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Comparison of demineralization around orthodontic brackets cured by conventional method and transillumination technique-an *in vitro* evaluation

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Abstract:

OBJECTIVE: To compare demineralization around orthodontic brackets cured by conventional method and transillumination method.

MATERIALS AND METHOD: Sixty freshly extracted human premolar teeth were divided into four groups. Group 1: Brackets bonded with conventional method of bonding by curing labially for 40 sec. Group 2: Brackets bonded with transillumination method of bonding for 50 sec. Group 3: Brackets bonded with conventional method of bonding by curing labially for 20 sec followed by 30 sec of transillumination. Group 4: Brackets bonded with transillumination method of bonding for 30 sec followed by labial curing for 20 sec. Ground sections were prepared of each tooth and microleakage was evaluated using a binocular microscope at 40× magnification (Olympus BX53) and an image was taken using a digital camera (Olympus EPL3) connected to the microscope. The images were analyzed using Magnus Pro Image software. Scores were assigned to different degrees of microleakage at the demineralization zone around enamel-adhesive-bracket complex at the occlusal, middle, and gingival margins using linear measurement tool. Data obtained was subjected to statistical analysis using SPSS software (Version 20.0). Level of significance was kept at 5%. Intragroup comparison was done using Kruskal-Wallis test followed by Mann-Whitney U-tests for pairwise comparison.

RESULTS: Group 4 showed least mean demineralization in occlusal, middle, and cervical areas as compared to other groups and the results were statistically significant ($P < 0.05$).

CONCLUSION: Transillumination can be employed as a method synergistically with conventional curing to achieve minimum amount of demineralization during fixed orthodontic treatment.

Keywords:

Bonding, demineralization, transillumination

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Introduction

Demineralization of enamel adjacent to orthodontic brackets is a widely acknowledged risk of orthodontic treatment and remains the most concerning aspect of fixed appliance therapy.[1] The complex structure of orthodontic brackets renders their periphery an amenable site for the retention of bacterial plaque and hence a potential risk for enamel demineralization. The prevalence of enamel demineralization after fixed orthodontic appliance placement includes up to 50% of patients when no preventive fluoride programs were used.[2]

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Most studies that have investigated the quality of the attachment of brackets to the tooth have used the conventional curing method with light directed from the sides of the bracket. However, the convexity of the labial tooth surface and the bracket material hinder or obstruct direct light propagation resulting in incomplete polymerization of the adhesive in the center of the bracket. It has been shown previously that polymerization of the adhesive under a metal bracket can be enhanced by adding light transmitting glass fibers in the resin interface.

As an alternative method to increase the degree of cure, light curing through the tooth has been suggested. However, there are only a few studies that have investigated the viability of this curing method. Despite the fact that most of the manufacturers advise to cure the orthodontic adhesive from the sides of the bracket, sometimes it has some clinical difficulties. Therefore, studies concerning light curing through the tooth are important not only to orthodontics but also for prosthetic treatment, for example curing ceramic fillings through the enamel.[3]

Although little information can be found in the orthodontic literature to confirm the usefulness of transillumination, there is a general agreement on increasing the curing time while using this technique. King *et al*.[4] tripled the trans-illumination curing time and found proper shear bond strength values regardless of the bucco-lingual thickness of the teeth ranging from 3.4 to 7 mm The purpose of this study was to compare demineralization around orthodontic brackets cured by conventional curing technique and transillumination technique.

Materials and Method

Study Setting

The study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, I.T.S.-CDSR, Muradnagar to compare demineralization around orthodontic brackets cured by conventional method and transillumination method. The study was approved by the Institutional Ethical Review Board.

Sample collection

Sixty freshly extracted human premolar teeth were taken for the study. These teeth were without caries, hypoplastic areas, cracks, or gross irregularities of the enamel structure and were stored in distilled water solution at room temperature. Immediately before bonding, teeth were cleaned with a scaler and pumiced to remove soft-tissue remnants, calculus, and plaque.

Bonding procedure

Specimens were prepared for bracket bonding according to the following procedures: 37% phosphoric acid gel (3M ESPE, Seefeld, Germany) was used to etch the teeth for 30 sec. The teeth were then rinsed with water from a 3-way syringe for 30 sec and dried with an oil-free air source for 20 sec. Subsequently, the liquid primer Transbond XT (3M Unitek, Monrovia, Calif) was applied to the etched surface. MBT premolar stainless-steel brackets (Victory series 3M Unitek) were bonded to teeth with Transbond XT light cure adhesive paste. Excess resin was removed with an explorer before it was polymerized and cured with the following varying procedures:

Group 1: 15 teeth were cured by conventional method of bonding by curing labially for 40 sec

Group 2: 15 teeth were cured for 50 sec by transillumination

Group 3: 15 teeth were cured labially for 20 sec followed by 30 sec of transillumination

Group 4: 15 teeth were first cured by transillumination for 30 sec followed by labial curing for 20 sec.

Section preparation

After curing, the specimens were immersed in an unstirred demineralizing solution[5] for 24 hours at pH 4. The teeth were further sealed with nail varnish wherein the buccal surfaces of all the teeth were coated with two consecutive layers of nail varnish. The samples were then immersed in distilled water to prevent dehydration. All the teeth were cut using a diamond disc mounted on low-speed hand piece motor under water irrigation. Longitudinal ground sections in mesiodistal plane were prepared using a laboratory lathe under the continuous cooling of water until the desired thickness was reached. Sections were then reduced using coarse side of an Arkansas stone, followed by the finer side and finally polished using 0.05 μm particle size aluminum oxide polishing paste to a thickness of approximately 100-200 μm. Later, the ground sections were cleaned carefully with xylene and mounted on glass slides using quinoline as the mounting media.

Photomicrographs were taken focusing on the demineralization around enamel-adhesive-bracket complex at the occlusal, middle, and gingival margins using Olympus EPL3 digital camera at 10× and 40× magnification and were then projected from the microscope to a monitor.

Polarized light microscopy

When examined in quinoline, a 30-40-μm-thick surface zone appeared distinctly positive birefringent, indicating that the outermost enamel reacted as a molecular sieve. Because of the lower content of minerals, the interpretation of this zone differed from that of similar "dark zones" observed in hypomineralized enamel.

Microleakage evaluation

Microleakage in each sample was evaluated using a binocular microscope at 40× magnification (Olympus BX53)

and an image was taken using a digital camera (Olympus EPL3) connected to the microscope [Figures 1-4]. The images obtained were analyzed using Magnus Pro Image software which enabled measurements to be made using different tools. Finally, a score was assigned to the different degrees of microleakage at the demineralization zone around enamel-adhesive-bracket complex at the occlusal, middle, and gingival margins using linear measurement tool. Average of three counted values was taken to avoid intra observer variability [Figure 5].

Statistical analysis

Statistical analysis was performed using SPSS software (Version 20.0). Level of significance was kept at 5%. Intragroup comparison was done using Kruskal-Wallis test followed by Mann-Whitney U-tests for pairwise comparison.

Results

On comparing demineralization scores within each study group, in group 1 demineralization on middle side (930.60) was significantly higher than cervical side (836.01) and occlusal side (660.3) (P = 0.001). Intergroup comparison of demineralization within group 1 showed significant difference among occlusal side and middle side (P = 0.001) and among occlusal side and cervical side (P = 0.044). Difference in demineralization between middle side and cervical side was non-significant (P = 0.237) [Table 1].

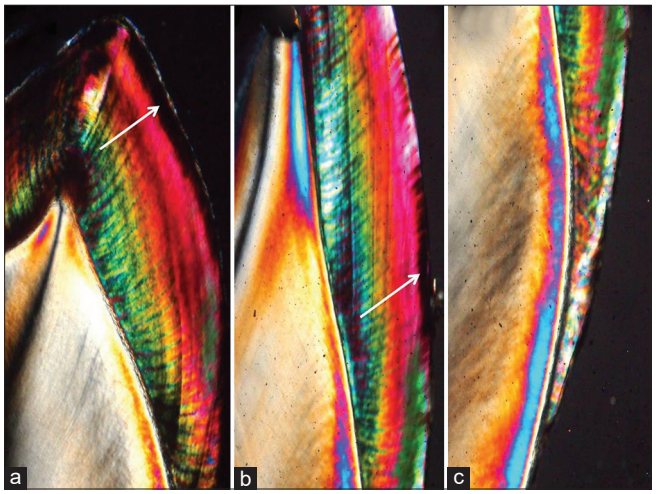


Figure 1: Photomicrograph representative of negatively birefringent demineralization zone in Group 1 enamel at occlusal (a), middle (b) and cervical third (c) area under polarizing microscopy with quinoline. At the lesion front, a zone with a higher degree of demineralization is seen. (Ground Section, PLM 10× magnification)

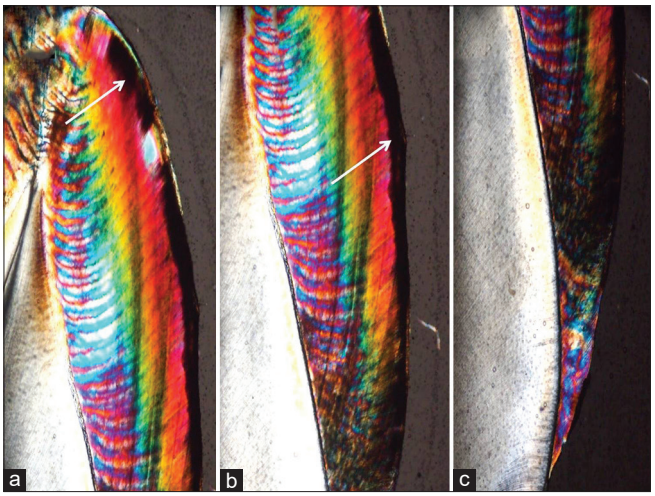


Figure 2: Photomicrograph representative of negatively birefringent demineralization zone in Group 2 enamel at occlusal (a), middle (b) and cervical third (c) area under polarizing microscopy. The lesion is seen as a non uniform demineralized zone, with a positive birefringent bulk below a negatively birefringent surface layer (Ground Section, PLM 10× magnification)

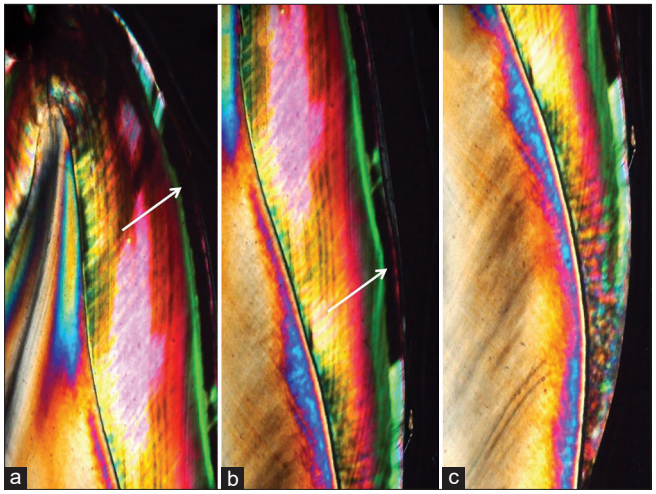


Figure 3: Photomicrograph representative of comparatively uniform negatively birefringent demineralization zone in Group 3 enamel at occlusal (a), middle (b) and cervical third (c) area under polarizing microscopy (Ground Section, PLM 10× magnification)

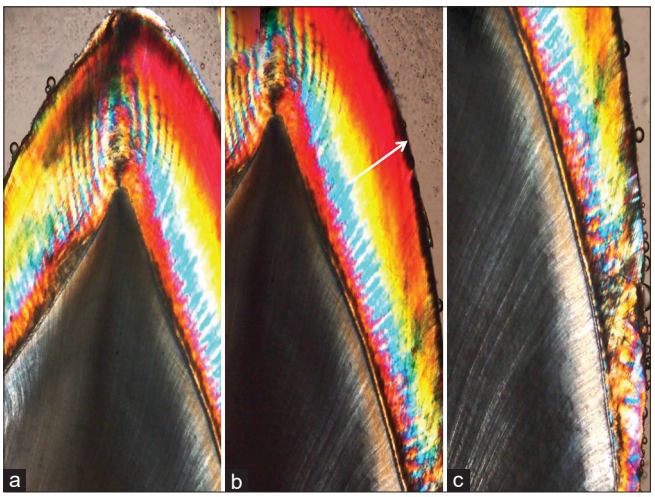


Figure 4: Photomicrograph representative of negatively birefringent demineralizing surface zone in Group 4 enamel at occlusal (a), middle (b) and cervical third (c) area under polarizing microscopy (Ground Section, PLM 10× magnification)

Within group 2, demineralization on occlusal side (1057.52) was significantly higher than cervical side (1014.97) and middle side (874.86) (P = 0.023). Intergroup comparison of demineralization within group 2 showed significant difference among occlusal side and middle side (P = 0.010). Difference in demineralization between occlusal side and cervical side was non-significant (P = 0.290). Difference in demineralization between middle side and cervical side was also non-significant (P = 0.065).

Within group 3, demineralization on cervical side (684.91) was significantly higher than middle side (562.31) and occlusal side (523.00) (P = 0.035). Intergroup comparison of demineralization within group 3 showed significant difference among occlusal side and cervical side (P = 0.008). Difference in demineralization between occlusal side and middle side was non-significant (P = 0.290). Difference in demineralization between middle side and cervical side was also non-significant (P = 0.165).

Within group 4, demineralization on cervical side (466.41) was significantly higher than middle side (446.47) and occlusal side (332.66) (P = 0.001). Intergroup comparison of demineralization within group 4 showed significant difference among occlusal side and middle side (P = 0.008) and among occlusal side and cervical side (P = 0.002). Difference in demineralization between middle side and cervical side was non-significant (P = 0.395) [Graph 1].

When comparing demineralization scores on each side of tooth among different groups, on the occlusal side, group 2 showed significantly higher demineralization score than other study groups (P = 0.001). Group 2 showed maximum demineralization score (1057.52) followed by group 1 (660.30) and group 3 (523.00). Group 4 showed least demineralization score on occlusal side (332.66). On middle side, group 1 showed significantly higher demineralization score than other study groups (P = 0.001). Group 1 showed maximum demineralization score (930.60) followed by group 2 (874.86) and group 3 (562.31). Group 4

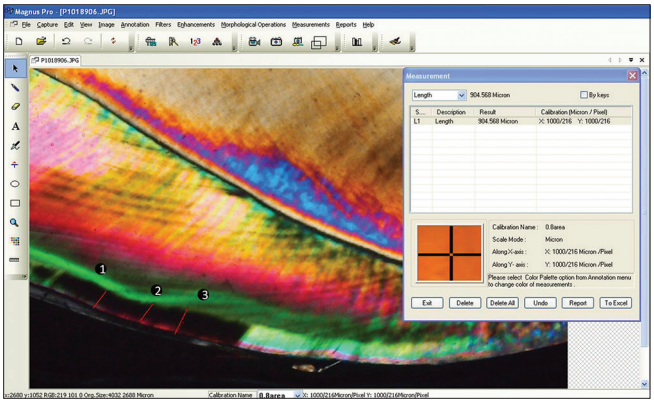
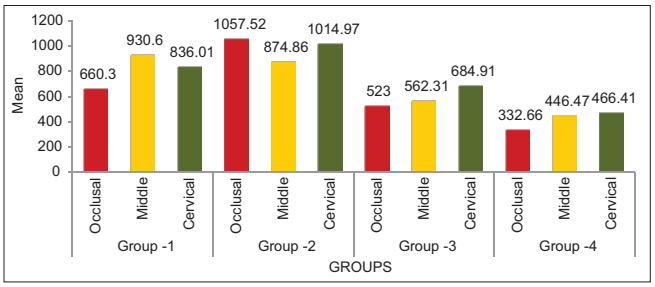


Figure 5: Linear depth measurement of demineralization zone in enamel under polarizing microscopy using morphometric analysis (Magnus-Pro image analysis software)



Graph 1: Comparison of the Demineralization Scores in Group 1, Group 2, Group 3, and Group 4 among Occlusal, Middle, and Cervical

Table 1: Comparison of the Demineralization Scores in Group 1, Group 2, Group 3 and Group 4 among Occlusal, Middle and Cervical

Groups	Mean±SD	*P*	O vs M MD (*P*)	O vs C MD (*P*)	M vs C MD (*P*)
Group 1					
Occlusal (O)	660.30±156.94	0.001*	270.30 (0.001*)	175.71 (0.044*)	94.59 (0.237)
Middle (M)	930.60±258.09				
Cervical (C)	836.01±272.00				
Group 2					
Occlusal (O)	1057.52±226.08	0.023*	182.66 (0.010*)	42.55 (0.290)	140.11 (0.065)
Middle (M)	874.86±151.52				
Cervical (C)	1014.97±190.18				
Group 3					
Occlusal (O)	523.00±165.19	0.035*	39.31 (0.290)	161.91 (0.008*)	122.60 (0.165)
Middle (M)	562.31±208.94				
Cervical (C)	684.91±177.60				
Group 4					
Occlusal (O)	332.66±135.51	0.001*	113.81 (0.008*)	133.75 (0.002*)	19.94 (0.395)
Middle (M)	446.47±102.78				
Cervical (C)	466.41±63.74				

Kruskal-Wallis *H* test; Mann-Whitney *U* test; *indicates significant difference at $P \leq 0.05$; MD: Mean Difference

showed least demineralization score on middle side (446.47). On cervical side, group 2 showed significantly higher demineralization score than other study groups ($P = 0.001$). Group 2 showed maximum demineralization score (1014.97) followed by group 1 (836.01) and group 3 (684.91). Group 4 showed least demineralization score on cervical side (466.41) [Table 2].

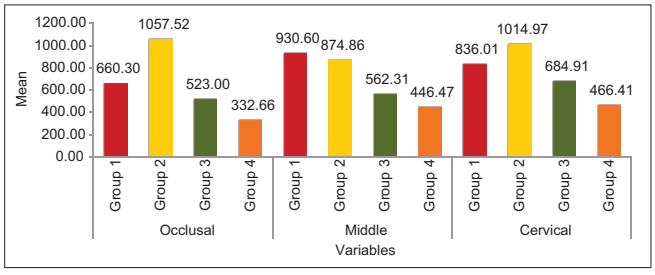
Pairwise or intergroup comparison of demineralization scores within occlusal, middle, and cervical sides among the study groups showed that on occlusal side, difference in demineralization scores in between all the tested pairs was significant ($P \leq 0.05$). On the middle side, difference in demineralization scores in between group 1 and group 2 was non-significant ($P = 0.237$). Rest all the pairs showed significant difference on middle side ($P \leq 0.05$). On cervical side, difference in demineralization scores in between group 1 and group 3 was non-significant ($P = 0.065$). Rest all the pairs showed significant difference on cervical side ($P \leq 0.05$) [Table 3 and Graph 2].

Discussion

Enamel decalcification during fixed orthodontic treatment is a major concern for clinicians. This process occurs rapidly and mineral loss has been reported even within a few months of treatment initiation.[6] Studies of orthodontic bracket (James *et al*., 2003; Arhun *et al*., 2006; Arikan *et al*., 2006) and band (Gillgrass *et al*., 1999) microleakage are few but in all of them some degree of demineralization due to microleakage has been observed. Therefore, although the area around a bracket is critical to the development of decalcification, the area beneath the bracket also requires investigation (Arhun *et al*., 2006).[7] The aim of the current study was to compare the amount of demineralization of enamel following the use of two different methods of light curing.

The assumption that the contraction of photo-activated composite resins is directed toward the light source,[8] and also the problem of not being able to directly cure the composite resin under metal brackets led to the idea of evaluating transillumination as a method of curing in this study. Behrents *et al*., also supported the use of this technique for bonding of lingual attachments due to its practical application in the oral environment.[9]

Another point that needed to be taken into consideration was that the greater the light energy received by the composite, the greater the polymerization; therefore, transillumination must provide greater light energy than direct curing. Since pulpal temperature should not exceed 5°-6° C, extending the exposure time should be done with caution. With 1 mm of dentine between the composite and the pulp, the temperature increases to 6°C with 40 seconds of continuous exposure.[6] Hence two different combinations of conventional curing and transillumination were used with varying time were assessed.



Graph 2: Comparison of the Demineralization Scores in Occlusal, Middle and Cervical among Group 1, Group 2 and Group 3 and Group 4

Table 2: Overall comparison of the Demineralization Scores within occlusal, middle and cervical sides

Side	Group	Mean±SD	*P*
Occlusal	Group 1	660.30±156.94	0.001*
	Group 2	1057.52±226.08	
	Group 3	523.00±165.19	
	Group 4	332.66±135.51	
Middle	Group 1	930.60±258.09	0.001*
	Group 2	874.86±151.52	
	Group 3	562.31±208.94	
	Group 4	446.47±102.78	
Cervical	Group 1	836.01±272.00	0.001*
	Group 2	1014.97±190.18	
	Group 3	684.91±177.60	
	Group 4	466.41±63.74	

Kruskal-Wallis *H* test; *indicates significant difference at $P \leq 0.05$

Table 3: Pairwise comparison of demineralization scores within occlusal, middle and cervical sides

Side	Comparison pairs	Mean difference	*P*
Occlusal	Gr 1 vs Gr 2	397.22	0.001*
	Gr 1 vs Gr 3	137.30	0.033*
	Gr 1 vs Gr 4	327.64	0.001*
	Gr 2 vs Gr 3	534.52	0.001*
	Gr 2 vs Gr 4	724.86	0.001*
	Gr 3 vs Gr 4	190.34	0.002*
Middle	Gr 1 vs Gr 2	55.74	0.237 (NS)
	Gr 1 vs Gr 3	368.29	0.001*
	Gr 1 vs Gr 4	484.13	0.001*
	Gr 2 vs Gr 3	312.55	0.001*
	Gr 2 vs Gr 4	428.39	0.001*
	Gr 3 vs Gr 4	115.84	0.040*
Cervical	Gr 1 vs Gr 2	178.96	0.050*
	Gr 1 vs Gr 3	151.10	0.065 (NS)
	Gr 1 vs Gr 4	369.60	0.001*
	Gr 2 vs Gr 3	330.06	0.001*
	Gr 2 vs Gr 4	548.56	0.001*
	Gr 3 vs Gr 4	218.50	0.001*

Mann-Whitney *U* test;* indicates significant difference at $P \leq 0.05$;
NS: Non-significant

Cervical side showed maximum mean demineralization score in our study. This finding is in agreement to the study done by Ulker *et al*.[10] who compared microleakage under orthodontic brackets cured by different types of LCU (Light Curing Unit). Arhun *et al*. indicated that microleakage scores obtained from the incisal and gingival margins of the brackets demonstrated significant differences, implying increased microleakage on the gingival side.[11] These findings corroborate with those of our study where demineralization on cervical area was more than middle and occlusal. In our study, only at the gingival margin of the samples, a significant amount of microleakage was observed. This may be explained by the gradual increase of buccolingual width from the incisal toward the gingival side. Consequently, although some studies reported adequate bond strength by transillumination, microleakage should be a concern especially in teeth with greater thickness as stated by Arhun *et al*.[11]

In studies by Ramuglu *et al*. and Uysal *et al*., light was irradiated from the occlusal surface and a significant amount of microleakage was reported at the gingival margin. They reasoned that this result might be due to the degradation of light intensity and insufficient polymerization of composite.[12]

Factor that should be taken into account regarding the microleakage scores is a phenomenon called percolation. The linear coefficient of thermal expansion for enamel, metal brackets and the adhesive is not the same (α = 12 for enamel, α = 16 for stainless steel brackets and α = 20-55 ppm/c for composite resin). These materials expand and contract at different rates when hot and cold foods are consumed; thus, the fluids are sucked in and pushed out at the margins of the brackets bonded to the teeth in both tooth-adhesive and adhesive-bracket interfaces. This can lead to microbial leakage at both interfaces.[11,13]

In vitro, microleakage is commonly assessed to detect bond failure at the enamel sealant interface through dye penetration. This failure can be due to polymerization shrinkage or different linear coefficients of thermal expansion from tooth hard substances and resin materials. Thermal cycles are widely used to simulate temperature changes in the mouth, generating successive thermal stresses at the tooth-resin interface. Several studies indicated that an increase in the number of thermal cycles was not related to an increase in microleakage of restorations.[14,15] Therefore, thermocycling was not performed in this study.

In our study, transillumination alone for 50 sec showed highest amount of demineralization followed by conventional labial curing. This is not in agreement with Oesterle and Shellhart[16] who reported comparable bond strength in the group using transillumination for 50 seconds with the group cured for 40 seconds at the margins as well as with Heravi *et al*.[17] who stated that to achieve an acceptable bracket bond strength to the posterior teeth, doubling the curing time from 40 to 80 seconds and increasing the light intensity to 800 mW/cm2 during the transillumination technique would give better results. Since, demineralization scores were more in individual transillumination curing technique and individual labial curing technique as compared to a combination of both, a combination technique like transillumination followed by labial curing can be employed to lessen the amount of demineralization.

It is impossible to extrapolate the results of an *in vitro* study to the actual oral environment; thus, future studies are necessary for further assessment of results.

Conclusion

Within the best of resources available for this in-vitro study, use of transillumination along with labial (conventional) curing caused least demineralization compared to the other methods.

Clinically, transillumination can be employed as a method synergistically with conventional curing to achieve minimum amount of demineralization during fixed orthodontic treatment.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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