per cent of bond failures occurred during the first 6 months of treatment although there were no significant differences between the time groups.

TABLE 2 *Bond failure rates of bracket/adhesive combinations*

Bracket/adhesive	No of quadrants	Brackets bonded	No. failed	% failure
APC	31	128	12	9·4
Dyna-Lock/Transbond	37	147	4	2·7
Dyna-Lock/Right-On	23	95	4	4·2
Straight-Wire/Transbond	29	121	13	10·7
Straight-Wire/Right-On	20	116	7	6
Total	140	607	40	6·6

TABLE 3 *Bond failure rates according to the site of failure*

Site of bond failure	No. of quadrants	Brackets bonded	No. failed	% failure
Upper arch	68	264	12	4·5
Lower arch	80	343	28	8·1
Right side	74	303	11	3·6
Left side	74	304	29	9·5
Incisor teeth	—	278	11	3·9
Canine teeth	—	143	9	6·3
Premolar teeth	—	186	20	10·7

Assessment of bonding times

The results of bonding times per bracket for the various bracket/adhesive combinations are presented in Table 5. ANOVA showed highly significant differences between the groups ($P<0{\cdot}01$). This was followed by a Tukey analysis to determine the locations of the differences (Table 6). For both mesh and Dyna-Lock brackets, use of the chemically-cured adhesive Right-On resulted in significantly less bonding time than when APC brackets were used or Transbond light-cured adhesive was applied to brackets.

Discussion

Study design

A clinical trial is a planned experiment on human beings which is designed to evaluate the effectiveness of one or more forms of treatment (Altman, 1991). It is vital, when planning the design of such a study, to ensure that the allocation of treatment regimes is independent on characteristics of the patients. The most acceptable method

TABLE 4 *Bond failure rate in relation to time interval following bonding*

Time following bonding (days)	No. of brackets failed	% failure
0–90	13	32·5
91–180	11	27·5
181–270	8	20
271–362	8	20

TABLE 5 *Bonding times of different bracket/adhesive combinations*

Bracket/adhesive	Mean bonding time/bracket(s)	SD
APC	81·44	16·82
Dyna-Lock/Transbond	92·48	19·74
Dyna-Lock/Right-On	53·67	16·05
Straight-Wire/Transbond	93·92	20·15
Straight-Wire/Right-On	57·40	21·47

TABLE 6 *Tukey's pairwise comparisons of bonding times*

Group	APC	Dyna-Lock/Transbond	Dyna-Lock/Right-On	Straight-Wire/Transbond
Dyna-Lock/Transbond	NS	NS	NS	NS
Dyna-Lock/Right-On	*	*	NS	NS
Straight-Wire/Transbond	NS	NS	*	NS
Straight-Wire/Right-ON	*	*	NS	*

*Denotes significance at the 0·05 level.

is random allocation. In the present study, patients were successively allocated into various treatment groups (bracket/adhesive combinations). This is sometimes referred to as 'Pseudo-randomization' due to the openness of the allocation system. However, if conducted properly, successive allocation should introduce no bias in the study and for all practical purposes may be considered random (Altman, 1991).

All patients were bonded by one clinician (S.S.) to eliminate inter-examiner variation. Only first time bond failures were recorded. This was to eliminate possible variation in bond strength introduced from rebonding which may have skewed the results. Kinch *et al.* (1988) found a less favourable survival rate of second and third time bonds compared to first time failures. This was evident in the present study since a small number of patients displayed a large number of failures. It is therefore recommended that clinical studies evaluating bond failure rates should either only record first time failures or analyse multiple failures of the same site in a different category.

Evaluation of bond failure rates

The overall bond failure rate over one year was 6·6 per cent. This is similar to the rates reported by O'Brien *et al.* (1989) and Sonis (1988) who found failure rates between 4·7–6·0 and 4·5–7·7 per cent for various bracket/adhesive combinations. For meaningful comparison of failure rates with other papers, it is important to note the observation period.

There were no significant differences between the bond failure rates for various bracket/adhesive combinations. This finding does not support the claim of a reduced failure rate with the use of APC brackets (3M Unitek Product Literature, 1995). None of the five bracket/adhesive combinations tested could therefore be recommended as clinically superior in terms of bond failure.

No significant differences were detected between failure rates for the upper and lower arches. This was in agreement with the work of O'Brien *et al* (1989), but disagreed with the work of Zachrisson (1977), Newman (1978) and Lovius *et al.* (1987) who reported more bond failures in the lower jaw than the upper jaw. This may have been due to occlusal interference. In the present study care was taken to open the bite by preliminary treatment with a flat bite plane on an upper removable appliance before the lower teeth were bonded.

Significantly more brackets failed on the left side of the mouth than on the right. This was surprising as great care was taken to follow the standardised bonding procedure. Ghassemi-Tary (1979) reported that bracket base fit at the tooth surface played a very important role in determining bond strength. This factor does not seem to have been important in the present study; the brackets must all have fitted equally well or equally badly. The fact that the operator was right-handed may have resulted in better moisture control and more accurate bonding on the right side of the mouth.

Significantly more premolar brackets failed than incisor brackets. This finding agrees with those of Zachrisson (1977), Newman (1978), Lovius *et al*. (1987), Sonis (1988), and O'Brien *et al.* (1989). Posterior bond failure may be increased by higher occlusal forces exerted on posterior teeth, more difficult isolation and larger amounts of aprismatic enamel on molars and premolars (Whittaker, 1982).

Evaluation of bonding times

Bonding time was on average 34 seconds per tooth less with the use of Right-On adhesive than with APC and Transbond. Light exposure was only 20 seconds per tooth with both light curing systems so that the fact that light curing was slower overall suggests that more time was spent on bracket placement and adhesive flash removal with this technique. No significant difference was found between the bonding times for APC and Transbond. The data therefore did not support the claim of a reduced bonding time with APC (3M Unitek Product Literature. 1995).

Ash and Hay (1996) found that there was a significant increase in the amount of adhesive flash around bracket peripheries associated with the use of Unite, a chemically-cured adhesive when compared to APC. In the present study it was the impression that the light-cured adhesive systems were more convenient, neater, and cleaner than the chemically-cured system. The absence of excess composite on tooth surfaces at debond would be expected to reduce problems at this stage.

Clinical applicability of ex vivo studies

Brackets, bonding adhesive systems, and the bonding protocol used in this study was exactly as that used by the authors in a previous *ex vivo* study (Sunna and Rock, in press). This was to allow comparison of results and to assess the applicability of *ex vivo* studies to the clinical situation. Results of the *ex vivo* study indicated that Transbond produced a significant increase in bond strength with both Dyna-Lock and mesh backed brackets. In the present clinical study there were no significant differences between bond failures for the various bracket/adhesive combinations tested, all produced adequate bond strengths. Bond failure appeared to be caused largely by local factors at an individual bracket site.

Conclusions

- None of the bracket/adhesive combinations evaluated was clinically superior in terms of bond failure rate.
- The use of APC had no significant effect on bonding time compared to light-cured adhesive applied by the operator. Significantly less bonding time was required when a chemically-cured adhesive (Right-On) was used compared to both of the light-cured systems.
- No time interval following bonding was associated with increased risk of bond failure.
- There were significantly more premolar than incisor bond failures. Significantly more teeth failed on the left side than on the right (right-handed clinician). No significant differences in bond failure rates were found between the upper and lower arches.
- *Ex vivo* shear bond strengths did not correlate with clinical failure rates. This casts doubt on the precise clinical applicability of *ex vivo* shear bond strength studies.

Acknowledgments

We wish to record our thanks to 3M Unitek for assistance with this study.

References

Altman, D. G. (1991)
In: *Practical Statistics for Medical Research*,
Chapman and Hall, London.

Andrews, L. F. (1976)
Straight-Wire appliance origin, controversy, commentary,
Journal of Clinical Orthodontics, **10,** 99–114.

Ash, S. and Hay, N. (1996)
Adhesive pre-coated brackets, a comparative clinical study,
British Journal of Orthodontics, **23,** 325–329.

Cooper, R. B., Goss, M. and Hamula, W. (1992)
Direct bonding with light-cured adhesive precoated brackets,
Journal of Clinical Orthodontics, **26,** 477–479.

Cueto, H. I. (1990)
A little bit of history: the first direct bonding in orthodontia,
American Journal in Orthodontics and Dentofacial Orthopedics, **98,** 276–277.

Ghassemi-Tary, B. (1979)
Direct bonding to porcelain: an *in vitro* study,
American Journal of Orthodontics, **76,** 80–83.

Kinch, A. P., Taylor, H., Warltier, R., Oliver, R. G. and Newcombe, R. G. (1988)
A clinical trial comparing the failure rates of directly bonded brackets using etch times of 15 or 60 seconds,
American Journal of Orthodontics, **94,** 476–483.

Lovius, B. B., Pender, N., O'Dowling, I. and Tomkins, A. (1987)
A clinical trial of a light activated bonding material over an 18 month period,
British Journal of Orthodontics, **14,** 11–20.

Mitchell, D. L. (1992)
The first direct bonding in orthodontia, revisited,
American Journal of Orthodontics, **101,** 187–189.

Newman, G. V. (1978)
A past treatment survey of direct bonding metal brackets,
American Journal of Orthodontics, **74,** 197–206.

Newman, G. V. (1992)
First direct bonding in orthodontia,
American Journal of Orthodontics, **101,** 190–192.

O'Brien, K. D., Read, M. J. F., Sandison, R. J. and Roberts, C. T. (1989)
A visible light-activated direct-bonding material: an *in vivo* comparative study,
American Journal of Orthodontics and Dentofacial Orthopaedics, **95,** 348–351.

Sonis, A. L. (1988)
Comparison of a light-cured adhesive with an autopolymerizing bonding system,
Journal of Clinical Orthodontics, **22,** 730–732.

Sunna, S. S. and Rock, W P. (in press)
An *ex vivo* investigation into the bond strength of orthodontic brackets and adhesive systems,
British Journal of Orthodontics

3M Unitek product Literature (1995)

Whittacker, D. K. (1982)
Structural variations in the surface zone of human tooth enamel observed by scanning electron microscopy,
Archives of Oral Biology, **27,** 383–392.

Zachrisson, B. U. (1977)
A post treatment evaluation of direct bonding in orthodontics,
American Journal of Orthodontics, **71,** 173–189.