

Effect of resin modified glass ionomer adhesive at different temperatures on the shear bond strength of orthodontic brackets

Authors:

Dr. Akash Mankare¹, Dr. Nitin Gulve², Dr. Amit Nehete³

¹Department of Orthodontics, KBH MGV's Dental College and hospital, Nashik- 422003, India.

²HOD and professor of department of Orthodontics, KBH MGV's Dental College and hospital, Nashik.

³Associate professor, Department of Orthodontics, KBH MGV's Dental College and hospital, Nashik.

Corresponding Author:

Dr. Akash Mankare

<https://doi.org/10.5281/zenodo.16747819>

Article Received: 25-June-2025, Revised: 14-July-2025, Accepted: 04-August-2025

ABSTRACT:

Aim: to compare and evaluate the effect of different temperatures of resin modified glass ionomer adhesive on the shear bond strength of orthodontic brackets. **Methods:** orthodontic brackets were bonded using resin modified glass ionomer cement on extracted premolar at four different temperature (4°C, 20°C, 37°C and 55°C). A universal measuring device was used to assess the shear bond strength with a crosshead speed of 0.5mm/min. Mode of bond failure was assessed using adhesive remnant index. One-way ANOVA, post hoc Tukey tests, and an independent t-test were used to analyse the data. **Result:** The shear bond strength of resin modified glass ionomer cement when heated at 37°C showed its highest strength and lowest when refrigerated at 4°C ($p < 0.001$). **Conclusion:** The bond strength of orthodontic brackets was improved by preheating resin modified glass ionomer cement to body temperature before bonding the brackets.

Keywords: Shear bond strength, Orthodontic brackets, resin modified glass ionomer adhesive, extracted premolars and adhesive remnant index.

INTRODUCTION:

Direct bonding of orthodontic brackets with composite resin was made possible because of the Buonocore's¹ development of the acid etch technique in 1955. This innovation resulted in improvements in orthodontic treatment, including greater comfort for the patient, elimination of pre-treatment separation, easier oral hygiene, improved aesthetics, and reduced gingival irritation.² However, the disadvantage of using composite resin is increased tolerance to moisture contamination during bonding leading to reduce incidence of bond failure.³ Also, the use of composites resins leads to plaque accumulation causing demineralization of enamel surrounding resin-bonded brackets leading to white spot lesions.⁴

In response to white spot lesions, manufacturers had attempted to increase fluoride emission levels of orthodontic adhesives. With the introduction of glass ionomer cement, the release of fluoride over the long term and generally at much higher levels than fluoride-releasing composites prevented enamel demineralization during orthodontic treatment.⁵ However, they have been found to have lower bond strength in the range of 2.37 to 5.5 Mpa with either phosphoric acid etch or polyacrylic acid conditioning.⁶

Resin modified glass ionomer adhesives were created to try and boost fluoride release and bond strength.⁷ Resin modified glass ionomer adhesive mimics glass ionomer cement with respect to fluoride release and fluoride recharging but widely varying bond strength have been reported ranging from 5.39 to 18.9MPa.⁸⁻⁹

While the majority of manufacturers advise keeping adhesive materials at room temperature, in clinical practise, physicians utilise the material straight from the refrigerator rather than waiting for it to warm up. Intriguingly, the low temperature can lead to a decrease in the effectiveness of the adhesive material.¹⁰

Friedman¹¹ described a polymerization method wherein a high degree of monomer conversion was obtained by heating the composite resin to 54-60°C, before the activation of the light. Preheating can lead to an increase in polymerization depth¹² and molecular mobility.¹³⁻¹⁴ In turn, polymer chains grow and polymerization is enhanced.¹⁵

Several factors affect the bond strength of orthodontic brackets, including temperature and humidity. Little is known about the effect of different temperatures of resin modified glass ionomer adhesive on shear bond strength of orthodontic brackets.¹⁶

Therefore, the purpose of this In-vitro study is to compare the effect of different temperatures of resin modified glass ionomer adhesive on the shear bond strength of orthodontic brackets

METHODS:

Preparation of samples:

The present cross-sectional in vitro study was performed in the MGV's KBH Dental college and hospital, Nashik. The study was approved by the ethical committee of KBH Dental College and hospital, Nashik. The sample size was calculated based on a power analysis using G*Power Software version 3.0.1 (Franz Faul universitat, Kiel, Germany). Total sample size of 80 teeth (i.e.20 premolar /samples per temperature; 4 study groups) would yield 80% power to detect significant differences, with effect size of

0.45 and significance level at 0.05. The 80 extracted premolars were mounted in pink coloured self cured acrylic blocks. Each tooth was placed in a metal mould in such a way that only crown portion of tooth was exposed and remaining root portion was embedded in acrylic resin (fig 1). The long axis of tooth remained parallel to long axis of acrylic block. (fig 1). Orthodontic metal premolar brackets (MBT 0.022" Gemini 3M Unitek, USA) were used for the present study. Using polishing brush and pumice, the buccal surface of mounted teeth was cleaned and rinsed thoroughly with distilled water.

All the samples were conditioned with 37% phosphoric acid for 30 seconds, teeth were then rinsed and air dried until frosted enamel surface appeared. The etched tooth surfaces were moistened with a cotton roll.



Figure 1: Mould for making acrylic blocks

Eighty premolar teeth were randomly assigned to four groups (n=20) for bonding with resin modified glass ionomer cement(GC Fuji Ortho LC) at various temperatures: Group A(4°C), Group B (20°C), Group C (37°C), and Group D (55°C).

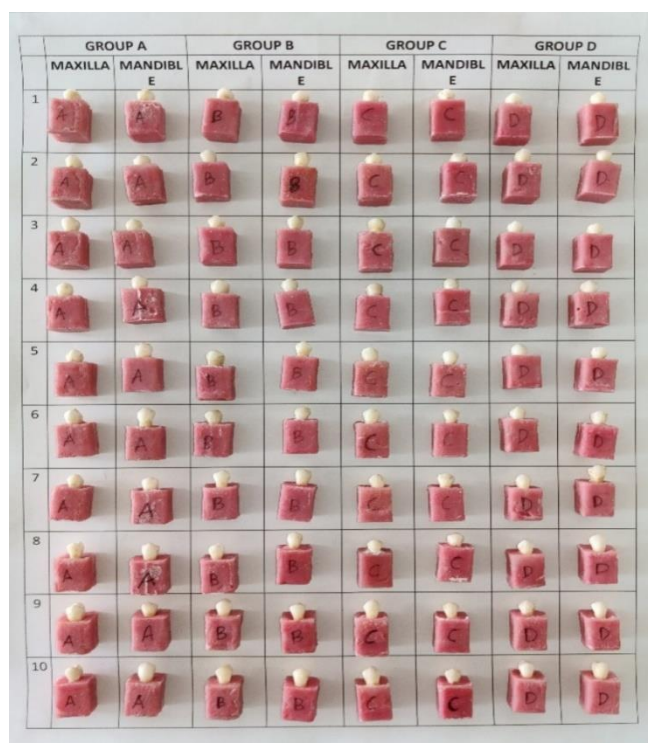


Fig 2: Human extracted premolars mounted on acrylic blocks (80 samples)

The Fuji Ortho LC was then removed from incubator and cement was mixed according to instructions of manufacturer, within 3 minutes of working time, and placed on base of bracket without any voids in it. Bracket was placed on buccal surface of tooth by bracket holding plier, enough force was applied to bracket. Excess adhesive was removed using explorer, bracket was light cured for 10 seconds each from mesial, distal, occlusal, gingival aspects. After bonding, all samples were stored in artificial saliva for 24 hours at room temperature in a water bath and then testing of shear bond strength was done while

debonding using universal testing machine (Twin Column Universal testing machine) (fig 3). The specimens were stressed in an occluso-lingual direction with a crosshead speed of 0.5 mm/min, with 50 KN load according to previous studies.¹⁷⁻²⁰ The maximum load necessary to debond or initiate bracket fracture was recorded in Newton's and then converted into megapascals as ratio of Newton's to surface area of the bracket (10.70mm²).

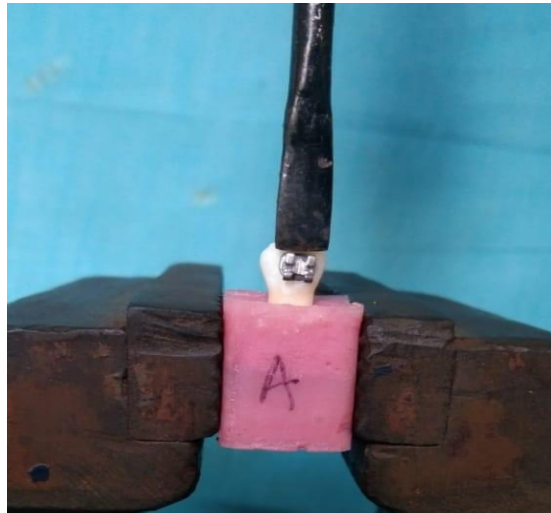


Fig 3: Shear bond strength testing of sample on a universal testing machine

After debonding brackets of all samples, the bond failure surfaces were examined using optical microscope at 10x magnification. The mode of bond failure was assessed using adhesive remnant index (Artun and Bergland),²¹ which defines mode of bond failure between the enamel, bracket base and adhesive. Enamel fractures if any during debonding were recorded.

Scores: 0: no adhesive left on tooth

1: less than half of adhesive left on tooth

2: more than half of adhesive left on tooth

3: all adhesive left on the tooth with distinct impressions of bracket mesh. pression of the bracket base, remaining (Figure 4).



Fig 4: Surface analysis of the bonded surface with Stereo-microscope to calculate Adhesive Remnant Index.

Statistical Analysis:

Statistical analysis was performed using Statistical Package for Social science (SPSS) version 21 for Windows (SPSSInc, Chicago, IL) of the SBS (MPa) data was performed using one-way ANOVA and post hoc Tukey tests on the normally distributed data (Shapiro–Wilks test). The frequency distribution of the ARI scores among the groups was evaluated using Pearson chi-squared test. Statistical significance was defined at $P < 0.05$.

RESULTS:

Table 1 depicts the shear bond strength of all samples. On overall comparison of shear bond strength of resin modified glass ionomer adhesive bonded at different temperatures, highly statistically significant ($p < 0.001$) difference was observed among four groups as depicted in table 2.

The mean shear bond strength values from higher to lower be in following sequence: -

Group C > Group B > Group D > Group A.

Table 3 shows pairwise comparative statistics of shear bond strength (in MPa) among four study groups using Tukey's Post Hoc test. It was found that Group A had lowest shear bond strength as compared to Group B, Group C and Group D and the difference was also found to be of highly statistical significance ($p < 0.001$). Group C had highest shear bond strength and the results were found to be of highly statistical significance ($p < 0.001$).

Table 4 depicts the values obtained by Adhesive remnant index scores in all eighty samples.

The frequency distribution of the Adhesive Remnant Index scores for all study groups is showed in Table 5.

Table 6 concluded that Group A vs Group B, Group A vs Group C, Group A vs Group D, Group B vs Group C, Group B vs Group D and Group C vs Group D showed no statistically significant difference in the ARI scores ($p > 0.05$).

Table 1: Mater table- Shear Bond Strength values in MPa (Megapascals) for all 80 samples.

Sr. No.	Group A	Group B	Group C	Group D
1	7.02	13.56	12.23	9.46
2	6.99	10.04	14.34	13.44
3	7.08	11.04	12.44	12.46
4	7.32	8.88	14.55	8.32
5	5.89	8.32	13.66	8.48
6	8.88	9.44	16.33	9.44
7	5.66	9.88	14.78	10.73
8	6.81	9.32	15.34	9.32
9	7.34	10.44	9.66	10.44
10	5.59	10.98	9.21	10.98
11	6.44	13.54	11.45	12.22
12	8.32	13.56	13.46	8.32
13	6.63	9.04	13.55	9.04
14	6.32	11.46	11.56	11.46
15	6.82	12.48	12.78	7.76
16	7.83	9.06	13.44	9.06
17	8.04	9.66	12.89	9.66
18	6.49	10.76	11.02	7.44
19	7.46	10.76	10.04	13.21
20	7.32	9.46	13.44	9.46

Table 2: Overall Comparative statistics of shear bond strength (in MPa) among four groups using one way ANOVA test.

	Mean	SD	P value significance
Group A	7.0125	0.8535	p<0.001*
Group B	10.584	1.619	
Group C	12.8085	1.894	
Group D	10.035	1.773	

Table 3: Pairwise comparative statistics of shear bond strength (in MPA) among four studies using Post Hoc tukey's test.

	Comparison group	Mean difference	P value significance
Group A	Group B	-3.572	p<0.001*
	Group C	-5.796	p<0.001*
	Group D	-3.023	p<0.001*
Group B	Group C	-2.225	p<0.001*
	Group D	0.5490	p > 0.05
Group C	Group D	2.774	p<0.001*

Table 4: Adhesive Remnant Index scores of all 80 samples

Sr. No.	Group A	Group B	Group C	Group D
1	2	3	1	1
2	1	1	2	2
3	2	0	0	1
4	3	0	2	2
5	0	1	1	3
6	0	3	3	0
7	1	2	1	3
8	2	1	1	1
9	3	0	1	2
10	2	0	3	1
11	3	1	0	3
12	3	1	1	0
13	2	3	0	2
14	3	3	2	1
15	3	0	1	3
16	2	2	2	1
17	1	2	3	3
18	3	1	3	2
19	1	2	2	0
20	0	1	1	1

Table 5: Adhesive Remnant Index Score Distribution

	Score 0 n (%)	Score 1 n (%)	Score 2 n (%)	Score 3 n (%)
Group A	3 (15%)	4 (20%)	6 (30%)	7 (35%)
Group B	5 (25%)	7 (35%)	4 (20%)	4 (20%)
Group C	3 (15%)	8 (40%)	5 (25%)	4 (20%)
Group D	3 (15%)	7 (35%)	5 (25%)	5 (25%)

Table 6: Comparative Statistics of Adhesive Remnant Index Score in different studygroups.

Overall Comparison^ (Group A vs B vs C vs D)	P value
Group A vs Group B	Chi square test value = 2.536, p = 0.469 (no statistical significant difference)
Group A vs Group C	Chi square test value = 2.242, p = 0.524 (no statistical significant difference)
Group A vs Group D	Chi square test value = 1.242, p = 0.743 (no statistical significant difference)
Group B vs Group C	Chi square test value = 0.678, p = 0.878 (no statistical significant difference)
Group B vs Group D	Chi square test value = 0.722, p = 0.868 (no statistical significant difference)
Group C vs Group D	Chi square test value = 0.178, p = 0.981 (no statistical significant difference)
	p>0.05 no statistical difference.

DISCUSSION:

Preheating resin systems prior to photopolymerization have many potential advantages like increasing the degree of conversion,²² increasing the surface hardness.²³ Previous studies have showed that preheating increased the flow and enhance the adaptation of the resin to the prepared tooth walls and, thus, potentially reduced microleakage.²⁴ Flow of commercial resin composites could be increased by preheating.²⁵ The overall extent and rate of monomer conversion in resin systems cured at higher temperatures are better than that performed at room temperature.^{22,26} In recent studies a significant increase in conversion were observed upon preheating.^{27,28}

In the current study, the samples were divided into four groups with 20 samples with each group containing 10 maxillary and 10 mandibular human premolar teeth. Total sample size of 80 samples (20 samples per group, 10 maxillary and 10 mandibular extracted human premolar teeth; 4 study groups). In the present study, the premolar brackets (MBT 0.022" Gemini 3M Unitek, USA) were used for bonding to the extracted teeth. The light cured adhesive used in the present investigation for bonding the brackets to the extracted teeth was Ortho Fuji LC (GC Corporation, Tokyo, Japan).

The resin modified glass ionomer cement was stored at four different types of temperatures and the groups that were formulated according it to were refrigerated at

4°C, room temperature at 20°C, body temperature at 37°C and heated at 55°C. Each sample was tested for shear bond strength by universal testing machine and further tested for Adhesive remnant index by a stereomicroscope.

The resin modified glass ionomer cement when refrigerated at 4°C showed the least shear bond strength of 7.01MPa(Table 2). On pairwise comparison using tukeys post hoc test, 4°C had lower shear bond strength as compared to 20°C, 37°C and 55°C, and highly statistically significant (p<0.001) difference was observed among four study groups (Table 3).

On comparison of mean shear bond strength, resin modified glass ionomer cement at 20°C had shear bond strength slightly higher than the resin modified cement heated at 55°C but the results were statistically insignificant(p>0.05). The mean shear bond strength of resin modified glass ionomer cement at 20°C and 55°C was 10.58 and 10.03 MPa respectively (Table 2 and 3).

The resin modified glass ionomer adhesive at 37°C showed highest mean shear bond strength among all the groups with bond strength of 12.8 MPa (Table 2). On pairwise comparison using tukey's post hoc test, Group C showed highest shear bond strength as compared to other groups and highly statistically significant (p<0.001) difference was observed in comparison with other groups (Table 3).

In the current study, the least bond strength values were achieved at 4°C (Table 2). Here, the preheated Resin modified glass ionomer cement up to 37°C

demonstrated greater Shear bond strength values than the lower temperature adhesive systems. At low temperatures, the resin component of resin modified glass ionomer cement increases adhesive viscosity significantly,^{29,30} making it difficult to wet the oral tissue due to a decrease in the adhesive speed. The decrease in viscosity, the rise in reactive mobility, and the degree of transformation all contribute to this increase in Shear bond strength values as seen in the present study.

Furthermore, when the resin modified glass ionomer cement used in this study were heated up to 55°C, the Shear bond strength values were found to be lower than those obtained at 37°C. Resin component of resin modified glass ionomer cement, such as HEMA, MDP and BIS GMA, can be chemically deteriorated due to their unsuitability for high temperature.³¹ As a result, the bond strength of the adhesive might decrease.

Adhesive remnant index is the most valuable way to assess the type of bond failure. Low adhesive remnant index score achieved with any bonding system is significant clinically in preventing major loss of enamel as less adhesive remains on tooth surface need minimum amount of cleaning and polishing. The scoring of adhesive remnant index is more subjective in nature but still it provides an insight into the type of bond failure which is valuable in studies of orthodontic adhesive systems.

The resin modified glass ionomer cement at 4°C showed highest score of 3 in 35% of samples among all the groups, indicating more of adhesive remains on tooth surface and increased loss of enamel surface while cleaning and polishing of the surface (Table 5).

The resin modified glass ionomer cement at 20°C, 37°C and 55°C showed highest score of 1 with 35%, 40% and 35% among the samples respectively. Score 1 is considered as good score indicating reduced loss of enamel surface while cleaning and polishing it after debonding (Table 5).

Subsequently, intergroup comparison of Adhesive remnant index scores of this study was done between four groups using Pearson Chi square test, and no differences were detected between the body temperature and the other temperatures with respect to the highest shear bond strength results (Table 6).

Adhesive remnant index scores and shear bond strength were found to be directly correlated by Faria-Junior et al.³² A high adhesive remnant index score correlates with a high shear bond strength value. The greatest bonding strength values in certain groups were found to have distinct adhesive remnant index scores in the current investigation, making it difficult to forecast the type of failure for a given bonding force. As a result, it's possible that the results for bonding strength and adhesive remnant index scores are incompatible.

Limitations of the present study:

It should be stressed that as this was an in vitro study, the test circumstances were not exposed to the stresses, temperature swings, changing electrolytes, microbes, or other highly changeable oral cavity elements that characterise the oral environment. This means that the findings of this study cannot be applied to the intraoral environment. Bond strength is affected by a number of substrate-related factors, including tooth type and source, orientation of enamel prisms, age of tooth donors, storage medium and time, bonding area of test samples, operator abilities, and procedure.

CONCLUSION:

On overall comparison of shear bond strength of orthodontic brackets bonded at different temperatures with resin modified glass ionomer cement adhesive showed highest shear bond strength when heated at 37°C and lowest at 4°C. There was statistically insignificant difference of Adhesive Remnant Index score between all the groups.

Hence, it can be concluded that preheating of resin modified glass ionomer cement to body temperature before bonding the brackets in the orthodontic treatment increases the adhesion of the brackets.

REFERENCES:

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res* 1955;34:849-53.
2. Bishara SE, Olsen ME, Jakobsen JR. Evaluation of a new light-cured orthodontic bonding adhesive. *Am J Orthod Dentofacial Orthop* 1998;114:80-7.
3. Yassaei S, Davari A, Moghadam MG, Kamaei A. Comparison of shear bond strength of RMGI and composite resin for orthodontic bracket bonding. *Int J Dent* 2014;11:282.
4. Øgaard B. Prevalence of white spot lesions in 19-year-olds: A study on untreated and orthodontically treated persons 5 years after treatment. *Am J Orthod Dentofacial Orthop* 1989;96:423-7.
5. Forsten L. Short and long term fluoride release from glass ionomers and other fluoride containing filling materials in vitro. *Eur J Oral Sci* 1990;98:179-85.
6. Wiltshire WA. Shear bond strengths of a glass ionomer for direct bonding in orthodontics. *Am J Orthod Dentofacial Orthop* 1994;106:127-30.

7. Rix D, Foley TF, Mamandras A. Comparison of bond strength of three adhesives: composite resin, hybrid GIC, and glass-filled GIC. *Am J Orthod Dentofacial Orthop* 2001;119:36-42.
8. Lippitz SJ, Staley RN, Jakobsen JR. In-vitro study of 24-hour and 30-day shear bond strengths of three resin–glass ionomer cements used to bond orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1998;113:620-4.
9. Cacciafesta V, Jost-Brinkmann PG, Süßenberger U, Miethke RR. Effects of saliva and water contamination on the enamel shear bond strength of a light-cured glass ionomer cement. *Am J Orthod Dentofacial Orthop* 1998;113:402-7.
10. Bishara SE, VonWald L, Laffoon JF, Warren JJ. The effect of temperature changes on the shear bond strength of composite and glass-ionomer adhesives. *World J Orthod* 2002;3:154-8.
11. Friedman J. Thermally assisted polymerization of composite resins. *Contemp Esthetics Rest Practice* 2003;7:46-55.
12. Borges GA, Spohr AM, Oliveira WJ, Correr-Sobrinho L, Correr AB, Borges LH. Effect of refrigeration on bond strength of self-etching adhesive systems. *Braz Den J* 2006;17:186-90.
13. Daronch M, Rueggeberg FA, Moss L, De Goes MF. Clinically relevant issues related to preheating composites. *J Esthet Restor Dent* 2006;18:340-50.
14. Mundim FM, Garcia LD, Cruvinel DR, Lima FA, Bachmann L, Pires-de FD. Color stability, opacity and degree of conversion of pre-heated composites. *Int J Dent* 2011;39:25-9.
15. Akarsu S, Aktuğ Karademir S. Influence of Bulk-Fill Composites, Polimerization Modes, and Remaining Dentin Thickness on Intrapulpal Temperature Rise. *Biomed Res Int* 2019;4:163-9.
16. Nystrom GP, Holtan JR, Phelps RA, Becker WS, Anderson TB. Temperature and humidity effects on bond strength of a dentinal adhesive. *Oper Dent* 1998;23:138-43.
17. Jobalia SB, Valente RM, de Rijk WG, BeGole EA, Evans CA. Bond strength of visible light-cured glass ionomer orthodontic cement. *Am J Orthod Dentofacial Orthop*. 1997;112(2):205-8
18. Sfondrini ME, Cacciafesta V, Pistorio A, Sfondrini G. Effects of conventional and high-intensity light-curing on enamel shear bond strength of composite resin and resin-modified glass ionomer. *Am J Orthod Dentofacial Orthop*. 2001;119(1).30-5.
19. Milett DT, Cattanaach D, McFadzean R, Pattison J, McColl J. Laboratory evaluation of a compomer and resin-modified glass ionomer cement orthodontic bonding. *Angle Orthod*. 1999;69(1):58-63.
20. Cacciafesta V, Bosch C, Melsen B. Clinical comparison between resin-reinforced self-cured glass ionomer cement and a composite resin for direct bonding of orthodontic brackets. Part 2: Bonding on dry enamel and on enamel soaked with saliva. *Clin Orthod Res*. 1999;2(4):186-93
21. Årtun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod Dentofacial Orthop* 1984;85:333-40.
22. Fan XC & Chen L. Effects of enamel surface preparation on bonding strength of resin modified glass ionomer cement: an in vitro study. *J of adhesion science and technology* 2017;31:2300 2311.
23. Daronch M, Rueggeberg FA, De Goes MF. Monomer conversion of pre-heated composite. *J Dent Res*. 2005;84:663–667.
24. Daronch M, Rueggeberg FA, De Goes MF. Monomer conversion of pre-heated composite. *J Dent Res*. 2005;84:663–667.
25. Lovell LG, Lu H, Elliott JE, Bowman CN. Understanding the kinetics and network formation of dimethacrilate dental resins. *Polym Adv Technol*. 2001;12:335–345.
26. Lovell LG, Lu H, Elliot JE, Stansbury JW, Bowman CN. The effect of cure rate on the mechanical properties of dental resins. *Dent Mater*. 2001;17:504–511.
27. Blalock JS, Holmes RG, Rueggeberg FA. Effect of temperature on unpolymerized composite resin film thickness. *J Prosthet Dent*. 2006;96:424–432

28. Prasanna N, Pallavi Reddy Y, Kavitha S, Lakshmi Narayanan L. Degree of conversion and residual stress of preheated and room-temperature composites. *Indian J Dent Res.* 2007;18:173–176.
29. Vale M, Afonso F, Borges B, Freitas AC Jr, Farias-Neto A, Almeida EO, Souza-Junior EJ, Geraldeli S. Preheating impact on the degree of conversion and water sorption/solubility of selected single-bottle adhesive systems. *Oper Dent.* 2014;39:637-643
30. Silikas N, Watts D. Rheology of urethane dimethacrylate and diluent formulations. *Dent Mater.* 1999;15:257-261.
31. Salz U, Zimmermann J, Zeuner F, Moszner N. Hydrolytic stability of self-etching adhesive systems. *J Adhes Dent.* 2005;7:107-116.
32. Faria-Júnior ÉM, Guiraldo RD, Berger SB, Correr AB, Correr-Sobrinho L, Contreras EF, Lopes MB. In-vivo evaluation of the surface roughness and morphology of enamel after bracket removal and polishing by different techniques. *Am J Orthod Dentofacial Orthop.* 2015;147:324-329.