ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 4, Issue – 2, March - 2021, Page No. : 479 - 490

The effect of three different caries removal techniques on the microtensile bond strength of the composite resin to dentine - A comparative study

[1]Dr Manasa D.R, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road, Cooke Town, Bengaluru

[2]Dr Veenakumari R, Professor, M.R Ambedkar Dental College Hospital, Cline Road, Cooke Town, Bengaluru

[3]Dr Anantha Krishna, Professor and Head, M.R Ambedkar Dental College Hospital, Cline Road, Cooke Town, Bengaluru

[4]Dr Pradeep P.R., Professor, M.R Ambedkar Dental College Hospital, Cline Road , Cooke Town, Bengaluru

[5]Dr Shreya Maiti, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road, Cooke Town, Bengaluru

Corresponding Author: Dr Manasa D.R, Postgraduate Student, M.R Ambedkar Dental College Hospital, Cline Road, Cooke Town, Bengaluru.

Citation of this Article: Dr Manasa D.R , Dr Veenakumari R, Dr Anantha Krishna, Dr Pradeep P.R, Dr Shreya Maiti, "Evaluation of the temperature rise in the pulp chamber during different interproximal reduction procedures – an in vitro study", IJDSIR- March - 2021, Vol. – 4, Issue - 2, P. No. 479 – 490.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background and Objectives: The purpose of in-vitro study is to evaluate the micro tensile bond strength of nanocomposite to dentin, and morphological changes and characteristics of the dentin by using three different caries excavation technology namely mechanical, LASER and air abrasion using a single step self etch adhesive.

Materials and Method: All teeth were sectioned at cementoenamel junction and fixed in acrylic block . Selected specimens (60 carious molar teeth) were grouped randomly into three experimental group ,(n=15) namely Group I Mechanical (bur) , Group II preparation with LASER ablation (Er;YAG) and Group III by Air abrasion (aluminium oxide) . After caries excavation five samples were randomly selected from each group for SEM. Then the surface were bonded with a single step self-etch adhesive (single bond universal) and cured with a light cure unit.

The bonded surface was restored using nanocomposite (filtek z 250). Then the specimens were sectioned and subjected to the universal testing machine to evaluate microtensile bond strength

Results collected were subjected to ANOVA test, Tukey's multiple post hoc to evaluate statistically.

Results: The mean microtensile bond strength of mechanical group i.e. group I (mechanical rotary bur) showed higher values 6.44 (S.D 1.64) among the three groups . This value was comparable with the value of group III (air abrasion) 5.77 (S D 1.29) . The second group II (Er- YAG laser) shows lower values 3.30(S D 1.07) than that of the other two groups (group I and group III).

Interpretation &Conclusion: It was found that mechanical rotary bur showed highest microtensile bond strength compared to air abrasion and laser method

Keywords: caries removal , Tungsten carbide bur, Er; Yag LASER, air abrasion , aluminum oxide , filtekz250, single bond universe, Scanning electron microscope, Universal testing machine , micro tensile bond strength, stereo microscope .

Introduction

Dental caries is one among the commonest diseases affecting the tooth structure from earlier mankind. It is a bacterial infectious disease characterized by a progressive demineralization process that affects the mineralized dental tissues. It is considered to be the most prevalent oral disease worldwide and main cause of tooth loss among the populations.1 The extent to which carious dentin should be removed in order to achieve a mechanically and biologically successful restoration is still a matter of debate. In particular, no definite diagnostic tool is available till date to clinically define the caries-removal endpoint, enabling complete removal of infected tissue without overextending cavity preparation. In addition, the different techniques presently available for caries removal/cavity preparation produce residual dentin substrates of different natures and thus different receptiveness for adhesion.2 Numerous caries excavation technique have been introduced such as spoon excavator, method of plastic and ceramic dental bur along with hand piece, caries disclosing dyes, enzymatic caries dissolving agent, ozone therapy, sonoabrasion , air polishing, chemical vapor deposition (CVD) , Caries infiltration of low viscosity resin , Ultrasonication, air abrasion, laser ablation .

These different techniques produces residual dentin substrate of different natures leading in to different receptiveness for adhesion.3 Conventional cavity preparation and caries removal are based on Black's principle of extension for prevention which requires removal of healthy tooth structure thereby leading to loss of tissue. Conventional caries removal and cavity preparation using dental round bur with high speed hand piece which improved the speed and efficiency of cavity preparation but has many inevitable

Drawbacks, such as (i) perception of unpleasantness by the patients, (ii) need of local anesthesia, (iii) deleterious thermal effects, (iv) pressure effects on the pulp and (v) may result in removal of healthy dentin, resulting in an excessive loss of sound tooth structure 4 Chemo mechanical caries removal (CMCR) method aims to remove caries infected tissue as selectively as possible while being minimally invasive through maximum preservation of caries affected tissue. Minimal invasive technique claim to achieve controlled removal of infected softened dentine while preserving healthy hard dentine tissue and causes minimum discomfort to the patient is a method of caries removal based on dissolution, which removes only softened carious dentin whilst preserving healthy tissue. Instead of drilling, this method uses a chemical agent assisted by an a traumatic mechanical force to remove soft carious structure. There are various chemical agents like Carisolv, cariecare, papacarie. 5 Recently fluorescent controlled LASER was introduced for the selective removal of carious dentine. It is relatively new conservative method of caries removal technique. It is an alternative approach to the rotary bur technique in order to prevent the considerable noise and vibration produced by it.

Commercially available laser system are a) Er;YAG laser b) Er, Cr;YSGG c) Co2 laser. Other applications of laser are caries prevention, cavity preparation, and bleaching, dentinal hypersensitivity treatment. Soft tissue laser are used for wound healing, aesthetic re-contouring and crown

lengthening, exposure of unerupted and partially erupted teeth and many more applications .6 Air abrasion method involves bombarding of tooth surface with high velocity Aluminium oxide carried in a stream of air. However due to the detrimental surface attack of sound tooth structure, this technique is employed more in removing carious dentine at the end of cavity preparation.7 This technique causes the remove of small amount of tooth structure producing a cavity with irregular contours which is compatible with adhesive restoration.8 All-in-one adhesive systems or self-etching adhesives which combine the etching, priming and bonding procedures into one solution and one step is the recent type of adhesive system introduced.4 Nano composites mainly contains nano particle of size (1-100nm), which is similar to that micro filled composite but particle are arranged in three dimensional agglomerates that increases the viscosity in micro filled resin type .

The Nano filled composite resin is discrete and have minimal effect on viscosity. The filler helps in mechanical properties for use in the posterior stress bearing restorations.9 The micro tensile bond strength (MTBS) method is one of the most commonly used methodology to mechanically access the strength of the resin- dentine interface complex. Since it has several advantageous over tensile and shear bond strength test methodology. This test is more versatile as multiple specimens can be obtained from a single tooth. Micro tensile bond strength produces more of adhesive failure than cohesive failure which permits the testing of bond to irregular surface as well as various small areas. A scanning electron microscopy (SEM) is a recently advanced technique for studying the morphology of dentin surface which will prove the success of dentin bonding using various methods. This in-vitro investigation was undertaken to evaluate the, and morphological changes and characteristics micro tensile bond strength of Nano composite to dentin by using three different caries excavation techniques namely MECHANICAL (rotary bur), LASER ABLATION (ER; YAG) and AIR ABRASION (Aluminium oxide) using a one-step self-etch adhesive (single bond universe).

Materials and Method

60 extracted molar teeth were randomly divided into 3 groups (n=20) according to the carious removal methods as follows.

Group I: Mechanical rotary preparation by round tungsten carbide bur (air turbine NSK)

Group II: LASER preparation by ER-YAG LASER.

Group III: AIR ABRASION (Aluminium oxide)

Specimen Preparation and Experimental Groups

The crown of each tooth till cement enamel junction is sectioned using a diamond disc and mounted in acrylic Mould. All the samples were ground with a diamond disc to expose the superficial surface. They were polished using 400- and 600- grit silicon carbide papers. Occlusion portion of tooth was removed till dentine perpendicular to long axis of tooth to expose 2mm the central zone of caries infected dentine was confirmed with radiograph and the dimension of preparation is limited to 4x2x4 mm which was measured using graduated probe.

Caries removal is done as follows

Mechanical Rotary Preparation

Entire carious tissue was excavated with a size 2 round tungsten carbide bur in a slow speed handpiece under water cooling. The maximum cutting diameter of the bur was 1.4 mm. Caries dentine was removed till the firmness of dentin was felt using sharp explorer.

Laser Preparation

Following 1mm of caries removal by dental bur, surface was irradiated with Er: YAG LASER to remove further structure till the firmness of dentine was felt.

Er:YAG laser (fotona) at a wavelength of 2.94 μm, a pulse duration of 250–500 μsec under water cooling (5 mL/min). The output power and repetition rate of this equipment was 350 mJ and 12 Hz, respectively. The beam diameter at the focal area for the handpiece R02 C-459 was 0.63 mm and the handpiece was held perpendicular to the dentin surface at a distance of 12 mm (focused mode).

Samples were irradiated once in each direction, horizontally and vertically, to ensure homogeneous irradiation on the entire surface area. The irradiation was performed under water cooled spray (5.0 mL/min). The energy density used for the laser irradiation was 4.20 W.

Air Abrasion Preparation

Following 1mm of caries removal by dental bur, dentin surface was sand blasted with a stream of 50 μm aluminum oxide particles from air abrasion unit (AIR FLOW PREP K1 MAX) at 50 psi pressure for 20 s . The internal nozzle tip diameter was 0.46 mm and was kept at a distance of approximately 2 mm from the dentin. Airborne particle abrasion was done in two different directions (mesio-distal and buccal-lingual) with the nozzle held at 45^{o} to the surface to remove the remaining carious dentine**.** Five samples from each group were taken and subjected to SEM analysis to evaluate the morphological changes in dentine.

Restorative Procedure

After caries excavation, A one step self-etch adhesive (single bond universal) was applied and cured with a light cure unit. The composite (filtek z 250) resin was constructed in 1.5mm incrementsto reach a height of 6mm, and width of 4mm using a metal block of the same dimension. Each increment was light cured for 20 seconds and then the samples were immersed in water at 37°c for 24 hour. Each tooth was sectioned perpendicular to the resin-substrate interface with a high speed diamond saw under water cooling making sections of approximately $1mm^2$. On an average three sections from each tooth were used for testing. Each specimen included tooth surface, bonding surface and composite resin.

Micro-Tensile Bond Strength

Prior to testing, these specimens were macroscopically analyzed and those with interfacial gaps, voids within the material, or any other relevant defects were excluded from the study. The beams obtained after sectioning were stressed to failure under tension in a Custom made stainless steel forceps held in an universal testing machine at a crosshead speed of 1.0mm/min. Subsequent to microtensile bond strength (μ-TBS), fracture modes were observed by Stereomicroscopic observations of both sides of the failed bonds.

Scanning Electron Microscope (Sem) Evaluation

After caries excavation 5 samples were randomly selected from each group for SEM. The specimen were immersed in 4% gluteraldehyde solution for 1 hour at room temperature. Then rinsed in distilled water, then placed in cold buffer solution to remove organic tissue for 90 minutes and dehydrated in ascending grades of ethanol (30%, 50%, 80% 90% ,100%) for 1 hour in each series and then dried in a dessicator. The dried specimen were mounted on a metal stand with a gold sputter coated (200-250nm) by cathode atomization under vacuum. SEM images of the caries excavated surface were obtained. For each specimen, these microphotographs of different magnification (800X, 1000X) were made and each was evaluated, and the morphological findings were compared.

Results

Table 1: comparison of micro tensile bond strength between bur, laser and air abrasion by one way anova test in mpa.

	N	MEAN	Std. Deviation	F-value	p-value
BUR	15	6.44	1.67	21.85	0.001**
LASER	15	3.30	1.07		
AIR ABRASION	15	5.77	1.29		

(p < 0.05 - Significant*, p < 0.001 - Highly significant**)

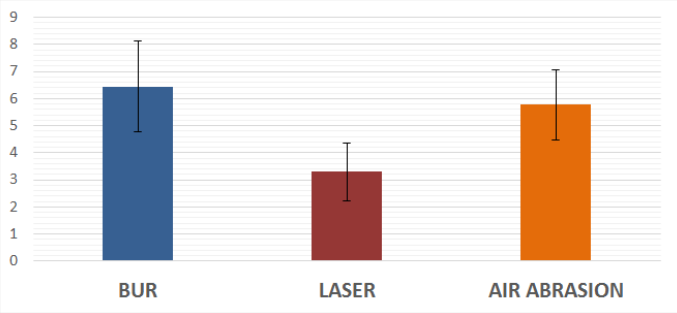


Figure 1: Comparision of Mean ± SD of Micro Tensile Bond Strength between the Three Groups (Bur, Laser, Air Abrasion)

Fracture mode analysis According to Trajtenberg, (2007)

Type I: complete adhesive failure between resin and dentin.

Type II: partial adhesive failure between resin and dentin and partial cohesive failure within resin.

Type III: complete cohesive failure within resin.

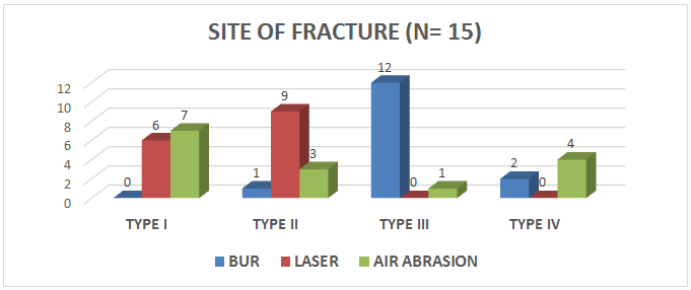
Type IV: partial cohesive failure within dentin.

Table 2: Distribution of caries removal methods according to the site of fracture

CARIES REMOVAL METHODS	SITE OF FRACTURE				TOTAL N (%)
	TYPE I N (%)	TYPE II N (%)	TYPE III N (%)	TYPE IV N (%)	
BUR	0	1(6.7)	12(80)	2(13.3)	15(100)
LASER	6(40)	9(60)	0	0	15(100)
AIR ABRASION	7(46.7)	3(20)	1(6.7)	4(26.6)	15(100)
P VALUE < 0.001**					

(p < 0.05 - Significant*, p < 0.001 - Highly significant**)

Figure 2: Distribution of caries removal methods according to the site of fracture



Scanning Electronic Microscopic Analysis

Group 1: Mechanical rotary preparation by round tungsten carbide BUR

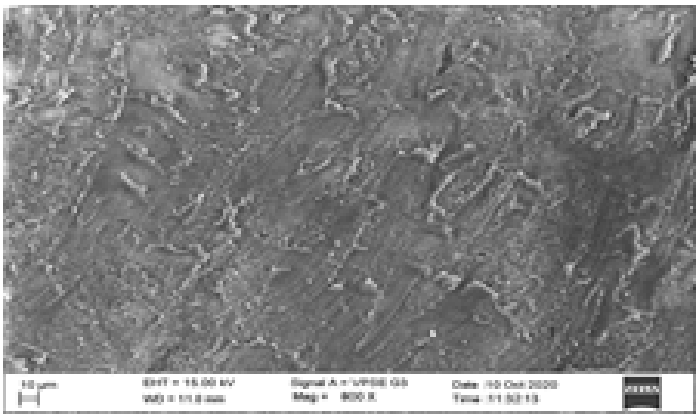


Fig. 3 at 800x magnification - Smooth and a well-defined smear layer

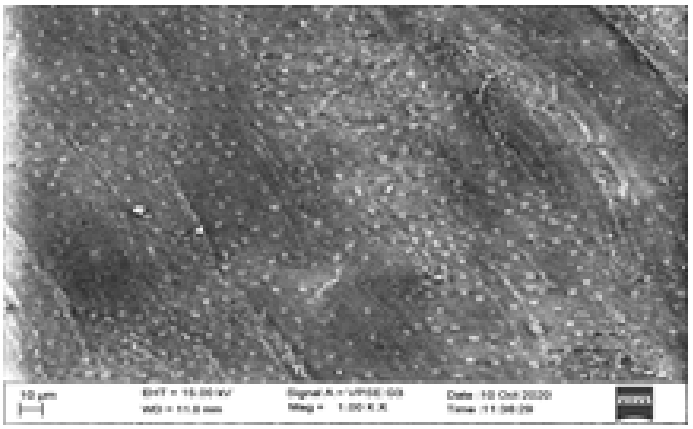


Fig. 4: at 1000 x magnification - Smearing effect was accentuated and the dentine tubule orifices were plugged with material

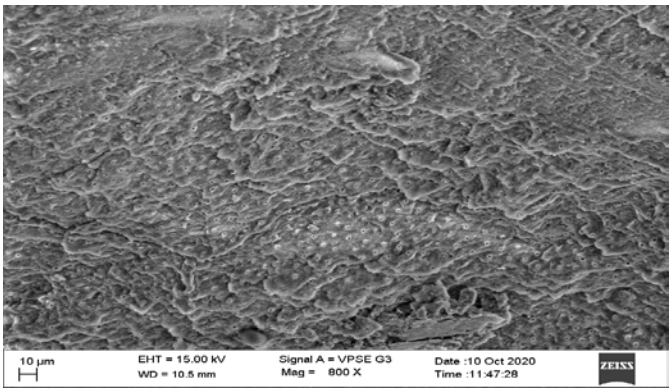


Fig. 5: At 800x magnification - Scaly and flaky irregular appearance of the dentin.

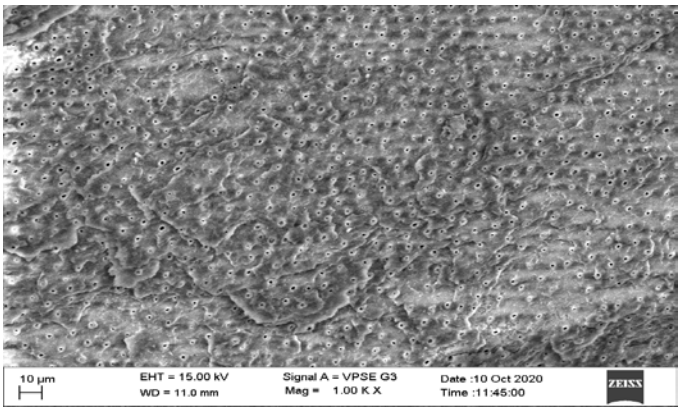


Fig. 6: At 1000 x magnification - Peritubular cuffing Absence of smear layer with partially closed dentinal tubules orifices

Group 3: Air Abrasion (Aluminium Oxide)

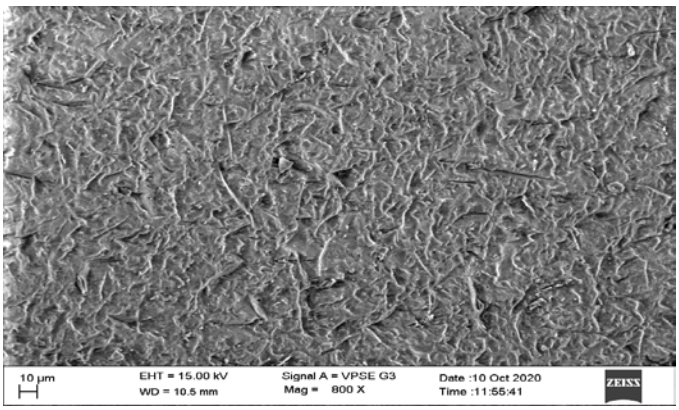


Fig. 7: At 800x magnification - Lack of any real surface definition and featureless surface studded with irregularly shaped particles

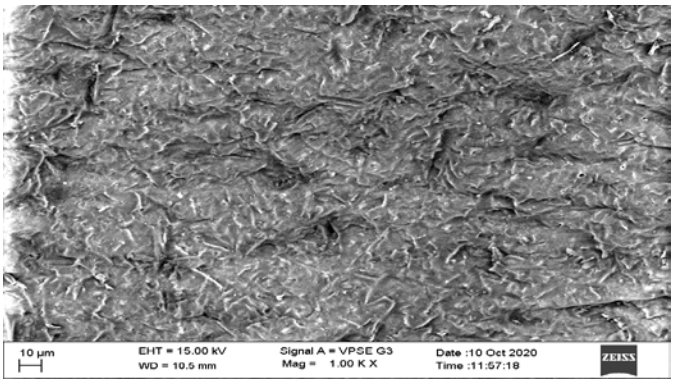


Fig. 8 : At 1000x magnification - The position of the tubular openings could be detected producing the featureless, stippled surface appearance.

Discussion

Minimal invasive dentistry has gained popularity with the development of new adhesive systems and technological improvements in tooth preparation. This helps to have a controlled removal of infected and softened dentin, preserving the healthy and hard tissues and perform with a minimal discomfort to the patient.10 The superficial necrotic zone of caries infected dentine which harbors core bacterial biomass should be excavated leaving only the residual caries affected dentine lining the cavity with sound enamel margin and dentine adjacent to the dentin-enamel junction.11 Carious dentin consists of two different layers having different ultramicroscopic and chemical structure. The outer carious dentin (infected) is irreversibly denatured, infected and not remineralizable and must be removed. The inner carious (affected) dentin is reversibly denatured, not infected, remineralizable and must be preserved.12, 13 The transition zone between infected and affected dentin is difficult to assess. The color is not good indicator. Defining the actual end point of caries excavation is the start point of restoration.14 Kidd EAM 2004 suggested removing carious dentin to the level until it is felt firm.15 The ability of a restorative material to achieve a strong and durable bond with the tooth structure is very important for clinical success.16 Hence a complete removal of infected dentin is a must to

achieve this goal. The conventional removal of dental caries using rotary instruments is proved to be quick and efficient however it is frequently associated with thermal and pressure effects on the pulp producing pain. Moreover, drilling may also involve the removal of sound tooth tissue adjacent to the caries affected area.17 Wherever possible, tissue should be preserved having the invasive treatment kept to minimum and natural tissue should be replaced with artificial substitutes only when it is absolutely unavoidable. The best way to ensure maximum life for the natural tooth is to respect the sound tissue and protect it from damage by using minimally invasive techniques in restorative dentistry.18 The search for a more gentle ,comfortable, conservative way of caries excavation as let to the development of methods which aim at providing minimal thermal changes, less vibration and removal of infected dentine only. The alternative techniques such as air abrasion, sonoabrasion, ultrasonic instrumentation, chemo mechanical and laser approach to caries removal were developed. 19,20 In current practice having gained access to the carious dentin using high speed air turbine , the slow speed bur and hand excavator can be used for carious dentin excavation. As the hand excavator will remove softened tissue with more sensitive tactile feedback than the bur, hand excavation is more self-limiting.21 Bur is considered as oldest, economical and most commonly used rotary method with less technique sensitive having lot of published data about its effectiveness. Hence bur method was taken as standard method to compare effectiveness with newer methods . The major factor to consider in terms of restoring a cavity with the current adhesive are the final dentine characteristics such as surface roughness, presence of smear layer which can affect the final bond on the seal achieved by adhesive system.22 The smear layer in carious affected dentin may be more resistant to the action of self etching primer as they include acid resistant crystals and extrinsic proteins that might have permeated into the mineral phase during demineralization cycle and lower resin retention. 23 If the residual smear layer is left on the surface, the adhesive resin will bond to crystals within it rather than to underlying dentin Therefore, in order to obtain an adequate bond to dentine, this smear layer must be initially removed or treated prior to the placement of the restoration; this is conventionally done by etching the dentine surface for a short period of time 24. Self-etch adhesives do not require a separate etching step as they contain acidic monomers that simultaneously condition and prime the dental substrate and form a highly hydrophilic and acidic monomers that make hybrid layer more permeable and sensitive to water sorption from the underlying dentin. This is an advantage over the etch and rinse adhesive system.[25]

SEM observation

In our present study SEM evaluation of cavity floor prepared with BUR, LASER & AIR ABRASION METHOD at 800x and 1000x magnification shows following morphological feature

Group 1; Mechanical preparation by round tungsten carbide BUR

Evaluation using rotary round tungsten carbide bur and spoon excavator produces smearing and smear plugs in the dentinal tubules orifices. This method leaves a homogenous smear layer with more or less a uniform dentinal tubule visibility obstructed with smear plug. Although residual dentine after mechanical excavation showed similar hardness to that of sound dentine, there are chances of sclerotic dentine formation with in the dentinal tubules that can lead to complete obliteration. With regard to bonding receptiveness smear covered surface does not interfere with self-etch adhesive.

Group 2; LASER preparation by ER-YAG

SEM evaluation using ER;YAG laser produced scaly, irregular and rugged appearance with the absence of smear layer with partially closed dentinal tubules orifices. All these features could increases the adhesive area and strength, but lack of good hybrid layer which could counteract these effect causing lower micro tensile bond strength.[26,27]

During this process, laser initially vaporizes the water and hydrated organic component of the dentine. The internal pressure increases in the dentin until the explosive destruction of the inorganic substance occur. Since the inter tubular dentin contains more water and has a low mineral content than the peritubular dentin, it is selectively more ablated than the peritubular dentine leaving protruding dentinal tubules with a cuff like appearance.[28] which is also evident in the SEM image of our study .

Group 3; AIR ABRASION (Aluminium oxide)

SEM evaluation using this method produces an irregular topography created by dentin surface preparation with the air abrasion system remained unaltered. These irregularities favored μTBS, due to an increase in the bonding surface combined with micro-retentions**.** It also demonstrated that the dentine surface were covered with the smear layer with the dentine tubules were completely closed but after acid conditioning, all dentin tubules were open and removed the smear layer [29]. The mean gap width between composite and dentin was significantly reduced by using air abrasion to roughen the surface before placing the resin composites.[30] which also helps in increasing MTBS.

Microtensile bond strength testing

The sample preparation for MTBS can be dumble shape , stick shape, hourglass shape. Studies shows that sticks and dumble shaped specimen with rectangle bonded area showed similar bond strength and failure mode. Interfacial stress during preparation can lead to pre test failure of the samples. Dumble or hourglass shaped trimming of the sample places additional pre test strain at stress concentration on the bonded area, hence stick shape were used in our study.

The mean microtensile bond strength of mechanical group i.e. group I (mechanical rotary bur) showed higher values 6.44 (S.D 1.64) among the three groups . This value was comparable with the value of group III (air abrasion) 5.77 (S D 1.29) . The second group II (Er-YAG laser) shows lower values 3.30 (S D1.07) than that of the other two groups (group I and group III).

The present study showed higher values for group I (mechanical rotary bur) method of caries removal which is in accordance with the study conducted **by Jaberi Ansari et al [31] , kouros et al [32] .**

Our study result showed lowest values for group II (laser) method of caries removal due to the composition of the intertubular dentin which has been modified by the laser irradiation. This could have lead to a dentin more resistant to demineralization, impairing the action of the mild pH hydrophilic primer used [33]

The results of our study were also in accordance with that of **Ceballos et al**.[34] Which states that the ablation of dentin fused collagen fibrils together resulting in a lack of interfibrillar space, restricting resin diffusion into the subsurface inter tubular dentin. The lack of resin penetration in laser-ablated dentin is the most likely explanation for lower bond strengths. **Jaberi Ansari et al [31] kouros et al [32]** and **Kameyama et al. [35]** postulated that acid treatment following laser irradiation amplified the deleterious effects on the dentin surface . **Yazici et al. [36]** in their study stated that bond strength decrease with laser and acid pretreatments and the air abrasion did not affect the adhesive performance.

Result of present study demonstrated that group III (air abrasion) showed higher value then group II (laser) which is in accordance with study conducted by **Mowery *et al.,*** [37] which showed that by increasing dentin surface roughness, higher μTBS values were obtained. **Mujdeci et al** s recent paper documented as APA (air born particle abrasion) treatment can produce a rough surface on dentin, preserving the original diameter of dentin tubule orifices and consequently, the amount of available intertubular dentin [38] . **Sohrabi et al** showed that aluminum oxide sand blasted enamel provides a reliable method for increasing the microtensile bond strength of composite resins to enamel[39]**. Mujdeci and Gokay** [40] **and Maurizio'Amario D et al** [41] concluded that thr surface treatment by air born particle abrasion with Al2O3 particles can increase the bond strength of total-etch adhesives to dentin.

With our present study result group III (air abrasion) values are comparable with group I (mechanical rotary bur) which is in consensuses with the study conducted by **Abdulkadir Senguna et al**[42] which showed less gap formation in air abraded and bur abraded groups than that of untreated control surfaces for self-etching bonding system, a significant of bond strength could be observed for the air abraded and bur abraded groups.

Present study result showed that air abrasion (group III) shows lower value then mechanical bur (group I) method which is in accordance with study conducted by **Nikaido et al** [43]suggest that air abrasion may weaken the enamel surfaces and some micro cracks occurred in the subsurface of enamel because the depth of penetration during cavity preparation cannot be controlled, and cohesive failure within enamel occurred which could cause decreasing of the bond strengths and **Rafael et al.** [44] reported some crack-like alterations on the tubule borders and on intertubular dentin which was seen after air abrasion with aluminium oxide particle

The fracture mode analysis

Group –I (**Mechanical rotary bur method)**

Fractured specimen typically showed a mixed cohesive fracture pattern. type II fractured in dentin (6.7%) and type III fracture within resin (80%).

It shows better adhesive bond between dentine and resin so it shows less type I fracture.

Group II- (Laser method)

Fracture specimen showed type II(60%) and type I (40%)

More number of adhesive failure could be observed because laser ablation did not create an appropriate hybrid layer.

Group-III (Air abrasion method)

Fracture specimen was showed typically type I (46.9%), followed by type IV (26.5%), type II (20.1%). And type III (6.7%)

More number of cohesive failures with in dentine could be because of formation of micro crack within dentine after using air abrasion method.

The inclusion criteria for samples were teeth with caries lesion limited to occlusal surface and extending half of the distance from dentin- enamel junction to pulp chamber. This was to minimize any regional variation between the peripheral and central dentine substrate

Generally micro specimens for MTBS were fixed to a jig with a help of cyanoacrylate glue, where in this study we used custom made forceps to fix the samples to jig. This method might have resulted in lower values compared to published data. Further research is recommended to study large number of samples for MTBS evaluation.

Conclusion

Within the limitation of this in vitro study it can be concluded that:

- It was found that the surface remaining after mechanical (bur) excavation and bonding with the mild self-etch adhesive seem to be very compatible allowing deeper penetration of the adhesive and resulting in a thick homogeneous hybrid layer.
- However the air abrasion also was found to be comparable with the mechanical excavation. Laser produced lower micro tensile bond strength even though it has advantage of minimal tooth preparation, good patient compliance.
- Fracture failure mode concluded that mechanical bur method and air abrasion shows more of adhesive failure whereas laser showed more cohesive failure within dentine.

References

1. Selwitz RH, Ismail AI, Pitts NB. Dental caries. The Lancet. 2007 Jan 6;369(9555):51-9.
2. de Almeida Neves A, Coutinho E, Vivan Cardoso M, Lambrechts P, Van Meerbeek B. Current concepts and techniques for caries excavation and adhesion to residual dentin. Journal of Adhesive Dentistry. 2011 Feb;13(1):7
3. Yazici, A. R., Ozgünaltay, G., & Dayangaç, B. (2002). A scanning electron microscopic study of different caries removal techniques on human dentin. *Operative dentistry*, *27*(4), 360–366.
4. Bussadori SK, Castro LC, Galvão AC. Papain gel: a new chemo-mechanical caries removal agent. Journal of Clinical Pediatric Dentistry. 2006 Jan 1;30(2):115-9.
5. Ganesh M, Parikh D. Chemomechanical caries removal (CMCR) agents: Review and clinical application in primary teeth. Journal of Dentistry and oral hygiene. 2011 Mar 31;3(3):34-45.
6. Jacobsen T, Norlund A, Englund GS, Tranaeus S. Application of laser technology for removal of caries: a systematic review of controlled clinical trials. Acta Odontologica Scandinavica. 2011 Mar 1;69(2):65-74
7. Ericson D, Kidd E, McComb D, Mjör I, Noack MJ. Minimally invasive dentistry—concepts and techniques in cariology. Oral Health Prev Dent. 2003 Jan 1;1(1):59-72.
8. Neuhaus KW, Ciucchi P, Donnet M, Lussi A. Removal of enamel caries with an air abrasion powder. Operative dentistry. 2010 Sep;35(5):538-46.
9. Anusavice ,shen, rawls. Phillip's of dental material 1st south asia edition. Pg no 301,
10. Tsanova S, Tomov G. Morphological changes in hard dental tissues prepared by Er: YAG laser (LiteTouch, Syneron), Carisolv and rotary instruments. A scanning electron microscopy evaluation. Folia medica. 2010 Jul 1;52(3):46-55.
11. Tyas MJ, Anusavice KJ, Frencken JE, Mount GJ. Minimal intervention dentistry—a review* FDI Commission Project 1–97. International dental journal. 2000 Feb;50(1):1-2.
12. Fusayama T. Two layers of carious dentin; diagnosis and treatment. Oper Dent. 1979;4:63-70.
13. Kidd EA. How 'clean'must a cavity be before restoration?. Caries research. 2004;38(3):305-13.
14. Neves AD, Coutinho E, Cardoso MV, De Munck J, Van Meerbeek B. Micro-tensile bond strength and interfacial characterization of an adhesive bonded to dentin prepared by contemporary caries-excavation techniques. dental materials. 2011 Jun 1;27(6):552-62.
15. Neves AD, Coutinho E, De Munck J, Van Meerbeek B. Caries-removal effectiveness and minimal-invasiveness potential of caries-excavation

techniques: a micro-CT investigation. journal of dentistry. 2011 Feb 1;39(2):154-62.

16. Silva NR, Calamia CS, Harsono M, Carvalho RM, Pegoraro LF, Fernandes CA, Vieira AC, Thompson VP. Bond angle effects on microtensile bonds: laboratory and FEA comparison. Dental Materials. 2006 Apr 1;22(4):314-24
17. Fure S, Lingström P, Birkhed D. Evaluation of Carisolv™ for the chemo–mechanical removal of primary root caries in vivo. Caries research. 2000;34(3):275-80
18. Mediteam Dental AB (publ), Carisolv clinical manual. Minimally-invasive, patient-friendly removal of caries. Sweden: Mediteam;2002.
19. Maragakis GM, Hahn P, Hellwig E. Chemomechanical caries removal: a comprehensive review of the literature. International dental journal. 2001 Aug;51(4):291-9
20. Pandit IK, Srivastava N, Gugnani N, Gupta M, Verma L. Various methods of caries removal in children: A comparative clinical study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2007 Apr 1;25(2):93
21. Banerjee A, Watson TF, Kidd EA. Dentine caries excavation: a review of current clinical techniques. British dental journal. 2000 May;188(9):476-82
22. da Graça Lopes RM, Steiner-Oliveira C, Aranha AC, Castellan CS, Bello-Silva MS, Júnior ND, de Paula Eduardo C. Microtensile bond strength to Er: YAG laser pretreated dentin. Brazilian Dental Science. 2014 Jan 27;17(1):54-61
23. Marshall GW, Habelitz S, Gallagher R, Balooch M, Balooch G, Marshall SJ. Nanomechanical properties of hydrated carious human dentin. Journal of Dental Research. 2001 Aug;80(8):1768-71.
24. Inokoshi S, Harada N, Nakaoki Y, Nikaido T, Urabe I, Sano H, Yamada T, Tagami J. Quality of bonding agents: adhesion mechanism. Factors influencing the quality of composite restorations: Theory and practice, Carimate (Como), Italy: Ariesdue Srl Printers. 1996 Nov:17-34.
25. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine AJ, De Munck J, Van Landuyt KL. State of the art of self-etch adhesives. Dental materials. 2011 Jan 1;27(1):17-28.
26. Li ZZ, Code JE, Van de Merwe WP. Er: YAG laser ablation of enamel and dentin of human teeth: determination of ablation rates at various fluences and pulse repetition rates. Lasers in surgery and medicine. 1992;12(6):625-30.
27. Keller U, Hibst R. Experimental studies of the application of the Er: YAG laser on dental hard substances: II. Light microscopic and SEM investigations. Lasers in surgery and medicine. 1989;9(4):345-51.
28. Aoki A, Ishikawa I, Yamada T, Otsuki M, Watanabe H, Tagami J, Ando Y, Yamamoto H. Comparison between Er: YAG laser and conventional technique for root caries treatment in vitro. Journal of dental research. 1998 Jun;77(6):1404-14
29. Van Meerbeek B, De Munck J, Mattar D, Van Landuyt K, Lambrechts P. Microtensile bond strengths of an etch&rinse and self-etch adhesive to enamel and dentin as a function of surface treatment. Operative Dentistry. 2003 Sep 1;28(5):647-60.
30. Hannig M, Femerling T. Influence of air-abrasion treatment on the interfacial bond between composite and dentin. Operative Dentistry. 1998 Sep 1;23(5):258-65

31. JABERI AZ, FEKR AR, FEYZI S, Younesian F. A comparative study of acid and laser etching on micro shear bond strength of enamel
32. Koliniotou-Koumpia E, Kouros P, Zafiriadis L, Koumpia E, Dionysopoulos P, Karagiannis V. Bonding of adhesives to Er: YAG laser-treated dentin. European journal of dentistry. 2012 Jan;6(1):16
33. Hossain M, Kimura Y, Nakamura Y, Yamada Y, Kinoshita JI, Matsumoto K. A study on acquired acid resistance of enamel and dentin irradiated by Er, Cr: YSGG laser. Journal of clinical laser medicine & surgery. 2001 Jun 1;19(3):159-63
34. Ceballos L, Toledano M, Osorio R, Tay FR, Marshall GW. Bonding to Er-YAG-laser-treated dentin. Journal of dental research. 2002 Feb;81(2):119-22
35. Martínez-Insua A, da Silva Dominguez L, Rivera FG, Santana-Penín UA. Differences in bonding to acid-etched or Er: YAG-laser–treated enamel and dentin surfaces. The Journal of prosthetic dentistry. 2000 Sep 1;84(3):280-8
36. Yazici AR, Karaman E, Ertan A, Ozgunaltay G, Dayangac B. Effect of different pretreatment methods on dentin bond strength of a one-step self-etch adhesive. J Contemp Dent Pract. 2009 Jan 1;10(1):41-8
37. Mowery Jr AS, Parker M, Davis EL. Dentin bonding: the effect of surface roughness on shear bond strength. Operative dentistry. 1987;12(3):91
38. Mujdeci A, Gokay O. The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. The Journal of prosthetic dentistry. 2004 Sep 1;92(3):245-9
39. Sohrabi A, Amini M, Afzali BM, Ghasemi A, Vahidpakdel SM. Microtensile bond strength of self-etch adhesives in different surface conditionings. European journal of paediatric dentistry. 2012 Dec;13(4):317-20.
40. Mujdeci A, Gokay O. The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. The Journal of prosthetic dentistry. 2004 Sep 1;92(3):245-9.
41. D'Amario M, Piccioni C, Di Carlo S, De Angelis F, Caruso S, Capogreco M. Effect of Airborne Particle Abrasion on Microtensile Bond Strength of Total-Etch Adhesives to Human Dentin. BioMed research international. 2017 Dec 17;2017.
42. Sengun A, Orucoglu H, Ipekdal I, Ozer F. Adhesion of two bonding systems to air-abraded or bur-abraded human enamel surfaces. European journal of dentistry. 2008 Jul;2:167
43. Nikaido T, Kataumi M, Burrow MF, Inokoshi S, Yamada T, Takatsu T. Bond strengths of resin to enamel and dentin treated with low-pressure air abrasion. Operative Dentistry. 1996 Sep 1;21(5):218-24.
44. Rafael CF, Quinelato V, Morsch CS, DeDeus G, Reis CM. Morphological analysis of dentin surface after conditioning with two different methods: Chemical and mechanical. Journal of Contemporary Dental Practice. 2016 Jan 1;17(1):58-62.