ORIGINAL RESEARCH

Construction of an *In Vivo* Debonding Device and Comparison of Bracket Failure Rate and Debonding Force for Indirect Orthodontic Bonding

Shrishtee Goyal[1], Narayan Kulkarni[2], Atri Naik[3], Binal Naik[4]

Abstract

Aim: A major limitation of indirect bonding is incomplete penetration of the curing light through transfer trays, leading to inadequate curing of light-cure adhesive resin, causing bracket bond failure. Dual-cure adhesive resin is both light and chemically cured, which reduces the requirement of light for curing of the composite. Comparative evaluation of bracket failure rate and bond strength between dual-cure composite and light-cure composite for indirect orthodontic bonding of brackets.

Materials and methods: A split-mouth randomized clinical study was carried out in 51 patients (30 females and 21 males). Indirect orthodontic bonding using Erkogum as adhesive to attach the bracket to cast and glue gun material was utilized to form a transfer tray. Conventional light-cure and dual-cure adhesive resins were compared with regard to their bracket failure rate, adhesive remnant index score, and *in vivo* clinical bond strength.

Results: Kolmogorov-Smirnov test was employed to test the normality of data. Mann–Whitney *U* test and Chi-square test were performed for the quantitative variables and it was observed that both the groups showed similar results for the parameters being measured. The mandibular arch showed more bracket failure, the dual-cure composite group showed more bracket failure, however, the adhesive remnant index (ARI) score for both the groups was similar. No statistically significant difference was seen concerning the clinical bond strength between the two adhesive resins.

Conclusion: Dual-cure adhesive system can be used for indirect bonding in orthodontics. The mandibular arch had a higher bond failure in the second premolar region. The sequence of bond failure was concordant among both the adhesive groups. However, dual-cure adhesive invariably showed more bracket failure. The highest bond strength was observed for the maxillary canine brackets in the light-cure group, and mandibular canine brackets in the dual-cure group. Whereas, the weakest bond strength in the light-cure group was observed for the mandibular second premolar brackets and for maxillary second premolar brackets in the dual-cure group. There was no significant difference between the *in vivo* clinical bond strength between the two adhesive systems. On debonding, majority of the adhesive was observed to be on the tooth surface.

Clinical significance: This study signifies that both light-cure and dual-cure resins can be used for indirect bonding procedures but light-cure composite resin shows a lower bracket failure rate as compared to dual-cure composite resin.

Keywords: Adhesive remnant index, Bracket failure, Dual-cure adhesive resin, Indirect bonding, *In vivo* bond strength, *In vivo* debonding device.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3310

Background

Bracket bonding is an integral part of fixed orthodontic treatment. The correct position of the brackets bonded to teeth determines the prognosis of the treatment. Orthodontic bonding can either be direct or indirect.[1]

In 1972, Silverman and Cohen introduced indirect orthodontic bonding,[2] in which brackets were positioned and stuck on a diagnostic cast and a transfer tray was constructed over it in the laboratory. Teeth were etched, rinsed, dried, bonding agent was applied and light-cured, composite was placed on the brackets, then transfer tray with the brackets was placed onto the dentition and light-cured, clinically.

Techniques developed over the years for indirect bonding include sugar daddy technique that was introduced by Swartz in 1974, in which he used caramel candy, a water-soluble material, as the adhesive for placement of brackets onto the model.[3] Moin and Dogon introduced a technique in which brackets were positioned on the model using drops of sticky wax. Impressions were recorded using polyether material, and this tray was separated while the brackets remained attached to the cast. The brackets were then retrieved from the cast, heated to remove residual wax, which is then embedded into the impression.[4] Thomas proposed a technique in which the brackets were bonded directly onto the cast with composite resin and a thermoplastic sheet was adapted over it using a vacuum former.[5] Transparent material was used to fabricate transfer trays by Read and O'Brien[6] and Read and Pearson[7] so that light-cure resin could

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How to cite this article: Goyal S, Kulkarni N, Naik A, *et al*. Construction of an *In Vivo* Debonding Device and Comparison of Bracket Failure Rate and Debonding Force for Indirect Orthodontic Bonding. J Contemp Dent Pract 2022;23(2):193–201.

Source of support: Nil

Conflict of interest: None

be used instead of self-cure resin. A "dual-tray" transfer system with chemically cured composite was developed by Hickham in 1993.[8] Cooper and Sorenson[9] in 1993 and Kalange[10] and Sondhi[11] in 1999 developed the adhesive precoated brackets (APC) which made the placement of brackets easy and reduced chair time significantly. Sinha et al. used the thermally cured, fluoride-releasing indirect bonding system in which the mixed sealants contained hydrogen fluoride. Moskowitz et al. modified the technique of Thomas and advocated the use of a thermal-cured adhesive system and reprosil vinyl polysiloxane impression material.[12] Kasrovi et al. in 1997 used light-cure composite for indirect bonding. He used opaque transfer trays which provided direct access and visualization to the brackets during laboratory as well as clinical procedures.[13] Tacky Glue was used by White in 1999, to place brackets on the cast. He used hot glue to make the matrix around the brackets.[14] Vashi and Vashi used thermoplastic glue as advocated by White in 1999 and thermoplastic impression compound was used along with thermoplastic glue to increase the rigidity of transfer trays. This indirect bonding technique was economical and also required less laboratory time.[15] Bhardwaj et al. used a double-sided sticky tape to place brackets on the working cast and then used a soft transfer tray made up of vacuum-formed thermoplastic material.[16] Madhusudhan et al. used micropore adhesive tape along with cyanoacrylate glue to attach the brackets to the working model and gelatin jigs were prepared over brackets for additional retention. A 2 mm thick bioplast was used to fabricate transfer trays.[17]

Incorrect appliance placement leads to a compromised orthodontic treatment, which occurs in the majority of patients. A minimal number of errors in bracket placement are the prime advantage of indirect bonding.[10] The additional advantages include reduced chairside time, enhanced comfort for the patient, and the clinician.

Incomplete curing of the composite due to partial light penetration through the transfer tray[18] is one of the major limitations of indirect bonding. Other drawbacks include additional laboratory time,[19] the need for an additional set of impression, and technique sensitivity.[3]

After searching the literature databases (Google, PubMed, and EBSCO) till date February 12, 2019, there was no *in-vivo* study conducted on the comparative evaluation of dual-cure composite and light-cure composite in indirect bonding of orthodontic brackets. Hence an attempt was made to assess bracket failure rate and clinical bond strength using dual-cure composite and light-cure composite for indirect orthodontic bonding.

The null hypothesis that was devised stated that there was no difference in bracket failure rate and clinical bond strength between dual-cure composite and light-cure composite in indirect orthodontic bonding. The aim and objectives of this study were to evaluate and compare bracket failure rate and clinical bond strength between dual-cure composite and light-cure composite for indirect orthodontic bonding of brackets.

Materials and Methods

The study was started after obtaining ethical approval from the Sumandeep Vidyapeeth Institutional Ethics Committee (SVIEC/ON/Dent/BNPG19/D20003). Sample size estimation was done using G Power Software and the estimated sample size was found to be 42. The effect size and power of the study were set at 0.80 with an alpha error of 0.05. The level of significance was also set at 5% and a p-value of ≤ 0.05 was considered to be significant. Considering 20% dropout during follow-up suggested an increase of 8.4 participants. Hence, a total of 51 participants were included in the study.

Inclusion Criteria

Participants were selected for this split mouth randomized clinical study as per the inclusion criteria which was as follows: Patients above the age of 18 and below 30 years who reported to the Department of Orthodontics and Dentofacial Orthopaedics with full permanent dentition indicated for fixed orthodontic treatment, no previous orthodontic treatment with fixed appliances, teeth with non-carious, sound buccal enamel, and no pre-treatment with chemical agents such as hydrogen peroxide and patients with malocclusion whose treatment duration was minimal.

Exclusion Criteria

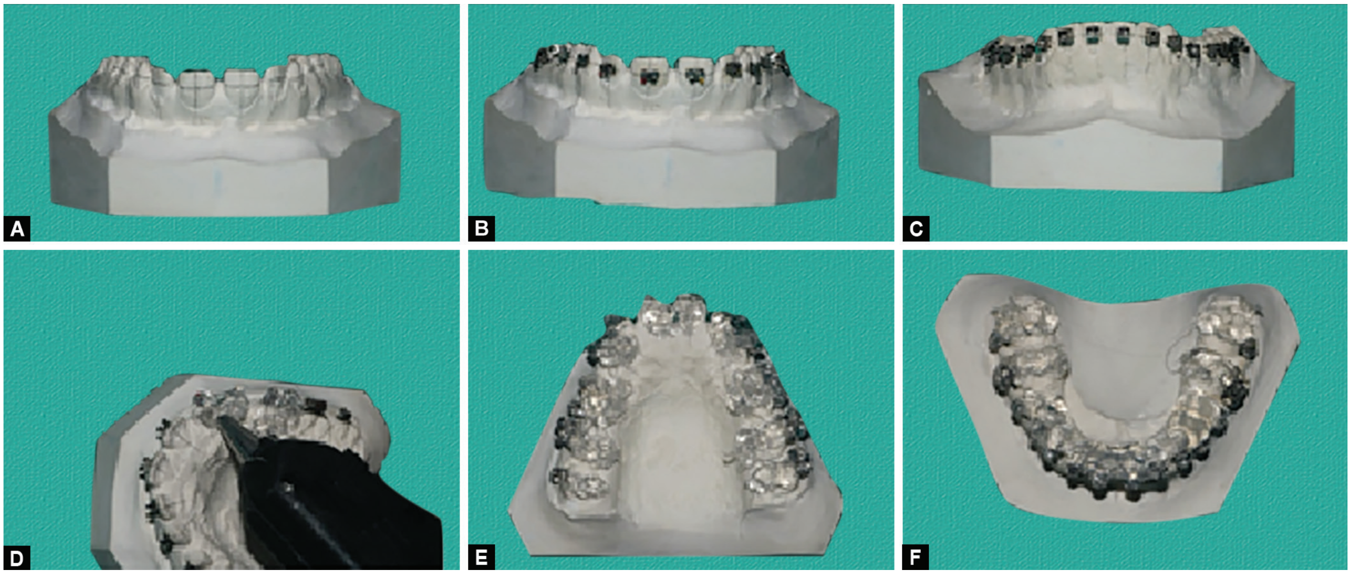
Patients who were not willing to be a part of the study, patients who have congenital syndromes, developmental anomalies, craniofacial abnormalities, and obvious facial asymmetry, patients who have any prosthetic replacement in the region of second premolar to contralateral second premolar in both lower and upper arches and those who require orthognathic surgery as part of their treatment were excluded from the study.

The brackets on the teeth were bonded using an indirect bonding technique. The transfer tray fabrication and bonding of all the brackets for the participants included in the study were carried out by the principal investigator only. The same type of bracket kits was used on all the patients (3M Unitek, MBT, 0.022").

The side allocation for bonding of brackets was randomized as: The composites included in the study were categorized into groups I (dual-cure composite) and II (light-cure composite). The split-mouth design was obtained by dividing each half of the maxillary arch into right and left sides with equal distributions of the two side allocations which were generated using the Microsoft Excel Randomizer tool. Fifty-one sets of random numbers were generated with two numbers per set ranging from 1 to 2, the same process was repeated for mandibular arch by dividing each half into right and left side with equal distribution of two-side allocation. The details of the type and side of allocation of brackets were written on blank paper and sealed in an opaque envelope. The principal investigator picked up the sealed envelope randomly.

Alginate impressions of upper and lower arches were recorded and casts were poured. A thin layer of separating medium was applied to the cast and allowed to dry (Fig. 1A). Brackets were positioned onto the cast and Erkogum was used as adhesive (Figs 1B and C). Glue dispensing out of glue gun was used to fabricate customized transfer trays over the casts and allowed to set (Fig. 1D). These transfer trays were retrieved and Erkogum was removed from the base of brackets (Figs 1E and F).

Before bonding of brackets, participant's teeth were cleaned and polished. Acid etching was performed using 37% orthophosphoric acid for 30 seconds (Fig. 2A). Teeth were rinsed thoroughly with an ample amount of water to ensure complete removal of the etchant, they were then air-dried (Fig. 2B) and a light-cure adhesive primer (Transbond XT Light Cure Adhesive Primer; 3M Unitek) was applied and light-cured (Figs 2C and D). Then as per the allocation participant's maxillary and mandibular teeth were bonded with dual-cure composite and light-cure composite by indirect bonding (Fig. 2E) and flash was removed with a probe (Fig. 2F). Then the composite was light-cured for 10 seconds per tooth with an LED curing light (Fig. 2G). The distance between the adhesive and the exit window was kept minimal to obtain adequate polymerization for both the composite resin systems. Transfer trays were then removed from the teeth (Figs 2H and I).



Figs 1A to F: Laboratory procedures

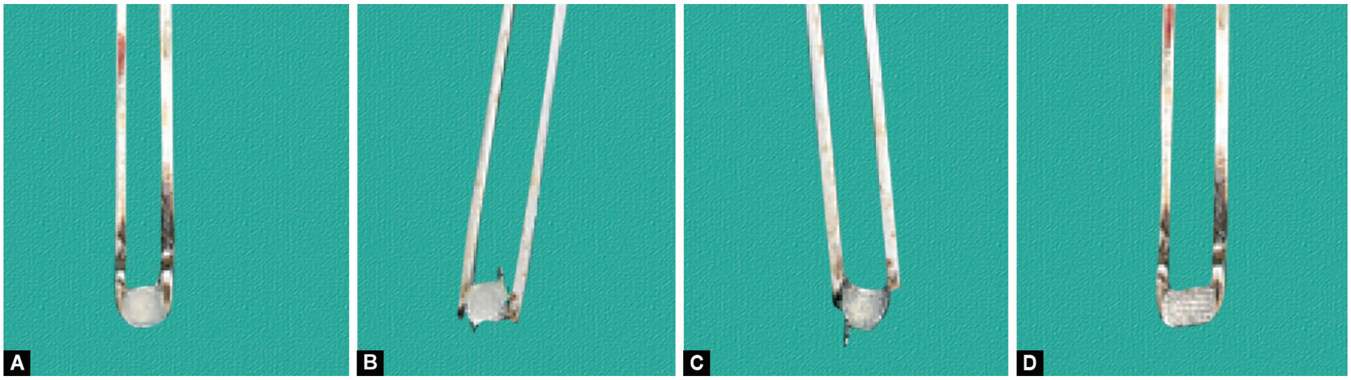
Figs 2A to I: Clinical procedures

The study was completed in 18 months. Bracket failure was documented at standardized appointment intervals of 4 weeks until the completion of the treatment. During the treatment only first-time bracket failure was recorded for each bracket and subsequent bracket failure was not recorded. In addition, the participants were informed to call and visit the doctor without further ado in case any bracket gets debonded. The participants were asked about the reason for bracket failure.

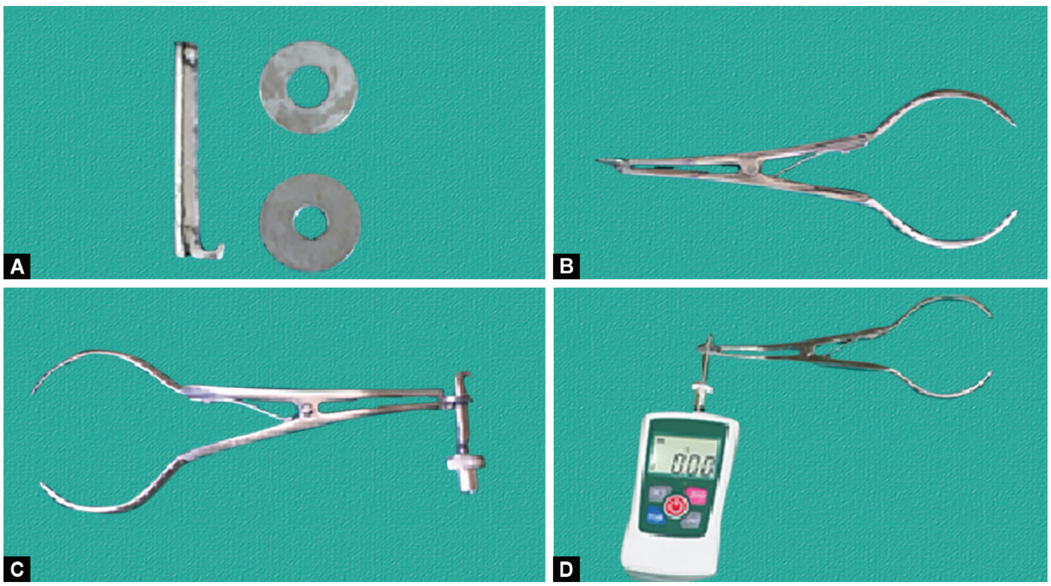
After completion of treatment clinical bond strength was evaluated only on those brackets which did not get debonded from the start till the end of orthodontic treatment.

Determination of Bracket Failure Rate

The failure mode was categorized as per ARI score. The participants were inquired for the reason for bracket failure and the reasons were recorded for the same.



Figs 3A to D: ARI scores. (A) 0; (B) 1; (C) 2; (D) 3



Figs 4A to D: (A) Metal framework; (B) Modified reverse action plier; (C) Reverse action plier attached to metal framework; (D) Assembled debonding device

Adhesive remnant index (ARI) score distribution: "Score 0 = entire bracket base covered by adhesive" (Fig. 3A). "Score 1 = more than 50% adhesive remains on bracket base" (Fig. 3B). "Score 2 = less than 50% adhesive remains on bracket base" (Fig. 3C). "Score 3 = bracket base completely free from adhesive" (Fig. 3D).

Determination of Bond Strength

A prototype debonding device was constructed using a digital force gauge and a modified reverse action plier.

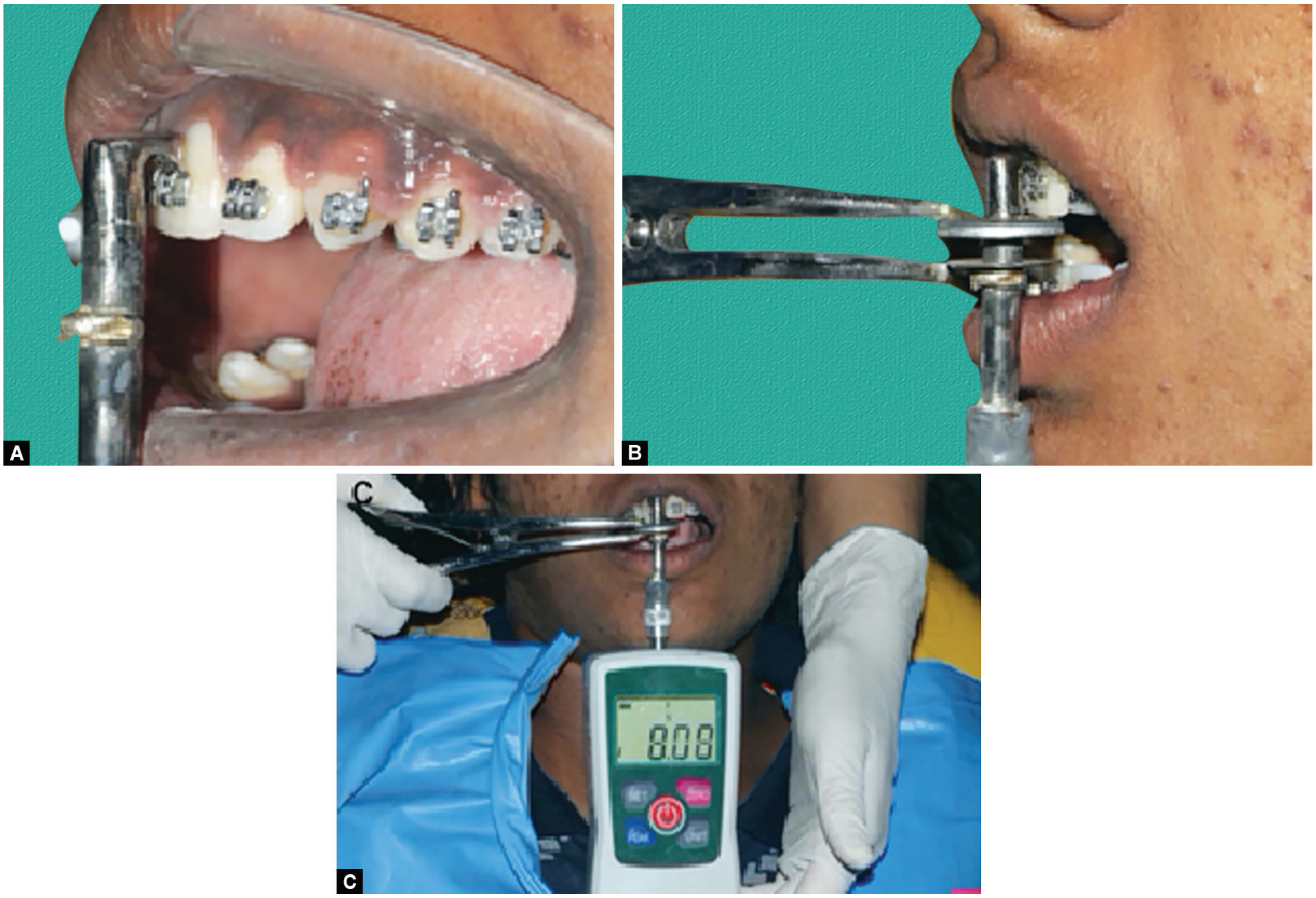
Design of the prototype debonding device: A customized metal framework similar to the bracket debonding plier was fabricated in such a way that it could be attached to the digital force gauge (Fig. 4A). A reverse action plier was modified by soldering two discs with holes to the engaging beak of the plier (Fig. 4B). The customized metal framework was fabricated using a stainless steel rod with one end similar to the beak of a bracket debonding plier to be engaged in the gingival wings of the bracket with a metal stop soldered 7 mm from the beak. One disk of the reverse action plier was then soldered to this metal stop while the other was kept free to rest on the incisal or occlusal surface of the teeth to form a bracket debonding assembly (Fig. 4C). This debonding assembly was then connected to a digital force gauge that would measure the debonding force in Newton (Fig. 4D).

The validity of this instrument was obtained from The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

After completion of the treatment, clinical bond strength was evaluated by the above-mentioned prototype debonding device on those teeth where bracket failure was not observed during orthodontic treatment (Fig. 5). All the scores obtained for bracket failure, ARI, and bond strength were recorded in the pro forma.

Statistical Analysis

The data collected were entered in Microsoft Excel and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS, IBM version 20.0). The level of significance was fixed at 5% and $p \leq 0.05$ was considered statistically significant. Mean and standard deviations were calculated for age of patients and clinical bond strength of the brackets. Kolmogorov-Smirnov test was employed to test the normality of data. Mann–Whitney *U* test and Chi-square test were performed to determine the statistical significance for all the quantitative variables, bracket failure, ARI scores, and clinical bond strength.



Figs 5A to C: (A) Beak of metal framework engaged to bracket wings; (B) *In vivo* debonding; (C) Measurement on debonding device

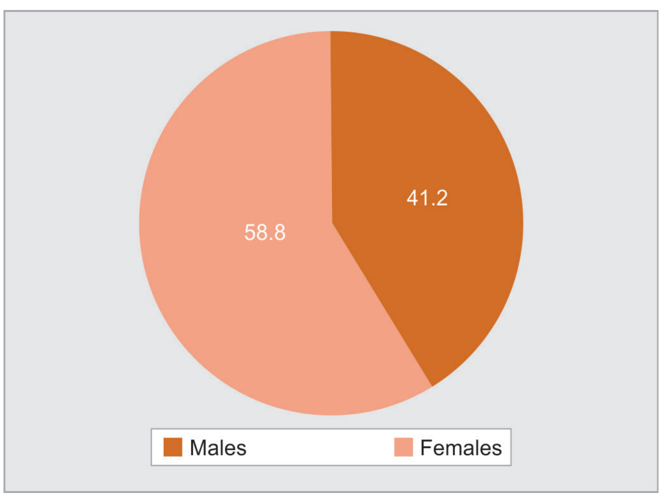


Fig. 6: Gender-wise distribution of study participants

Observations and Results

The present study was carried out to evaluate and compare bracket failure rate and clinical bond strength using light-cure composite and dual-cure composite for indirect orthodontic bonding. The results are based on an analysis of 51 patients subjected for evaluation and comparison of the bracket failure rate and bond strength in split-mouth design.

Figure 6 shows the demographic characteristics of study participants. A major proportion of the study participants were females (58.8%). The mean age of the male and female participants was found to be 21.0476 $\pm$ 3.38 and 20.9667 $\pm$ 2.41 years, respectively.

Table 1 shows the bracket failure rates in the maxillary and mandibular arch. A comparative evaluation revealed no significant differences in failures rates between the two composites for both maxillary (*p*-value 0.350) and mandibular (*p*-value 0.828) arch. Insignificantly, higher bracket failure was seen in the dual-cure composite for both the arches, and higher overall bracket failure was seen in the mandibular arch. Table 2 shows the evaluation of bracket failure by adhesive and tooth type in maxillary and mandibular arches with more bracket failure rate in the dual-cure group, central incisor bracket showing maximum bracket failure rate (8), followed by second premolar (6) for the maxillary arch. In the light-cure group, maximum bracket failure was seen with the second premolar bracket (7). No bracket failure was seen in canine brackets in the dual-cure group and with canine and first premolar brackets in the light-cure group.

For the mandibular arch, it was observed that maximum bracket failure was observed in the dual-cure group, the second premolar bracket being the most common to fail (17), followed by central incisor (10) and first premolar (4). In the light-cure group also, the second premolar showed maximum bracket failure (11).

Table 2 shows the evaluation of bracket failure by adhesive and tooth types. A comparative evaluation revealed no failures in

Table 1: Bracket failure rates in arches

Arch type	*Maxillary arch*				*Mandibular arch*			
Study group	*Total (n)*	*Failures (n)*	*Failure rate*	*p value*	*Total (n)*	*Failures (n)*	*Failure rate*	*p value*
Dual-cure composite	255	18	7.058824	0.35	255	36	14.12	0.828
Light-cure composite	255	11	4.313725		255	19	7.45	
Overall	510	29	11.37255		510	55	10.78431	

Table 2: Evaluation of bracket failure by adhesive and tooth types

Arch type	*Maxillary arch*		*Mandibular arch*	
Tooth type	*Light-cure composite failure*	*Dual-cure composite failure*	*Light-cure composite failure*	*Dual-cure composite failure*
Central incisor	3	8	3	8
Lateral incisor	1	1	1	1
Canine	0	0	0	0
First premolar	0	3	0	3
Second premolar	7	6	7	6

Table 3: Adhesive remnant index scores among the two groups

ARI score	*Dual-cure composite [n (%)]*	*Light-cure composite [n (%)]*	*p value*
0	1 (1.85)	1 (3.33)	0.795
1	2 (3.703)	2 (6.66)	
2	30 (55.55)	18 (60)	
3	21 (38.88)	9 (30)	
Overall	54 (100)	30 (100)	

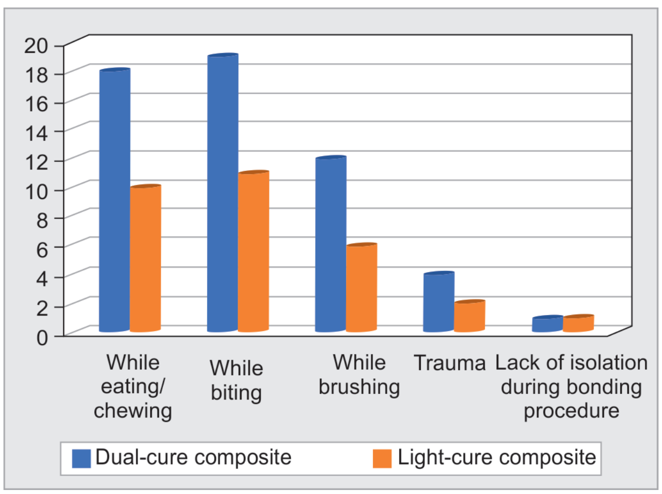


Fig. 7: Reasons for bracket failure among the two groups

canine and first premolar by light-cure composite and in canines by dual-cure composite in the maxillary arch. Maximum failure was reported in the second premolar for both the composites in the mandibular arch.

Table 3 shows the evaluation of the ARI scores among the two groups. A comparative evaluation revealed no significant difference (*p*-value 0.795) between the two groups. Although insignificantly, a greater proportion of score 2 (60%) was seen with light-cure composite. Similarly, score 2 (55.55%) was highest with the dual-cure composite.

Figure 7 shows the reasons for bracket failure among the two groups. A comparative evaluation of the reasons for bracket failure among the two groups revealed no significant difference between the two groups (*p*-value 0.993). Eating/chewing and biting were the reasons for bracket failure reported in major proportion in both the groups; biting is the most common reason in dual-cure composite (19) and light-cure composite (11) followed by chewing (18 in dual-cure composite and 10 in light-cure composite) Flowchart 1.

Table 4 shows the comparative evaluation of the debonding force among the two groups which revealed no significant difference in debonding force between dual-cure composite and light-cure composite (*p*-value 0.722).

Table 5 shows the tooth-wise evaluation and comparison of debonding force among the two groups. A comparative evaluation revealed no significant difference in debonding force between the two groups for any tooth. The highest clinical bond strength in the dual-cure group was seen for the mandibular canine bracket (8.09 + 1.36 N) and the lowest for maxillary second premolar (7.03 + 1.24 N). Whereas, in the light-cure group, the highest clinical bond strength was seen for the maxillary canine bracket (7.98 + 1.25 N) and lowest for the mandibular second premolar (7.04 + 1.22 N).

Discussion

Indirect bonding is the process of positioning the brackets on a cast outside the mouth, fabricating a transfer tray over it, and then bonding those brackets on the teeth through this transfer tray which is convenient for both patient and the clinician.

Various authors have introduced different adhesive systems to bond brackets to teeth and a variety of materials to fabricate the transfer tray for the same. The "Gum and Gun" method was introduced by Aileni et al.[20] to stick brackets to the casts using Erkogum and glue to fabricate a customized transfer tray over the casts. The Erkogum, glue, and glue gun are readily available in the market and economical. Additionally, the weaker strength of Erkogum provided optimal strength for the bracket to stick to the cast, but also facilitate easy removal of transfer tray and brackets from the cast. The flexibility of the glue transfer tray provided the ease of removal of the tray from the oral cavity without causing any bracket failure. The authors of this technique claimed the requirement of attention in detailing but reduced the complexity of the indirect bonding procedure. Hence this technique of bonding was selected in our study.

Flowchart 1: CONSORT flow diagram

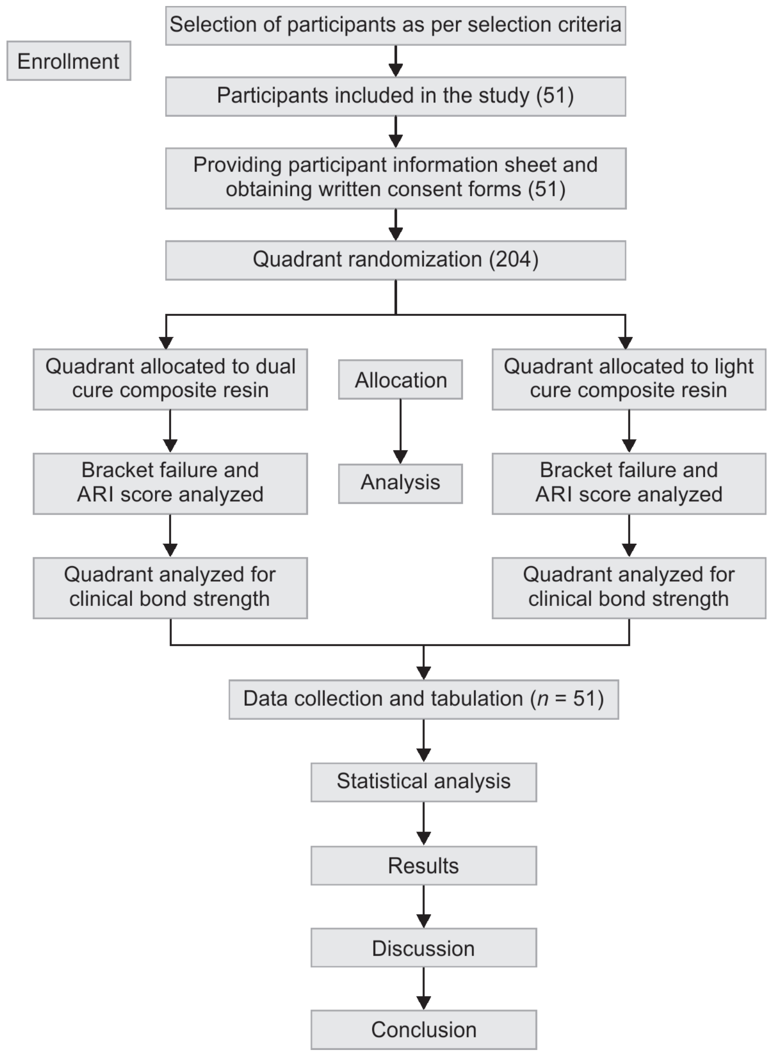


Table 4: Debonding force among the two groups

	Dual-cure composite	*Light-cure composite*	*p value*
Debonding force	7.60 ± 1.23	7.57 ± 1.21	0.722

Customarily, orthodontists used single or double paste chemically cured systems for indirect orthodontic bonding. These resins provided adequate strength to withstand orthodontic forces but provided the clinician with limited working time, due to which the clinician had to quickly position the bracket in the desired position and wait for it to set for any further process to be carried out. The introduction of resins that are cured by visible light and ultraviolet light has helped the clinicians overcome this problem by allowing them to control the setting time as per their requirements. The major drawback with light-cured resin for orthodontic bonding was incomplete curing of metal brackets due to improper light penetration, resulting in partial curing of the composite under the bracket base. Also, light penetration through transfer trays decreased when the indirect method for orthodontic bonding is used. This situation demanded a type of resin that would use the feature of light cure to initiate the process of curing and continue to set chemically after the initiation of photocuring. This property of material was observed in the dual-cure composite. Li et al.[21] and Smith et al. conducted an *in vitro* study on dual-cure composite and suggested that shear bond strengths were adequate to withstand normal orthodontic forces, increased control of the setting time, and complete polymerization with its dual property facilitate its use in orthodontics.

Adhesive remnant index is one of the most common and reliable methods used to evaluate adhesive left on the tooth surface in orthodontics.[22] Hence ARI was used to appraise the amount of adhesive remaining on the tooth surface.

No *in vivo* study was observed in the pretext of evaluation of dual-cure composite resins for orthodontic bonding. Hence, an *in vivo* study was conducted to evaluate and compare conventional light-cure and dual-cure resin considering its bracket failure rate and clinical bond strength. To compare both materials in the oral cavity, a uniform environment was required; hence, a split-mouth design was implemented in the study, which also allowed participants to become their own controls. Elimination of the selection bias, balancing the groups concerning many known, and unknown confounding variables were taken care of by the randomization process. Microsoft Excel had the advantages of ease of operation and wide acceptance; therefore, this method was employed in this

Table 5: Evaluation and comparison of tooth-wise debonding force among the two groups

Tooth number	*Dual-cure composite Mean ± S.D. (N)*	*Light-cure composite Mean ± S.D. (N)*	*p value*
11	7.77 ± 1.34	7.78 ± 1.32	0.982
12	7.48 ± 1.26	7.53 ± 1.03	0.877
13	7.75 ± 1.29	7.45 ± 1.12	0.389
14	7.74 ± 1.34	7.78 ± 1.22	0.911
15	7.52 ± 1.03	7.78 ± 1.16	0.479
21	7.66 ± 1.24	7.40 ± 1.04	0.435
22	7.79 ± 1.14	7.46 ± 1.18	0.327
23	7.47 ± 1.19	7.98 ± 1.26	0.285
24	7.69 ± 1.17	7.67 ± 1.11	0.937
25	7.03 ± 1.24	7.24 ± 1.44	0.605
31	7.22 ± 0.99	7.55 ± 1.13	0.335
32	7.67 ± 1.38	7.73 ± 1.18	0.870
33	8.09 ± 1.36	7.36 ± 1.24	0.06
34	7.70 ± 1.34	7.46 ± 1.26	0.523
35	8.06 ± 0.97	7.36 ± 1.35	0.084
41	7.69 ± 1.18	7.84 ± 1.25	0.453
42	7.36 ± 1.16	7.93 ± 1.28	0.107
43	7.35 ± 1.34	7.35 ± 1.12	0.995
44	7.56 ± 1.20	7.41 ± 1.33	0.674
45	7.41 ± 1.26	7.04 ± 1.22	0.366

study. This also provided equal inclusion of adhesive systems for each quadrant.

In the present study, 51 participants (21 males and 30 females) were included to compare both adhesive systems. Group I was allocated to dual-cure composite resin and light-cure composite resin was allocated to group II.

Orthodontic treatment is a long-term treatment that requires the brackets to stay in the oral cavity for a minimum of 12–15 months during which the brackets are exposed to orthodontic and masticatory forces. Bond strength plays a vital role to overcome these forces. However, the bond strength should not be so high that it damages the teeth during its removal; therefore, orthodontists strive to achieve optimal bond strength. Since no *in vivo* study was conducted to evaluate the dual-cure bond strength, an attempt was made to appraise it.

When the literature was appraised, intraoral bond strength was evaluated either with a customized force gauge or a force-sensing resistor. It was observed that the force-sensing resistor evaluated the bond strength in an indirect method wherein the amount of force exerted by the operator on the handles of the devices significantly affected the results. Hence the bond strength was evaluated with the customized force gauge which could measure the force in Newton from 0.01 to 50 N. Pressure measured in megapascal signifies the amount of force applied per unit area. Pressure measured in MPa denotes the average stress that debonds the bracket but not the average force, whereas Katona[23] advocated that average force in Newton is a better indicator to determine the bond strength of the bracket through a finite element approach. Therefore, the customized force gauge was selected to measure the bond strength of brackets in this study.

When the gender was appraised in the study, majority of the patients were observed to be females. The average age of males and females did not differ much (Fig. 6).

The bracket failure was evaluated for maxillary and mandibular arch, light-cure and dual-cure resin individually, and tooth type. Bracket failure was observed in maxillary and mandibular arches. On average, the mandibular arch had higher overall bracket failure in comparison to the maxillary arch. When bracket failure was appraised for both the adhesive system, the dual-cure resin had a higher bracket failure rate in both maxillary and mandibular arches; (Table 1) these results are similar to a study by Linklater and Gordon,[24] and Khan et al.[25] for conventional light-cure adhesive. However, no literature was observed that compared the bracket failure between dual-cure and conventional light-cure composite systems in an *in vivo* setting.

The only maxillary canine did not show any bracket failure in both the adhesive system and maxillary first premolar did not show any bracket failure in the conventional light-cure adhesive. Maximum overall bracket failure was observed with mandibular second premolar bracket, followed by mandibular central incisor, maxillary central incisor, and maxillary second premolar brackets. Dual-cure resin showed more bracket failure in each of these when compared with their light-cure counterpart (Table 2). This observation was concordant with the observations made by Linklater and Gordon[24] for the conventional light-cure adhesive system.

The reasons for the failure of brackets were also evaluated. Reasons like eating/chewing, biting, brushing, external trauma, and lack of isolation were prevalent for the participants included in the study. Maximum bracket failure was observed due to eating/chewing, followed by biting and brushing in both dual-cure and light-cure resin groups. A study by Khan et al.[25] concluded that bracket failure was maximum in cases with an increased overbite, which results in interferences in the mandibular brackets while eating/chewing and biting (Fig. 7).

Our study also shows that the ARI score of 2 and 3 is predominant among both the adhesive systems (Table 3). The observation of this study correlated to the observations made by Ahmed et al.[26] for conventional light-cure adhesive.

The debonding forces recorded in our study were similar to those recorded by them ranging from 5.5 to 9.5 N, the average being 7.60 N for dual-cure resin, and 7.57 N for light-cure resin (Table 4) which correlates to the observations made by Pickett et al.[27] Highest clinical bond strength in the dual-cure group was seen for the mandibular canine bracket (8.09 + 1.36 N) and lowest for maxillary second premolar (7.03 + 1.24 N). The highest bracket failure in this group was seen with mandibular second premolar and the lowest bracket failure was seen with maxillary canine bracket. Whereas in the light-cure group, the highest clinical bond strength was seen for the maxillary canine bracket (7.98 + 1.25 N) and lowest for mandibular second premolar (7.04 + 1.22 N). Maxillary canine brackets in the light-cure group showed the lowest bracket failure and highest bond strength, and mandibular second premolar brackets in the same group showed the highest bracket failure and lowest bond strength which indicates that a high bond strength aids in a low bracket failure rate. Bond strength and bracket failure showed a mutual relationship in conventional light-cure adhesive. No such mutual relationship was observed in the dual-cure resin adhesive, probable cause for such an observation could be attributed to the decreased working time of dual-cure resin adhesive and lack of isolation. Hence, to achieve a minimal bracket failure, factors like bond strength, isolation, amount of masticatory forces, and type of malocclusion have a predominant influence (Table 5).

Some of the limitations in this study included decreased working time of dual-cure composite, problems maintaining isolation when transfer tray had to be inserted in the mouth, and dislodging the transfer tray that sometimes got stuck in undercuts.

Further studies are required with a higher sample size to establish and verify a mutual relationship between bond strength and bracket failure for dual-cure composite adhesive and technological advances in the indirect bonding procedures.

Conclusion

This study evaluated the bracket failure rate and clinical bond strength when dual-cure and light-cure composite resins are used in the indirect orthodontic bonding technique. The following conclusions can be drawn:

The study brought to light that Gum and Gun is an easy and feasible method to carry out indirect bonding procedure. Bracket failure in mandibular arch is more than maxillary arch in both the groups. Bracket failure rate of brackets bonded with dual-cure composite is more than those bonded using light-cure composite, especially in the mandibular second premolar. Most common reason for bracket failure was chewing and biting, which suggests that bracket failure occurred due to undue masticatory forces. Even though dual-cure composite showed higher bracket failure, it is statistically and clinically insignificant. Most common ARI score was 2, followed by 3, which interprets to minimal damage to the enamel of teeth. Average clinical bond strength of the dual-cure composite is slightly more than that of the light-cure composite but it is not statistically significant.

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