Original Article

In Vivo Comparative Assessment of Bracket Bond Failure Rates of Single-Component Adhesives

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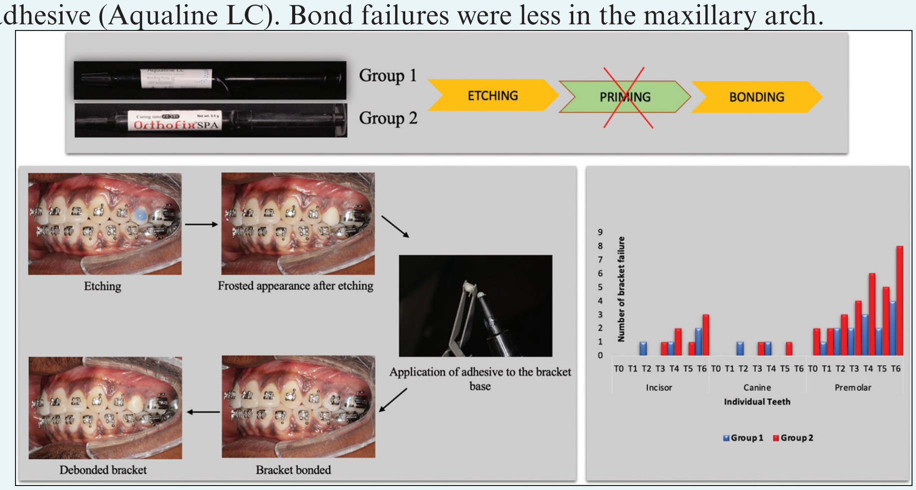
Abstract

Background: Single-component adhesives do not require the application of a primer on the enamel surface that has been etched and has been reported to have acceptable shear bond strengths on *in vitro* evaluation. **Aim:** This split-mouth study aimed to examine and assess the rates of bracket bond failure of hydroxyethyl methacrylate (HEMA)-based (Aqualine LC) and bisphenol A-glycidyl methacrylate (BisGMA)-based (Orthofix SPA) single-component adhesives used to bond orthodontic brackets over 6 months. **Materials and Methods:** This *in vivo* study involved the participation of 50 adult subjects, with 1080 metallic brackets directly bonded to the labial/facial surface in a split-mouth design. After 6 months of treatment, 49 patients with 490 brackets bonded using a HEMA-based adhesive and 490 brackets bonded using a BisGMA-based adhesive were evaluated for bracket bond failures. Descriptive statistics and chi-square tests were done to compare the results. **Results:** The overall bracket bond failure rate (BFR) with single-component adhesives was 6.02%. Bracket BFRs of HEMA-based and BisGMA-based adhesives were 4.16% and 7.8%, respectively, and the difference was statistically significant ($P < 0.05$). Significant differences in BFRs between maxillary teeth (4.28%) and mandibular teeth (7.75%) were noted ($P < 0.05$). No significant differences in bond failures between either side or region were noted. **Conclusion:** Bond failures were more in brackets bonded with BisGMA-based adhesive (Orthofix SPA) compared with HEMA-based adhesive (Aqualine LC). Bond failures were less in the maxillary arch.

Graphical Abstract



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Introduction

Effective orthodontic treatment relies on the successful bonding of attachments to teeth, which facilitates precise tooth movement.[1] This process is influenced by several factors, including enamel surface characteristics, the chosen adhesive system, bonding protocol, bracket design, and individual patient variables.[2-4] Orthodontic adhesives fall into three main categories: Etch-rinse (three-step or two-step), self-etch, and universal.[5-7] The two-step etch-rinse method combines etching with a combined priming and bonding step.[3,8-13] Primerless, single-component adhesives primarily consist of bisphenol A-glycidyl methacrylate (BisGMA) and hydroxyethyl methacrylate (HEMA) phosphate, often mixed with various diluents.[3,14] These adhesives eliminate the need for a separate primer step, offering orthodontists increased working time, reduced procedural errors, and improved patient comfort due to less technique sensitivity.[8,10,15,16]

Earlier research compared the shear bond strength (SBS) of various single-component adhesives. Heliosit, a single-component adhesive, and Maxcem Elite, a self-adhesive resin (SAR) requiring and not requiring an etching step, were compared with a conventional adhesive (Transbond XT, 3M Unitek, USA). Whereas Transbond XT exhibited the highest mean SBS, the self-adhesive Maxcem Elite resin followed closely, then Heliosit, with the nonetched Maxcem Elite demonstrating the lowest SBS. These findings support the clinical use of these adhesives.[17] Among single-component adhesives, Orthofix SPA (Anabond Stedman, Chennai, Tamil Nadu, India) is a light-cured, radiopaque option containing BisGMA and diluents like TEGDMA. Aqualine LC (TOMY, Tokyo, Japan) is another commonly used light-cured single-component adhesive resin, primarily composed of HEMA.

Eliminating the priming step in single-component adhesives offers time-saving benefits, but accurately assessing their clinical bond failure rates (BFR) remains crucial.[1,2,4,18] This study, therefore, aims to evaluate the BFR of HEMA and BisGMA-based single-component adhesives over 6 months. The null hypothesis proposes that no significant difference exists in bracket BFR between HEMA and BisGMA-based adhesives during the initial 6 months of fixed orthodontic treatment.

Materials and Methods

Setting and design

This prospective, split-mouth clinical trial was conducted over 6 months in the Orthodontic Department of Saveetha Dental College and Hospital, Chennai, Tamil Nadu, India. Patients seeking orthodontic treatment were enrolled in the study. The primary investigator, AK, a postgraduate resident in the department, executed the study.

Ethical Approval and Informed consent

The research protocol received ethical approval from the Saveetha Dental College Scientific Review Board (IEC No.: IHEC/SDC/ORTHO-2106/22/007) on January 13, 2023. All participants provided written informed consent before participating in the study. All procedures adhered to the ethical principles outlined in the Declaration of Helsinki.

Sampling criteria

Fifty-four adult subjects aged 18–35 years participated in this split-mouth clinical trial. An *a priori* power analysis using G Power software (version 3.0.10) determined a sample size of 54 to achieve 80% power with an alpha error of 0.1. Inclusion criteria were: A full complement of healthy, non-carious permanent teeth, the need for fixed orthodontic treatment in both maxillary and mandibular arches, and nonextraction cases. Exclusion criteria included: Physical or mental disabilities, congenital enamel defects, craniofacial syndromes, and partially erupted teeth with hypoplasia.

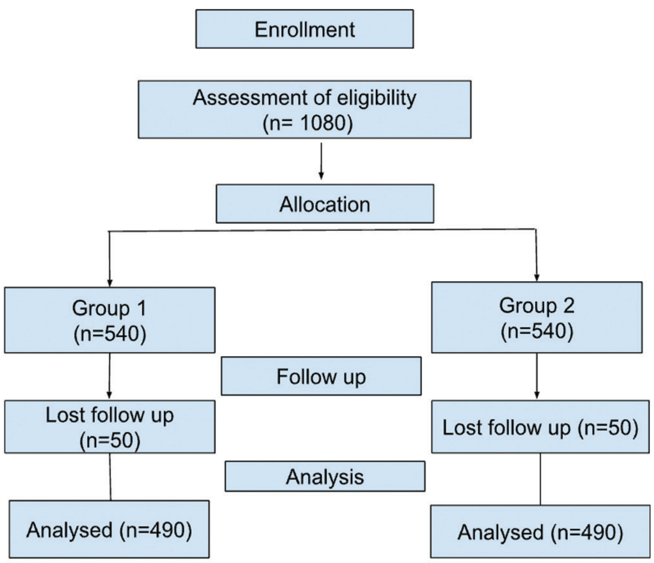
Demographic data of the participants and the consort flow chart are presented in Table 1 and Figure 1, respectively. Figure 2 illustrates the number of bracket bond failures within 6 months across different quadrants and regions for both groups.

Grouping and allocation

As a split-mouth trial, each subject had two opposing quadrants bonded with different adhesives: HEMA-based (Aqualine LC) on one side (Group 1) and BisGMA-based (Orthofix SPA) on the other (Group 2). For odd-numbered subjects, the first and third quadrants received HEMA-based adhesive, whereas the second and fourth received BisGMA-based, and vice versa for even-numbered subjects. Any dropouts per appointment was also noted.

Table 1: Study sample characteristics

Number of subjects				Number of brackets				Distribution of brackets by tooth type		
T0		T1		T0		T1		Incisors	Canines	Premolars
M	F	M	F	M	F	M	F			
27	27	25	24	540	540	500	480	392	196	392



n: number of brackets

Figure 1: CONSORT flowchart diagram N = number of brackets

Methodology

Before bonding, meticulous oral prophylaxis was performed using a rubber cup, pumice, and water slurry. Teeth were then isolated with self-retaining cheek retractors, cotton rolls, and a low-volume oil-free suction evacuator. The labial/facial surfaces were etched for 15–20 s with 37% phosphoric acid, followed by thorough rinsing and drying until a dull, frosty white appearance was achieved. All subjects received bonding with 0.022 MBT metallic brackets (Mini Master Series, AO-Sheboygan, Wisconsin, USA). The adhesive was loaded onto the bracket bases and carefully positioned without a priming step. Before curing, any excess adhesive was meticulously removed from the bracket margins using an explorer. Using a curing unit (Ivoclar Bluephase Powercure, Ivoclar Vivadent Inc., Liechtenstein) delivering 2000 mW/cm^2 light intensity for 3 s, the adhesive was cured on all sides of the brackets (gingival, occlusal, distal, and mesial). The entire bonding procedure for each participant was performed by the operator (AK) in a single appointment. Posterior bite turbos were added as needed to manage any bracket interference encountered during bonding. Following the completion of bonding, a predetermined wire sequence was employed, starting with 0.014 nickel titanium and progressing through 0.016 nickel titanium, 0.017 × 0.025 nickel titanium, 0.019 × 0.025 nickel titanium, and finally, 0.019 × 0.025 stainless steel wires. Both verbal and written instructions on maintaining proper oral hygiene and dietary restrictions were provided to all participants immediately after the procedure.

Observational parameters and follow-up

Throughout the 6-month study period (T0–T6), subjects were recalled for appointments every four weeks. At each appointment, the operator (AK) meticulously assessed and documented any bracket bond failures. For each failure, the following details were recorded: (1) the precise location of the bond failure, (2) the number of brackets involved, (3) the date of failure occurrence, and (4) the potential cause of the failure. Importantly, any brackets that were rebonded after debonding were excluded from the study analysis.

Statistical analysis

The SPSS software version 13.0 (SPSS Inc., IBM, Armonk, NY, USA) was used to perform the statistical analysis. The chi-square was used to compare the probability of bracket bond failures between groups with risk estimation. The odds ratio was done to predict the bond failures between the two groups, the arches involved (maxilla and mandible), the regions involved (anterior and posterior), and the sides involved (right and left).

Results

The study concluded after six months of follow-up, with 49 patients and 980 brackets evaluated. Disappointingly, 59 (6.02%) brackets experienced debonding throughout the study period. While Group 1 exhibited 20 failures (4.16%), Group 2 saw a higher rate of 39 failures (7.8%), demonstrating a statistically significant difference between the two adhesives (P = 0.011) [Table 2]. Interestingly, the maxillary arch displayed a lower debonded bracket rate (4.28%) compared with the mandibular arch (7.75%), with this difference also reaching statistical significance (P = 0.022) [Table 3]. Overall, Group 2

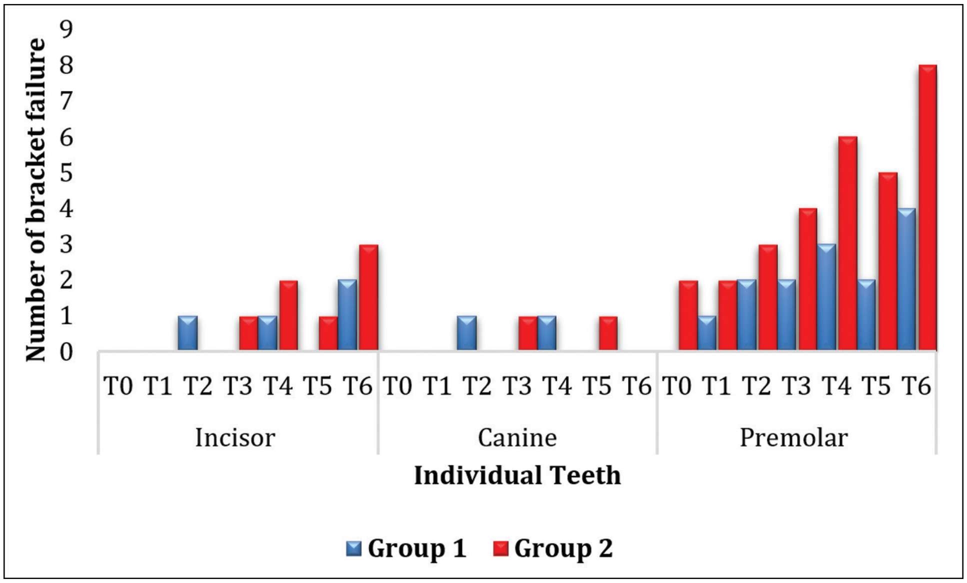


Figure 2: Number of bracket failures observed in individual teeth

Table 2: Bracket bond failure (%) observed in both groups

Adhesives	Bonded (T0)	Evaluated (T1)	Failed	Failed %	Odds ratio	Chi-square test	*P* value
Group 1	540	480	20	4.16	2.032	0.015	0.011
Group 2	540	500	39	7.8			
Total	1080	980	59	6.02			

Table 3: Bracket failures (%) observed in the maxillary, mandibular, and right and left sides of the arches involved

Category	Characteristic	Bonded (T0)	Observed (T1)	Failed	Failed (%)	Odds ratio	Chi-square test	*P* value
Arch	Maxilla	540	490	21	4.28	1.878	0.031	0.022
	Mandible	540	490	38	7.75			
Teeth	Anterior	648	588	15	2.55	1.134	0.595	0.552
	Posterior	432	392	44	11.22			
Side-posterior arch	Right	216	196	25	12.7	0.734	0.424	0.337
	Left	216	196	19	9.69			

Table 4: Percentage of bracket failures (%) observed in both arches, teeth involved, and sides involved in the respective groups

Location	Bracket observed	Bracket failures %		Chi-square value	*P* value
		Group 1	Group 2		
Maxilla	490	1.42	2.44	5.21	0.022
Mandible	490	2.65	5.51	4.61	0.032
Anterior teeth	588	1.02	1.53	0.35	0.552
Posterior teeth	392	3.57	7.65	6.54	0.042
Posterior right	196	3.57	9.18	9.22	0.007
Posterior left	196	3.57	6.12	6.4	0.033

consistently presented a higher percentage of bracket bond failures across the study period [Table 4]. To further analyze bracket survival time over the 6-month treatment period, a Kaplan–Meier survival analysis was conducted [Figure 3]. This analysis revealed a significantly higher survival rate for Aqualine LC compared with Orthofix SPA at the 6-month post-intervention mark (Log-rank mantel cox $P = 0.013$). In specific terms, Aqualine LC boasted a superior survival rate of 99.4% compared with Orthofix SPA's 98.9% at 6 months postintervention, further solidifying its superior performance.

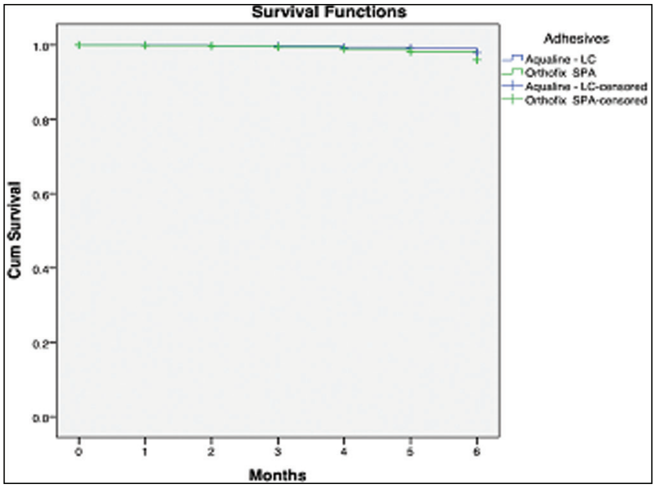


Figure 3: Survival plots for bracket bonded with Aqualine LC and Orthofix SPA adhesive

Discussion

Orthodontic bracket bond failure poses a significant challenge in treatment, leading to increased cost and overall treatment duration.[19-22] While primer-based adhesives have been extensively studied, research on single-component alternatives is limited. Single-component adhesives offer the advantage of reduced clinical working time as they eliminate the priming step.[23] This split-mouth investigation aimed to assess and compare the bracket BFR of two single-component adhesives, HEMA-based (Aqualine LC) and BisGMA-based (Orthofix SPA), in bonding orthodontic brackets. Our findings revealed a significant disparity in BFR between the two adhesives. The BisGMA-based adhesive demonstrated a higher overall BFR (7.8%), with a slightly higher rate in the mandibular arch (7.75%) compared with the maxilla. However, no notable differences in BFR were observed between the left and right sides or between anterior and posterior teeth.

In vitro research has shed light on the bond strength of different dental materials. Atik *et al*.[17] evaluated the bond strength and s of various orthodontic bracket adhesives. Their study identified Transbond ™ XT, a non-primer adhesive, as possessing the strongest bond, followed by self-adhesive and no-primer adhesives.

The weakest bond was observed with an etch-free adhesive. In a separate study, Ryou *et al*.[3] focused on the bond strength between different flow composites and an orthodontic bonding adhesive. Their findings revealed that the bonding adhesive itself demonstrated the strongest bond, whereas among the flow composites, UniFil Flow and DenFil Flow exhibited relatively good bond strengths, followed by UniFil LoFlo and Grandio Flow. The restorative composite[3] showed the weakest bond within this group. These studies provide valuable insights into the comparative bond strengths of various materials used in orthodontic and restorative dentistry.

In a study by Joseph *et al*.[24], the bond strength (SBS) of a novel primer-incorporated orthodontic resin (GC Ortho Connect, TOMY Inc., Tokyo, Japan) surpassed both conventional bonding systems and a self-etching primer, demonstrating promising clinical potential for its use in securing orthodontic brackets. This finding suggests that GC Ortho Connect may offer a reliable and effective alternative to existing bonding methods in the realm of orthodontics.[24]

Several studies shed light on promising primerless adhesives for orthodontic bonding. Joseph *et al*.[24] found a primer-incorporated resin (GC Ortho Connect) outperformed both conventional systems and a self-etching primer in bond strength, suggesting its clinical potential. Ok *et al*.[25] reported strong *in vitro* performance for two nonprimer adhesives (Biofix, GC Ortho Connect) compared with a primer-based one, with similar clinical BFRs. Whereas Krishnan *et al.* (2016) showed comparable BFRs for a flow composite and conventional adhesive, our study revealed an even lower rate with a HEMA-based primerless adhesive.[26] However, treatment variations across studies warrant cautious interpretation. Furthermore, research should explore the long-term clinical performance and potential positioning challenges of these promising primerless options.

Krishnan *et al.* (2016) observed similar BFR across upper and lower arches (3.3% and 3.8%), whereas our study found significantly higher BFR in mandibular posterior teeth for both adhesives. Additionally, they reported a 2.6% premolar BFR and 4.5% anterior BFR, contrasting with our higher posterior BFR for both adhesives. Previous research[27,28] on primer-based adhesives reported BFR ranging from 5.8% to 17.6%, considerably higher than the 4.16% BFR observed with HEMA-based single-component adhesives in this study. This suggests that HEMA-based adhesives may offer a promising alternative for clinical application due to their lower BFR compared with traditional primer-based options.

Limitations

The authors acknowledge several limitations to their study. First, the 6-month duration represents only a fraction of the typical fixed orthodontic treatment timeline, potentially limiting the generalizability of the findings. Second, the study involved a single center and operator, reducing the diversity of participants and potentially introducing operator bias. Finally, subject selection was not standardized based on factors like occlusal contact force distribution and growth patterns, which can influence BFRs. The bracket base area and adhesive remnant index score were not calculated as this was an *in vivo* study and the debonded brackets were replaced with new brackets immediately. These limitations highlight the need for further research with a broader scope and standardized protocols to solidify the potential of the HEMA-based primerless adhesive.

Conclusion

This preliminary observation suggests that HEMA-based single-component adhesive (Aqualine LC) demonstrated a lower BFR compared with BisGMA-based adhesive (Orthofix SPA) for orthodontic bracket bonding. Notably, the BFR was also lower in the maxillary arch for both adhesive types.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Author contributions

RKJ: Conceptualization and designing, editing, validation, reviewing, supervision, and visualization. AK: Investigation and methods, acquiring of the data and analyzing, and preparation of the original draft. Written consent was obtained from subjects included in the study. The Scientific Review Board at Saveetha Dental College, Chennai, Tamil Nadu, India, provided approval for the study.

Ethical policy and Institutional Review Board statement

Not applicable.

Patient declaration of consent

Not applicable.

Data availability statement

Not applicable.

Abbreviations

SBSShear bond strength
BFRBond failure rate
SARSelf-adhesive resin

References

1. Grubisa HSI, Heo G, Raboud D, Glover KE, Major PW. An evaluation and comparison of orthodontic bracket bond strengths achieved with self-etching primer. Am J Orthod Dentofacial Orthop 2004;126:213-9; quiz 255.
2. Sukhia RH, Sukhia HR, Azam SI, Nuruddin R, Rizwan A, Jalal S. Predicting the bracket bond failure rate in orthodontic patients: A retrospective cohort study. Int Orthod. 2019;17:208-15.
3. Ryou DB, Park HS, Kim KH, Kwon TY. Use of flowable composites for orthodontic bracket bonding [Internet]. Angle Orthod 2008;78:1105-9.
4. Bherwani A, Fida M, Azam I. Bond failure with a no-mix adhesive system. Angle Orthod 2008;78:545-8.
5. Shapinko Y, Eleftheriadi I, Brosh T, Adler-Abramovich L, Davidovitch M, Sella-Tunis T, *et al*. Evaluation of an orthodontic adhesive with combined primer and composite. Open J Stomatol 2018;08:205-16.
6. Iglesias A, Flores T, Moyano J, Artés M, Gil FJ, Puigdollers A. In vitro study of shear bond strength in direct and indirect bonding with three types of adhesive systems. Materials 2020;13:2644.
7. Naqvi ZA, Shaikh S, Pasha Z. Evaluation of bond failure rate of orthodontic brackets bonded with green gloo-two way color changes adhesive: A clinical study. Ethiop J Health Sci. 2019;29:187-94.
8. Ozer M, Bayram M, Dincyurek C, Tokalak F. Clinical bond failure rates of adhesive precoated self-ligating brackets using a self-etching primer. Angle Orthod 2014;84:155-60.
9. Aljubouri YD, Millett DT, Gilmour WH. Six and 12 months' evaluation of a self-etching primer versus two-stage etch and prime for orthodontic bonding: A randomized clinical trial. Eur J Orthod 2004;26:565-71.
10. Bishara SE, VonWald L, Laffoon JF, Warren JJ. Effect of a self-etch primer/adhesive on the shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop 2001;119:621-4.
11. Romano FL, Correr AB, Correr-Sobrinho L, Magnani MBB de A, Ruellas AC de O. Clinical evaluation of the failure rates of metallic brackets. J Appl Oral Sci 2012;20:228-34.
12. Pandis N, Eliades T. A comparative in vivo assessment of the long-term failure rate of 2 self-etching primers [Internet]. Am J Orthod Dentofacial Orthop 2005;128:96-8. .
13. Cardoso MV, de Almeida Neves A, Mine A, Coutinho E, Van Landuyt K, De Munck J, *et al*. Current aspects on bonding effectiveness and stability in adhesive dentistry. Aust Dent J 2011;56:31-44.
14. Krishnan S, Pandian S, Rajagopal R. Six-month bracket failure rate with a flowable composite: A split-mouth randomized controlled trial. Dental Press J Orthod 2017;22:69-76.
15. Demirovic K, Slaj M, Spalj S, Slaj M, Kobaslija S. Comparison of shear bond strength of orthodontic brackets using direct and indirect bonding methods *in vitro* and *in vivo*. Acta Inform Med. 2018;26:125-9.
16. Khan H, Mheissen S, Iqbal A, Jafri AR, Alam MK. Bracket failure in orthodontic patients: The incidence and the influence of different factors. Biomed Res Int 2022;2022.
17. Atik E, Kızılırmak M, Akcan CA, Taner T. No-primer adhesive vs. self-adhesive resin: Bonding strength following LED curing. J Orofac Orthop 2022;83:141-50.
18. Tümoğlu M, Akkurt A. Comparison of clinical bond failure rates and bonding times between two adhesive precoated bracket systems. Am J Orthod Dentofacial Orthop 2019;155:523-8.
19. Sunna S, Rock WP. Clinical performance of orthodontic brackets and adhesive systems: A randomized clinical trial. Br J Orthod 1998;25:283-7.
20. O'Brien KD, Watts DC, Read MJ. Light cured direct bonding--Is it necessary to use a primer? Eur J Orthod 1991;13:22-6.

21. Adolfsson U, Larsson E, Ogaard B. Bond failure of a no-mix adhesive during orthodontic treatment. Am J Orthod Dentofacial Orthop 2002;122:277-81.
22. Ramsundar K, Jain RK, Balakrishnan N, Vikramsimha B. Comparative evaluation of bracket bond failure rates of a novel non-primer adhesive with a conventional primer-based orthodontic adhesive – A pilot study. J Dent Res Dent Clin Dent Prospects 2023;17:35-9.
23. Samantha C, Sundari S, Chandrasekhar S, Sivamurty G, Dinesh S. Comparative evaluation of two bis-GMA based orthodontic bonding adhesives - A randomized clinical trial. J Clin Diagn Res 2017;11:ZC40-4.
24. Joseph R, Ahmed N, Younus AA, Bhat KRR. Evaluation of shear bond strength of a primer incorporated orthodontic composite resin: An in-vitro study. Cureus 2022;14: e24088.
25. Ok U, Aksakalli S, Eren E, Kechagia N. Single-component orthodontic adhesives: Comparison of the clinical and in vitro performance. Clin Oral Investig 2021;25:3987-99.
26. Krishnan S, Pandian S, Rajagopal R. Six-month bracket failure rate with a flowable composite: A split-mouth randomized controlled trial. Dental Press J Orthod 2017;22:69–76.
27. Sayahpour B, Buehling S, Kopp S, Jamilian A, Chhatwani S, Eslami S. Reliability of qualitative and quantitative assessment of adhesive remnants after debonding of ceramic brackets bonded with TransbondTMXT on human molar teeth: An in vitro study. Int Orthod 2022;20:100680.
28. Akl R, Ghoubril J, Gall ML, Shatila R, Alliez CP. Evaluation of shear bond strength and adhesive remnant index of metal APCTM flash-free adhesive system: A comparative in vitro study with APC™ II and uncoated metal brackets. Int Orthod 2022;20:100705.