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The Influence of Surface Roughness and Conditioner on The Shear Bond Strength of Glass Ionomer Cement to Dentin

Muharri AF[1], Suprastiwi E[2], Djauharie N[2]

[1] *Department of Operative Dentistry, Faculty of Dentistry, Universiti Kebangsaan Malaysia, Malaysia*

[2] *Department of Conservaticve Dentistry, Faculty of Dentistry, University of Indonesia (UI), Jakarta, Indonesia*

ABSTRACT

Aim. To investigate the influence of surface roughness and conditioner on the shear bond strength (SBS) of glass ionomer cement (GIC) to dentin.

Materials and methods. Thirty-six dentin specimens were created by grinding the buccal/lingual surfaces of extracted sound human premolars using wet No.1000-grit rotary abrasive paper, until a smooth and flatteneddentin surfacewasobtained. The specimens were then randomly divided into 4 groups. Group (G) 1: GIC was inserted without any pretreatment. G 2: conditioner was applied prior to inserting GIC. G3: dentin surface was roughened by scratching three times using rough diamond burs, rinsed and dried, and GIC was then inserted. G.4: same procedures as to group 3, but conditioner was applied prior to inserting GIC. The SBS was measured after 24 hours using a universal testing machine, and statistically analyzed using One Way ANOVA.

Results. The highest score was found in group 4 (mean: 5.71 ± 1.08 Mpa), and the lowest score was in group 1 (mean: 3.12 ± 0.22 Mpa). However, regarding influence of surface roughness, the rough dentin, even revealed higher scores, but were not statistically different from the smooth ones. Meanwhile the conditioned dentin significantly recordedhigher scores than the unconditioned ones, with the significance level of G1:G2 and G3:G4 being 0.002 and 0.010, respectively ($P < 0.05$).

Conclusion. Shear bond strength of GIC to dentin canbe increased by application of conditioner, but not by surface roughness.

Key Words: Roughness, Conditioner, Shear, Bone strenght, Glass ionomer cement.

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INTRODUCTION

Glass ionomer cement (GIC) is a type of tooth-coloured restorative material widely used in dentistry. One of its principle advantage is that it self-adheres to tooth structure by chemically bonding to enamel and dentin. This characteristic provides favorable adhesion which reduces leakage and increases retention, a factor important to achieve optimum performance of a dental restoration.[1-4]

Different types of burs used during cavity preparation result in an assortment of dentin topography,[5-8] which will influence the quality of adhesion between restoration andtooth structures.[7,8] The surface rugosity and roughness of the adherend are presumed to produce increased area that will adhere to the restoration, thus adhesion will subsequently become stronger.[8] However, Di Nicolo et al reported no significant difference of shear bond strength (SBS) of resin modified glass ionomer cement (RMGIC) on deciduous dentin prepared by either diamond or carbide burs.[9] Ayat et al found no influence of dentin roughness prepared by three different types of burs on the retentive strength of luting-type GIC.[10]

In the principles of adhesion, an importantcriterion is that the two materials being joined must be in sufficiently close relation.The presence of smear layernormally formed during cavity preparation disturbs the intimate contact between restorative materials and tooth structure, and is considered a hindrance which willlower the quality of adhesion.[11] Some literatures suggest the use of conditioner to be applied on the prepared cavity prior to inserting GIC, in order to remove or modify the smear layers, and clean away all contaminants from the tooth surface.[11,12] Glasspole et alfound significant increase of SBS of conventional GIC as well as RMGIC to bovineenamel after pretreatment with 10% polyacrylic acid conditioner.[13] Inoue et alalso recommended the use of acid conditioner to improve bonding effectiveness of glass ionomer adhesive to human dentin.[14] On the contrary, Hassan and Badrconcluded from their invitro studythat polyacrylic acid dentin pretreatment did not enhance the SBS of chemically cured GIC to dentin.[15] Thisfinding was supportedby Tanumiharja et alwho reported no significant differencein bond strength of both Photac-Fil Quick and Fuji IX GP for groups that were conditioned and not.[16] They formed an opinion that conditioning the tooth structure is not a necessary step to achieve good bonding. Illustration of the ultramorphology of the interface in their study indicatedan intimate adaptation between the non-conditioned specimens of the GIC and tooth structure.[17] Furthermore, result of a 4-year clinical investigation have shown no significant difference in retention rate and marginal staining between cavities conditioned with two types of conditioner and those only cleaned with pumice and water.[18]

Due to these conflicting data regarding surface roughness and conditioner, an invitro study was then initiated. The aim of this study was to analyse the influence of surface roughness and conditioner on the shear bond strength of GIC to dentin. The null hypothesis was: surface roughness and conditioner significantly improve the shear bond strength of GIC to dentin.

MATERIALS AND METHODS

This study was carried out at the Laboratory of Dental Material, Faculty of Dentistry University of Indonesia in Jakarta. Eighteen clinically sound human premolars with no structural abnormalities wereselected. These teeth were longitudinally sectioned in mesiodistal direction into two halves resulting in 36 buccal/lingual parts, andembedded in self-cured acrylic resin cylinders withtheir buccal/lingual surfaceswere exposedpointing upwards.The buccal/lingual enamel was then grinded using wet No.1000-grit rotary abrasive paper (Figure 1), until a flat surface of dentin was obtained. At this stage, dentinspecimen was considered smooth (Figure 2).

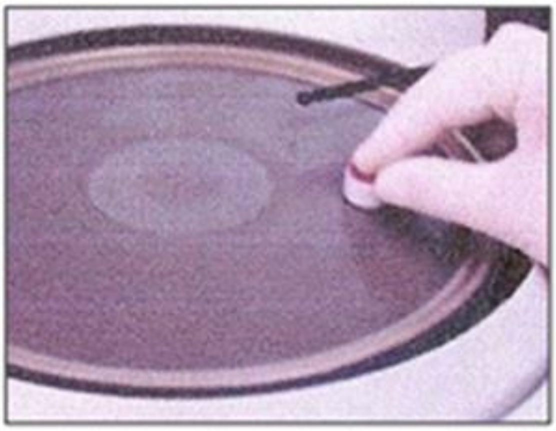

Figure 1. Buccal/lingual surfaces of enamelwere grinded using wet No.1000-grit rotary abrasive paper

Figure 2. Flat dentin was obtained, with smooth surface

Figure 3. Roughening pattern createdin cervico-occlusal direction (white arrows) parallel to the tooth axis

The specimens were then randomly divided into 4 groups (n=9). G1: GIC (GC Fuji II XP) was inserted without any pretreatment. G2: conditioner (10% polyacrilic acid; Dentin Conditioner GC) was applied for 15 seconds, rinsed under flowing distilled water, dried, and GIC was then inserted. G3: specimen was roughened by scratching three times using a high-speed rough diamond bur (Carlo Italy) in cervico-occlusal direction parallel to the tooth axis (Figure 3). At this stage, dentin was considered rough.

The specimens wererinsed under flowing distilled water, dried, and subsequently GIC were inserted. G.4: same procedures as to group 3 until the stage of obtaining rough dentin, followed by same procedures as to group 2.After 24 hours, all specimens were thereafter submitted to a mechanical test.

Figure 4. Knife-edge probe was applied at the GIC-dentin interface

The SBS was measured using a universal testing machine (Shimadzu Autograph AG 5000; Japan) with a crosshead speed of 0.5 mm/min, byapplying the knife-edge probe at the GIC-dentin interface, and pushing the restoration away until it was detached from the dentin surface(Figure 4). The score appeared in the reading machine was in Kgf, and converted to MPa. Data were gathered, and then statistically analysed using One Way ANOVA. The significance level was $p<0.05$.

RESULTS

Table 1 shows that group of rough dentin with conditioner revealed the highest score of all other groups. This means that SBS of GIC is the strongeston rough dentin that being applied conditioner. While the lowest score was found in group of smooth dentin without being applied conditioner. The data gathered were submitted in a normal distribution, and One Way ANOVA wasthen used with significance level $p<0.05$ for the statistical analysis.

Table 1. Means of SBS (MPa) and standard deviations of all tested groups

GROUP (G)*	MEAN ± STANDARD DEVIATION	CONFIDENCE INTERVAL 95%
SMNOCOND	3.12 ± 0.22	2.9481 - 3.2919
SMCOND	4.89 ± 1.05	4.0785 - 5.7015
RONOCOND	4.23 ± 1.07	3.4051 - 5.0549
ROCOND	5.71 ± 1.08	4.8787 - 6.5413

*SmNoCond: Smooth dentin without conditioner; SmCond; Smooth dentin with conditioner; RoNoCond; rough dentin without conditioner; RoCond; rough dentin with conditioner.

Table 2a. Degree of significant of SBS among all tested groups

Group (A)*	GROUP (B)*	sIGNIFICANCE (A-B)
SmNoCond	SmCond	0.002 £
	RoNoCond	0.075
SmCond	RoCond	0.264
RoNoCond	RoCond	0.010 £

*SmNoCond: Smooth dentin without conditioner; SmCond; Smooth dentin with conditioner; RoNoCond; rough dentin without conditioner; RoCond; rough dentin with conditioner; £: Significant difference.

From table 2, we can observe that the SBS between group of smooth dentin without conditioner compared to rough dentin without conditioner (p=0.075) was not significantly different.A similiar finding was noted in the group of smooth dentin with conditioner compared to rough dentin with conditioner (p=0.264).In constrast, we can observethat the SBS was significantly different between the group of smooth dentin without conditioner when compared to the group of smooth dentin with conditioner (p=0.002).andfor the group of rough dentin without conditioner compared to rough dentin with conditioner (p=0.010).

DISCUSSION

Laboratory studies and clinical investigation to test the adhesion of dental materials to tooth structure have been extensively investigated in the last decades, and GIC material.[13,19-22] Improvements have been continuously attempted in order to obtain abetter quality of adhesion to tooth structure, especially to dentin.[6,9,14-18,22]

Dentin is a structurally-complex tissue. Unlike enamel, dentin is dynamic, and contains a greaterproportion of water and organic materials. It is connected to the pulp through dentinal tubules that contain fluids. This fluid is responsible for the intrinsic humidity of this structure. Adhesion to dentin is more difficult to achieve than to enamel, therefore restorative procedures to dentin requires special attention.[2,11,23,24]

Figure 5. Samples were positioned on the shear guillotine

Different mechanical tests have been recommended to assess bonding performance of restorative materials, and shear bond strength is one of thosethat isprevalent and reliable.1,24Several previous invitro studies have also used the same method.[9,13,15,19,22]

Premolar teeth were chosen because they were more easily collected intact, as they were usually extracted for orthodontic purposes. The teeth visually had no structural abnormalities.However, there was lack of data regarding the teeth's age and how long they have been extracted. These could possibly havehad effect to the study's outcome. Since dentin is a dynamic substrate, it is subject to physiologic and pathologic changes in both composition and microstructure. Due to aging process, dentin undergoes physiologic dentinal sclerosis, resulted from obstruction of tubules by apposition of peritubular dentin and precipitation of mineral crystals.[11,24] Dentin also becomes less wet with age. How long a tooth has been extracted determines degree of dehydration of the tubules, because when the pulp dies, the outward fluid flow from the pulp to dentin is likely to be considerably reduced.[23] These will influence the depth of material's penetration to the dentin.[11,24]

Dentin surface was gained by grinding the buccal/lingual aspect of the toothuntil a smooth flattened surface of dentin was obtained. This was performed to all samples before giving any pretreatments, so that all samples were considered the same at baseline.For the groups of rough dentin, smooth dentin surface was roughened by scratchingmotion in cervico-occlusal direction. Diamond burs, rather than carbide burs, were used because they create waves and more irregular features,and produce greater surface area, so coarser surfaces could be obtained.[5,6,9]

The conditioner used in this study was 10% polyacrylic acid, because it is a mild acid most commonly used as a conditioner for conventional GIC.It removes smear layer without causing demineralisation of the dentin.[12] Polyacrylic acid contains numerous functional carboxyl ion groups, which can form a multiplicity of hydrogen bonds, which promote cleansing and wetting of the substrates.[16] It will lower the surface energy of the tooth and thus increase wettability of the surface and encourage the adaptation of GIC to the tooth.

In addition, polyacrylic acid is used in the cement itself, and any residue inadvertently left on the tooth surface will not interfere with the setting reaction.[12] Hajizadeh et all found that 10% polyacrylic acid yielded the highest bond strengthcompared to two other conditioning agents for restoring RMGIC.[22]

After the mechanical test, all restorationswere detached in the restoration-dentin interface. However, the inspection was done only using magnifying glass (30 times magnification), it should have used scanning electron microscope (SEM) to inspect more clearly and more detailed location of the detachment.

The findings showed that surface roughness, bothfor groupswhich were applied conditioner (G2:G4) and not (G1:G3), did not significantly increase the SBS, with the significance scoresbeing p=0.264 and p=075, respectively. When the mechanical tests were performed on the shear guillotine,samples were not set in the position that tooth axis (cervico occlusal)were parallel to the floor (Figure 5), This was despite the dentin roughening being done in a cervico-occlusal direction(Figure 3). As a consequence,when the crosshead was functioning,direction of the mechanical loadapplied could not be ascertained to be perpendicular to the direction of the roughness pattern. This was due to operator'snegligence in observing the importance of load direction.This situation mayhave influencedthe final result in which thesurface roughness was noted to cause insignificant increase of the SBS. Nevertheless, these findings agreed with previous reports.[10]

The underlying GIC's adhesion to tooth structure is primarily based on an ion-exchange process, resulting in a shallow demineralisation followed by infiltration of the tooth surface by the polyalkenoic acid, and in a strong ionic bond between calcium of hydroxiapatite and carboxyl groups of of polyalkenoic molecules. An intermediate adsorption layer of calcium and aluminum phosphates and polyacrylates is also formed at the GIC-hydroxyapatite interface. Direct evidence of primary chemical bonding of the carboxyl groups of polyalkenoic acid to calcium of hydroxyapatite is also provided.[11] Therefore the surface roughness only minimally influences the retentive strength of GIC. The null hypothesis which states that surface roughness improves the SBS of GIC to dentin was rejected.

Other results from this study showed that application of conditioner, for the groups of both smooth (G1:G2) and rough dentin (G3:G4), significantly increased the SBS, with the significance scores being p=0.002 and p=0.010, respectively. This findings agree with those of other studies.[13,14,21,22,25] De Munk et al reported significent higher bond stength of Fuji Bond LC for specimens which received pretreatments with polyalkenoic acid conditioner than those without pretreatments, within intervals of both 24-hour and 4-year evaluation.[25]

Intimate contact at the interface, and cleanliness of the surface from any contaminants, are of primary importance to achieve optimum adhesion. The presence of smear layer on dentin surfaceis a detriment to effective bonding, because it restrains this effective contact.[11] In this study, application of conditioner clearedthe smear layer created due to roughening process using diamond burs. For group 3 (rough dentin without conditioner), the SBS was significantly lower than those of group 4 (rough dentin with conditioner).

Furthermore, in the process of creating smooth dentin by grinding the buccal/lingual enamel using wet rotary abrasive papers, smear layer was also believed to have been formed. For group 1 (smooth dentin without conditioner), dentin surface was not clean enough and the smear layer was not effectively removed away because the sample was just rinsed with distilled water and then dried without application of any acidic liquid. The SBS was then found significantly lower than those of group 2 (smooth dentin with conditioner). This is likely the reason why the lowest SBS scores was found in group , of all other groups.

Application of mild acid conditioner promotes effective removal of smear layer, and exposure of collagen fibrils without completely unplugging the dentinal tubules. Thus, the dentin surface will not be overdehydrated. Polyalkenoic acid was then adsorbed onto hydroxyapatite surfaces, which contributes to the micromechanical retention.[9,11,13,14] The increase in bonding efficiency can be attributed to: (1) a cleansing effect which removes loose cutting debris; (2) a partial demineralisation effect which increases the surface area and creates microporosities; (3) a chemical interaction of the polyalkenoic acid with residual hydroxyapatite.[11] The null hypothesis saying that conditioner improves the SBS of GIC to dentin was accepted.

Further research is warranted to investigate the influence of surface roughness on the bond strength of GIC to dentin. This can be conducted either by using different methods or similar to what was implemented in the present study, provided some limitations are anticipated.

CONCLUSION

Within limits of this study,it is concluded that the bonding performance of GIC to dentincan be increased by application of conditioner, but not by increasing surface roughness.

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Corresponding Author:
Dr Ahmad Fauzi Muharriri
Department of Operative Dentistry
Faculty of Dentistry
Universiti Kebangsaan Malaysia
50300 Kuala Lumpur, Malaysia
Tel: 603-92897722; Fax: 603-92897798
Email: afaudzi_muh@yahoo.co.id