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SCIENTIFIC SECTION

A clinical comparison of two chemically-cured adhesives used for indirect bonding

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Abstract

Objective: To compare and evaluate the clinical failure rates of the chemically-cured composite bonding resins Sondhi Rapid Set (SD) and Maximum Cure (MC) when used in an indirect bonding technique.

Setting: *In vivo* study in the private orthodontic practice of a solo practitioner.

Materials and methods: Forty consecutive patients meeting the inclusion criteria were assigned to alternating groups in a split-mouth study design. Group 1 had the maxillary right and mandibular left quadrants indirectly bonded using SD adhesive, while the contralateral quadrants were bonded using MC adhesive. Group 2 had the opposite sides bonded to Group 1. One patient was lost from each group. Over a 6-month observation period, all loose brackets were recorded and the data compared with a Wilcoxon sign-rank test.

Results: Of the 363 brackets placed in each group, 36 with the SD adhesive came loose (9.9 per cent failure rate) compared with five from the MC group (1.4 per cent failure rate, $P = 0.0001$). In the maxillary arch, seven brackets from the SD quadrants came loose versus one for the MC ($P = 0.109$). In the mandibular arch 29 brackets from the SD quadrants came loose during the 6-month observation period compared with four from the MC quadrants ($P = 0.001$).

Conclusions: Both chemically-cured adhesives (SD and MC) examined in this study were suitable for the indirect bonding of brackets. The SD adhesive had seven times the number of breakages than the MC adhesive in both arches ($P = 0.0001$).

Index words:
Bond strength, chemical-curing, indirect bonding, orthodontic brackets.

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Introduction

The outcome and efficiency of orthodontic care are influenced by numerous variables including errors in bracket placement, wire selection and bending, variations in adhesive thickness, manufacturer tolerances, operator acuity and fatigue, and ability to accurately monitor treatment.[1] Orthodontics is constantly changing and evolving to improve quality and efficiency. One such advance was the advent of direct bonding of orthodontic attachments to the etched enamel surface as first described by Newman.[2] In an effort to produce a more accurate and efficient bracket placement system, Silverman *et al*.[3] developed indirect bonding involving a two-stage process of bracket placement in the laboratory on a plaster model and transfer of these attachments to the patient's mouth by means of a tray, where they are bonded to the etched enamel surface.

Over the years this technique has been refined and variations described as new techniques or materials have become available.[4–9] The technique originated with the brackets being placed on the plaster model with sugar candy which was later removed and a composite bonding agent placed at the time of bonding.[3] This led to excessive flash and clean up and evolved to the use of custom bases, whereby the brackets are attached to the model with either a chemical, light or thermal activated composite.[4–6] Once set, only a thin layer of bonding agent

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was required to bond to the etched enamel producing minimal flash.

Initially, bond failure rates for indirect bonding (13.9 per cent) were higher when compared with direct bonding (2.5 per cent).[10] However, with modifications and improvements to the technique, the two systems now have similar bond strengths and failure rates.[5,11,12] When using certain types of clear brackets, it has been reported that light-cured custom bases were superior to thermally cured bases.[13] For ease of placement only one type of custom base would be desired so a light-cured base may be the more appropriate. A technique has been previously described used adhesive pre-coated brackets (APC—3M/Unitek, Monrovia, Ca) providing uniform application of adhesive to the bracket base.[7] This technique has been modified and a new adhesive (Sondhi Rapid Set—3M/Unitek, Monrovia, Ca) has been advocated that was designed specifically for indirect bonding.[9]

The purpose of this investigation was to compare and evaluate the clinical performance over 6 months of two chemically-cured composite bonding resins when used in an indirect bonding technique: Sondhi (SD) Rapid Set compared with Maximum Cure (MC) filled resin (Reliance Orthodontic Products, Ithaca, Ill.). The null hypothesis was that there was no significant difference in bracket failure rates between SD and MC adhesives when used for indirect bonding.

Materials and methods

Subjects were prospectively selected from the private orthodontic practice of the author (PM) who had routinely indirect bonded for 8 years. Forty consecutive patients meeting the following inclusion criteria participated in this study:

(1) all brackets were placed in both maxillary and mandibular arches at the same appointment;
(2) cases were either non-extraction or had symmetrical extractions (e.g. loss of both upper first or second premolars, but not loss of upper right first premolar and upper left second premolar).

Patients were excluded if:

(1) they had facial restorations where brackets were placed;
(2) fixed intermaxillary appliances were used (e.g. Forsus—3M/Unitek, Monrovia, Ca), but intermaxillary elastics were acceptable.

Each patient was consecutively assigned to one of two alternating groups. Group 1 had the maxillary right quadrant and mandibular left quadrant from second premolar to central incisor indirectly bonded using SD (filler content approximately 5 per cent , range 1–10 per cent) adhesive, while the maxillary left and mandibular right quadrants were indirectly bonded using MC filled (filler content 12 per cent +) adhesive. Group 2 had the opposite side of the arch bonded with SD or MC compared to Group 1. The author had previously used MC for 6 years and SD for 4 months prior to commencing the study. Accurate alginate impressions (Aroma Fine Fast Set, GC International Corp., Tokyo, Japan) were used to fabricate models that were coated with alginate separating medium (Vertex Divosep, Dentimex BV, Zeist, The Netherlands) diluted one part to three parts water. Light Bond (Reliance Orthodontic Products, Ithaca, Ill.) composite was applied to the base of each bracket and the bracket positioned. Spirit MB (ORMCO/'A' Company, Orange, CA) brackets were placed on the maxillary anteriors canine to canine and light-cured with a Demetron 500 curing light (ORMCO/'A' Company, Orange, CA) for 10 seconds each, while all other teeth had Mini-Diamond metal brackets (ORMCO/'A' Company, Orange, CA) placed and cured for 50 seconds to create custom bases. A 1.5 mm (0.006-inch) clear mouthguard material (Henry Schein Inc., Melville, NY) was vacuum formed over the brackets and model. A thin coat of CRC 808 silicone spray (CRC Industries (Australia) Pty Ltd., Sydney, Australia) was sprayed over the inner tray and a second 1.5-mm clear splint material (Henry Schein Inc., Melville, NY) was then vacuum formed to hold the tray and brackets stationary when placed in the mouth. After soaking in water for 30 minutes, the trays were removed with the brackets trapped within the mouthguard material. The trays and brackets were thoroughly dried, the inner mouthguard material tray trimmed to extend only 1 mm beyond the gingival margin while the rigid outer tray was trimmed to only just cover the gingival aspect of each bracket on the facial aspect. Each bracket custom base was lightly micro-etched with 110 μm aluminium oxide particles (Korox 110, BEGO, Bremen, Germany) using a micro-etcher (Danville Engineering, San Ramon, USA) to remove any adherent plaster or separating medium, and then cleaned with liquid household detergent and water for approximately 30 seconds to remove any remaining etchant powder.

To improve adhesion with the bonding agent, 10 minutes prior to placement of the brackets the custom base was lightly painted with methyl methacrylate monomer (Dentaurum Orthocryl, Pforzheim, Germany)

and air-dried. Teeth were not pumiced prior to etching, but if plaque was visible, the teeth were brushed with a toothbrush and toothpaste by the operator. The teeth were isolated throughout the bonding procedure with a dry field system saliva evacuator/retraction device (NOLA Specialties, Inc., New Orleans, USA) and etched for 30 seconds, rinsed, and dried for 10 seconds each and MIP (3M/Unitek, Monrovia, Ca), a moisture insensitive primer, applied. The lower brackets were placed first with the SD tooth side material applied to the appropriate side bracket custom base (depending on which group to which the patient was assigned) and the bracket side material applied to the tooth, as suggested by Dr Sondhi to reduce discoloration of the adhesive. The MC resin was then immediately mixed in equal parts with a small dab applied to the custom base and the tooth surface on the contralateral side to the SD material. The lower inner tray with the brackets was then seated, and the rigid tray placed over the top to hold them still and in position for a minimum 3 minutes, while the chemical cure took place. The upper trays were then applied in the same manner and held for a minimum 3 minutes. The isolating lip and tongue retractors were removed, and the rigid trays removed. The lower inner tray was then gently peeled off the lower brackets followed by the upper tray. Any excess flash was removed with a hand scaler from around the brackets and the occlusion then checked. If the brackets interfered in the occlusion, a composite bite plane or wedge (Herculite XRV, Kerr Corp., Glendora, USA) was built up on the palatal surface of the maxillary incisors or if not suitable, on the buccal cusps of the lower molars to disclude any contact with the lower brackets during the initial alignment. A 0.014- or 0.016-inch thermally active NiTi wire (G&H, Greenwood, USA) was then placed (size depending on the degree of irregularity), and identical standard instructions regarding care and diet were given. The normal wire sequence used after nine weeks was a 0.018 × 0.018-inch thermally active NiTi wire (G&H, Greenwood, USA) and after an additional nine weeks, a 0.017 × 0.017-inch stainless steel wire (G&H, Greenwood, USA) as the final working wire. Any loose brackets were recorded for every patient and these were collated for a 6-month period after the brackets were placed. Once a bracket had become dislodged once, it was not included after that time if it came loose again.

Results and data analysis

Of the 40 patients included, one from Group 1 transferred to another area and one from Group 2 was unable to continue treatment for family reasons leaving 38 in the sample (22 females, 16 males, average age = 13.5 years, SD = 1.4 years). A total of 726 brackets were placed, 363 in each group. The number of loose brackets in each quadrant for each patient is recorded in Table 1. As the data was paired from contralateral quadrants from each patient and the distribution was not normal, statistical analysis involved the use of the Wilcoxon sign-rank test. A total of 20 brackets came loose from Group 1 and 21 brackets from Group 2. Of the brackets placed with SD adhesive, 36 came loose (9.9 per cent failure rate), while five came loose when using the MC adhesive (1.4 per cent failure rate), this difference being statistically significant ($P = 0.0001$). In the maxillary arch, seven brackets from the SD quadrants came loose versus one for the MC ($P = 0.109$). In the mandibular arch, 29 brackets from the SD quadrants came loose during the 6-month observation period compared with four from the MC quadrants ($P = 0.001$). Therefore, the null hypothesis was rejected for the overall comparison, as well as for the mandibular arch as the SD adhesive had a significantly higher bracket failure rate.

Discussion

The failure rates for both adhesives (SD = 9.9 per cent, MC = 1.4 per cent) were similar to the range (2.5–13.9 per cent) reported by previous studies on indirect bonding.[5,10,11,13] However, there was a statistically ($P = 0.0001$) and clinically significant (seven times) higher failure rate for the SD adhesive when compared with the MC adhesive. This was also true in the mandibular arch ($P = 0.001$), but not for the maxillary arch ($P = 0.109$). This may have been due to no effect or a lack of power and a larger sample size may well have shown a difference. In the original description of SD adhesive,[9] one of its proposed advantages is its rapid set in only 2 minutes. The trays were left in place a minimum of 3 minutes and by the time the trays were actually removed; a further 1–2 minutes would have passed so the higher failure rate cannot be attributed to early tray removal. MC has a setting time of one minute forty-five seconds, similar to the SD adhesive, so again the higher failure rate of the SD adhesive is unlikely to be due to early tray removal. The original SD article did not record the bracket failure rate so no comparison could be made between studies.[9] It has been suggested that moisture contamination has been the chief cause of failure in indirect bonding.[14] Conversely, it has also been suggested that one of the great advantages of indirect bonding is its

Table 1 Number of loose brackets in the maxillary and mandibular arches using Sondhi Rapid Set (SD) and Maximum Cure filled (MC) adhesives

Group number	Maxillary loose Brackets—SD	Maxillary loose Brackets—MC	Mandibular loose Brackets—SD	Mandibular loose Brackets—MC	SD total	MC total
1	0	0	2	1	2	1
2	0	0	0	0	0	0
1	0	0	2	0	2	0
2	0	0	2	0	2	0
1	0	0	2	0	2	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	1	0	1	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	0	1	1	2	1
1	0	0	0	1	0	1
2	0	0	0	0	0	0
1	0	0	2	0	2	0
2	2	0	1	0	3	0
1	0	1	0	0	0	1
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	1	0	1	0
2	1	0	1	0	2	0
1	1	0	2	0	3	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	0	4	0	5	0
1	0	0	0	0	0	0
2	0	0	4	0	4	0
1	1	0	0	0	1	0
2	0	0	0	0	0	0
1	0	0	0	1	0	1
2	0	0	0	0	0	0
1	0	0	2	0	2	0
2	0	0	2	0	2	0
Totals	**7**	**1**	**29**	**4**	**36**	**5**
Mean	0.18	0.03	0.76	0.11	0.95	0.13
SD	0.46	0.16	1.13	0.31	1.31	0.34
95% CI	0.03–0.33	–0.03–0.08	0.39–1.13	0.00–0.21	0.52–1.38	0.02–0.24
Wilcoxon test	$P = 0.109$		$P = 0.001$		$P = 0.0001$	

ability to isolate the teeth from moisture contamination.[5] As a split-mouth design was used in this study, it seems unlikely that this could have contributed to the higher failure rate for SD adhesive without also affecting the MC adhesive.

The author placing the brackets (PM) had been using MC adhesive when indirect bonding for 6 years and SD adhesive for only 4 months prior to this study. This difference in experience with each material may have an impact on the results. As all bonding was performed by the one operator, these results are not transferable to other operators who may experience different success

rates. However, the pattern of significantly higher failures of the SD adhesive in the mandibular arch would still be anticipated. At a lecture presented by Dr Sondhi attended by the author (PM), it was suggested that to reduce potential discoloration of the SD Rapid Set over time the tooth side material could be placed on the bracket custom base and the bracket side material could be placed on the tooth. Although this is not as per the instructions for the material, it is unlikely to have affected the bond strength, as it should not affect contact or mixing of the two materials. However, it was noted during this study that a yellow staining around the brackets did occur in the quadrants with the SD adhesive compared with minimal or no discoloration with the MC adhesive.

The use of composite bite wedges in this study is a routine procedure by the author (PM) whenever occlusal interference occurs on a bracket. This is seldom recorded in research, but potentially could have a significant impact on failure rates when comparing studies. As a split-mouth design was used in this study, it is unlikely to have affected the outcome. However, it may help explain the lower failure rates (1.4 per cent) for the MC adhesive when compared with other studies. Bond failure rates vary between studies and also when comparing direct and indirect bonding methods. Previous studies evaluating indirect bonding have reported failure rates from 4.5 per cent[11] over 3 months, 6.5 per cent[5] over 6 months to 13.9 per cent[10] over 6 months. None of these studies reported the use of bite wedges or other forms of occlusal protection of the brackets. Bracket type and base area can affect bond failure. In this study the same type of bracket was used in every patient (Spirit MB on maxillary anteriors and mini-diamond on all mandibular teeth and maxillary premolars: ORMCO, Orange, USA). Although Spirit MB brackets were used on maxillary incisors and canines, there were minimal failures in the maxillary arch so this would not have affected the result. With the split-mouth study design, bracket type and base area is unlikely to have influenced the observed pattern of failures.

It has been suggested that another source of weakness when indirect bonding with unfilled resins is the presence of marginal voids.[12] Filling these voids increased the bond strength when using unfilled bonding resins. Both the MC and SD used in this study are partly filled resins, which are more viscous making it less likely for voids to occur than with unfilled resins.[9] However, MC (12 per cent +) does have a slightly higher filler content than SD (5 per cent) so this may have an impact on the observed difference between the two adhesives.

One possible reason for the higher failure rate for the SD adhesive may lie in the custom base fabrication. Anecdotally, failures appeared to be at the enamel/adhesive interface, but as this was not measured, it cannot be confirmed. The original study describing the SD adhesive used APC brackets to make the custom bases, whereas this study used individually applied Light Bond composite. Both SD and MC adhesives, Light Bond and Transbond XT (APC brackets) are based on BIS-GMA with differing minor components and filler contents. These differing minor components may or may not affect adhesion between the custom base composite and the adhesives. There may be a better adhesion between Light Bond composite and the MC adhesive than with SD adhesive. The study would have to be repeated with APC brackets to exclude this possibility. However, the excellent clinical result (1.4 per cent failure rate) for the MC adhesive and the Light Bond composite custom bases over the 6 months of this study, when used with protective composite bite wedges when required, indicates this is a very reliable combination for indirect bonding.

Conclusions

1. Both chemically-cured adhesives (SD and MC) examined in this study were suitable for the indirect bonding of brackets.
2. When comparing the two chemically-cured adhesives the SD adhesive had a significantly higher (seven times, $P = 0.0001$) number of breakages than the MC adhesive.
3. When comparing the two chemically-cured adhesives in each arch, the SD adhesive had a statistically significantly higher ($P = 0.001$) number of breakages than the MC adhesive in the mandibular arch only.

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