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Evaluation Of Fusion Liquid Efficiency In Improvement Of Shear Binding Strength Of Synthetic Teeth To Thermo-Plastic Denture Material

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Abstract

Background: Due to increased chewing capability, one of the most common problems with dentures is that prosthetic teeth can come loose from the denture. The mechanical design of the connection between thermoplastic base materials and acrylic teeth has increased the problem of tooth debonding.

Objective: The current study was conducted to assess the shear bind strength of artificial teeth to thermoplastic resin utilizing fusing liquid and mechanical modifications (Alumin-ablasting, T. hole) of tooth ridge lap before and after 100 hours of accelerated ageing.

Materials and method: A total 120 maxillary central incisors have been chosen and grouped into 6 groups of 20 samples each, according to surface treatments. each group subdivided into before and after 100hrs according to artificial ageing (n=10). Shear bond strength test conducted by a universal measurement apparatus with crosshead speed 0.5mm / min. Data were statistically analyzed by one-way ANOVA and Tukey's (HSD).

Results: Various surface treatments techniques significantly affected the shear bond strength with statistical high difference in mean bond strength after various surface treatments compared to the control group at ($p < 0.001$). Regarding surface treatment, Dual treatment of "alumina-blasting + fusion liquid" showed considerably elevated strength compared to alumina-blasting alone at ($p < 0.001$). also "T. hole +fusion liquid" treatment yielded a significant elevation in strength reading compared to T. hole alone at ($p < 0.001$). Great significant full in strength value was noted in all groups post 100hrs of artificial ageing process at ($p < 0.001$). The combined surface treatment revealed the lowest percentage reduction in SBS yielded in (T. Hole + fusion), (Alumina-blasting + fusion) than T. hole alone and alumina-blasting alone after 100hrs of artificial ageing process.

Conclusion: Surface treatment with T. hole + fusion liquid or alumina-blasting + fusion liquid enhanced SBS.

Keywords: karadent TCS, Thermoplastic, Fusion liquid, Ageing, Shear bond strengt

Introduction

In the 1970s and 1980s, patients sought the 'Hollywood Smile,' forcing dentists to find both cosmetic and practical prosthetic treatments. Flexible partial dentures were becoming a therapy option for patients who desired excellent aesthetics and had healthy remaining teeth (1). Flexible dentures are made of a specific thermoplastic material that is both pleasant and durable (2). Thermoplastic materials are utilized to create complete and partial dentures due to their numerous benefits, including low solvent solubility, elevated strength, acceptable toughness, flexible nature, ductile consistency, abrasion tolerance, increased temperature withstanding, and chemical reactions resistance. One downside of these materials is that they have a lower bonding strength to prosthetic teeth due to the bind is essentially mechanical (3, 4). Artificial teeth constitutes an essential part of denture prosthesis which must be bonded to the denture foundation to enhance the duration time of the prosthesis (5). The success of the dental prosthesis depends on the proper binding of acrylic teeth to denture base for implant-supported and retained prostheses, separation of artificial teeth from denture base remains single most widely occurring complaint (3). Due to artificial teeth have no chemical attachment to the thermoplastic denture foundation in most flexible resin RPDs, they can readily detach from the denture base(6). Mechanical retention for artificial teeth is required in flexible resin RPDs to enhance the attachment strength of synthetic teeth to the thermoplastic denture base resin (7). So, T-shape designed holes having two dimensional grooves (vertical and horizontal) produces enhanced mechanical retention between acrylic teeth and thermoplastic resins. T-holes are also employed in dentistry, and ready-made composite resin teeth with T-holes are available (8). Studies have shown that using adhesives may enhance the strength of binding of acrylic teeth to denture resin. (9). TCS manufacturer introduces Fusing Liquid, a new glue, The Fusing Liquid is administered to the region to be bonded immediately before injection. Artificial accelerated aging simulates oral environmental factors extra-orally. Artificially aged prosthetic materials have been exposed to UV radiation, fluctuating temperatures, and humidity (10). Aging causes periodic contraction and swelling, which causes tension inside the materials, reducing prosthesis lifetime and weakening the bond between denture bases and teeth. Stress exposure exposes materials to temperature effect, causing minor (cracks) (11). This study utilizes recently developed thermoplastic monomer free semi-rigid micro crystalline polymer denture base materials (Karadent by TCS, INC, USA). So, it acts as alternatives to PMMA in patients having allergy (12). The purpose of this scientific study was to determine the most effective type of surface modification strategies for maximizing the shear binding strength between acrylic teeth and thermoplastic denture substance.

Materials and method

specimen`s preparation

Total 120 cylinder-shaped specimens (35mm length, 12mm diameter) with acrylic teeth were fabricated. The laser-cutting equipment (TIL-6090, India ,2009) prepared the custom-made acrylic discs and 7 shaped piece (Sumi-pex acrylic sheets (2.0mm, India)). Auto CAD 2015 software was used to create the final model. The specimen molds were created using an acrylic discs and copper tubing as follows: (13).

Acrylic discs designing:

A pair of rounds, custom-made acrylic discs with a hole in the center for custom copper tubing were fabricated. A slot was created in the discs for a (7) shaped piece. The discs are secure a copper tube mould and a (7) shaped piece. According to (JIST 6506 , 1989) A seven (7) shaped piece with 45º angle end essential for accurate acrylic tooth placement. The dimensions are shown in Figure (1a).

Copper Tube designing:

A turning machine was employed to create a unique tubing mold for a test specimen wax design with outside diameter of 24.5mm, inner hole diameter of 12mm, and length of 35mm (13). Maxillary central incisor acrylic teeth (Sinalident, Hencheng Shuzhi) were utilized for testing. The tooth was only embedded into the wax cylinder to the neck of the central incisor. The mold portions of the shear binding with acrylic teeth test are shown in the Fig. (1b), (1c).

Fabrication of stone mold for SBS test samples:

The conventional flasking procedure for flexible denture fabrication was followed Using special aluminum flasks, (IRIS, China). The specimens were coated with separating medium (sinalident, China) and dried. Then type III dental stone (Syna Rock, Bulgaria), mixed according to supplier's guidance 100gm/20 ‘The specimens were inserted within the slurry stone half of them immersed and uncovering the remaining half after that left till stone setting completely. special sprues were selected (6-8mm) in diameter and bounded to the wax specimens to permits material to be injected (11), after that the upper metal flask was screwed onto the lower metal flask and filled with slurry stone. A vibration device (Quayle Dental, England) was applied to remove air bubbles during stone pouring. Prior to wax eliminating, the flasks were fully set by waiting before opening. The metal flasks were placed in a boiling water bath (XMTE-205, Germany) for 15 minutes to eliminate wax (14). Then the mold cavity was gently cleaned. Before injection, the specimens were categorized into 6 categories according to modification in their (n=20 per group)

Surface Treatment of The Acrylic Teeth Ridge Lap:

- **Control group:** without any surface treatment
- **T. Holes group:** To maintain optimum material flow, hole perforations must be T-shaped. utilizing a (0.06) inch twist drill on the ridge lap surface (14). Figure (2a).
- **Alumina-blasting group:** Surfaces of teeth's ridge laps were roughened up using aluminum oxide particles (250µm) for 30 seconds using a sandblasting machine at 2.5 bar pressure (5). A custom-made fixture was created to standardize the distance between the teeth ridge lap and the nozzle of the sandblasting machine (10 mm) as shown in Figure (2b) (15). Substantially, fine remnants were cleaned with an air- water mixed spray for ten seconds, associated by three seconds of drying process with compressed air flow.
- **Fusion liquid group:** applying drop of Fusion liquid over the tooth ridge lap Immediately prior to injection with

a micro brush (According to manufacturer instruction) as shown in figure (2c).

- **T. Hole + fusion liquid group:** Teeth treated with preparation T. Shape daitoric and fusion liquid.
- **Alumina-blasting +fusion liquid group:** Teeth treated with aluminum-oxide abrasion and fusion liquid.

Injection Process

Injection is carried out with the AX-YD manual Dental injection system machine (ISO 9001, CN). The procedure starts by heating the cylinder in an electrically powered furnace until it reaches the desired temperature of 550°F (288°C). Manufacturer's instructions then the thermoplastic resin cartridge (Karadent by TCS, USA) was then inserted into the heated cylinder, crimped top first (labelled part facing out). Set a timer for 15-16 minutes (as manufacturer's instructions). After the resin has melted, gently withdraw the cylinder from the furnace, maintaining it horizontal until it reaches the sprue hole of the flask. Turn handles with both hands once piston enters cylinder. When the cartridge explodes, spin the handle with both hands to gently compress the springs. allow compression for 3 minutes before removing (12).

Finishing and Polishing the Specimens:

The Specimens ' sprues were cut with a cutoff disc under mild pressure and water cooling to minimize overheating, then the Specimens borders were cut by using a grinding stone bur with rotation speed at 1500 (rpm) (according to ADA specification), then the specimens were subjected to sand using 220 grain sand paper. Polishing was done in lathe polishing machine (SD-La54, China) by using bristle brush and rouge wheel with pumice. Digital vernier (Vaster, China) was used to check the specimen’s dimension (13).

Storge of specimens

Every tested specimen group was collected and put inside plastic containers containing distil water, which were then incubated for 48 hours at 37o C. (ADA 1999 Specification No.12 in 1999). Following to that, half of the samples subjected to shear tests utilizing a universal testing apparatus (Instron 1195, USA). The second half of the samples were aged using an Accelerated Weathering Tester (Model QUV/Spray, Q-Lab Corps, USA) for about (100 hours) of alternating periods of ultraviolet radiation (UVA-340), increased temperature, and darkness with condensation of filtered water. Each aging cycle, according to ASTM G154/cycle 7 (2006), was completed in (12 hours) (16, 17).

Shear Bond strength (SBS)test

Shear load was applied at 45 degrees from the longitudinal axis of each denture tooth by a wedge designed end metal stud used to direct the load on the incisal one-third on the palatal side in a trial to produce the exact simulation of clinical situation of forces on the maxillary central incisor at 0.5mm/min speed of the cross head. until fracture using a universal testing machine (Instron 1195, USA, 50 kg full scale) (21), (14,12) Figure (3). The load at failure was recorded in (kg) multiplication to 9.81to obtain the bond strength in (N) in compliance to Japanese Standard for acrylic teeth (JIST 6506, 1989) (22).

Fracture mode Analysis

The fractured locations on all specimens were visually inspected to establish the kind of fracture as shown in figure(4). The joint failure was classified as adhesive, cohesive, or mixed (15).

Adhesive: a bond interface fracture (No residues of denture base material could be seen on the tooth's surface after the fracture.).

Cohesive: When the denture base or tooth was fractured (any residue of denture base resin on the tooth surface or any fragments of tooth remaining on the denture base).

Mixed: When the fracture included both adhesive and cohesive.

Scanning Electron Microscope (SEM) Evaluation:

SEM was performed on one sample from each group at random to test the sample's topography. The SEM photomicrographs was done by Electro scanning microscope (Inspect S50, FEI company, Netherlands, 2013), under 250 x and 3mm magnification with working distance of 10 mm and an acceleration voltage of 20 Kev for studied groups as shown in figure(5)

Statistical Analysis

The ANOVA test was used to compare the treatment and control groups before and after the ageing process. Afterwards, the Tukey Honestly Significant Differences (HSD) multiple comparison test was employed to discover significant differences at $\alpha = 0.05$

Results

The mean bond strength for all evaluated groups is demonstrated graphically in Figure (6). Table 1 illustrated one-way ANOVA findings revealed extremely significant variation between groups prior ($F = 400.091$, $P< 0.01$) and post ($F = 431.929$, $P < 0.01$) of artificial ageing. Table 2 shows the mean SBS values in (N), standard deviations (SD), and their significance. All surface treated groups exhibited greater SBS than control groups before and after 100 hours of artificial ageing ($p<0.01$). Among all test groups, both aged and non-aged investigating about the mode of surface modification, there were substantial variation within all groups of study ، such as T. Hole, alumina-blasting, and fusion liquid at ($p < 0.01$), and T. Hole + fusion, alumina-blasting +fusion at ($p < 0.001$). The findings revealed that combining T. Hole with fusion yielded in much improved SBS than T. Hole alone, and combining alumina-blasting with fusion led to greatly better SBS than alumina blasting only. The similar pattern was seen before and after artificial ageing, with T. Hole + fusion exhibiting the greatest SBS value before (295.67 ±12.16 N) & after (268.27 ± 8.95N) and fusion liquid group exhibiting the lowest SBS value before (109.43+10.37 N) & after (87.75 ± 10.83N).

After 100 hours, the effect of artificial aging on all groups was very obvious. All groups had considerably decreased SBS levels after ageing at ($p < 0.01$). The control group had the highest percentage decrease in SBS (25.80%), whereas the fusion liquid therapy had a percentage reduction in SBS of about (19.81%) Both kinds of mechanical treatment groups, T. Hole and Sandblasting, had similar percentage decrease outcomes (13.20% and 14.66%, respectively). The combined surface treatment gave the lowest percentage reduction in SBS in (T. Hole + fusion), (Sandblasting + fusion), and the lowest percentage reduction in SBS was with T. Hole + fusion, which resulted in just 9.27 % reduction in SBS, as shown in figure

(7). The SEM images of fractured surfaces were shown in Figure (5), figure (5A) shows smooth surfaces with few scratches in the control group. The alumina-blasting resulted in a pitted and uneven surface as in Figure (5b), The application of fusion liquid resulted in a fewer unequal surface than alumina-blasting, with shallow troughs and hollows as shown in Figure (5c). The combination of alumina-blasting and fusing liquid produced a variety of surface topography and a microporous surface appearance as in Figure (5d). For control specimens with brittle fracture characteristics in Figure (5e). While in alumina-blasted, fusion liquid, and alumina-blasted with fusion liquid groups displaying ductile fracture features, as in Figures (5f), (5g), and (5h).

Visual examination revealed two kinds of failures: adhesive and mixed failures in all testing groups as in Figure (4), and cohesive failure missing in all research groups. The T. Hole group and the other chemo-mechanically treated groups exhibited mixed failures, whereas the control and fusion liquid groups failed mostly adhesively.

Discussion

Debonding of artificial teeth from denture foundation is a very prevalent problem in prosthodontics (3). SBS refers to the strength of the connection between two substances and the amount of load they can sustain before fracturing or separating (18). Due to the selection of substance used to make the denture foundation may impact the binding strength of artificial teeth the semi-rigid microcrystalline polymer as a thermoplastic resin (Karadent by TCS, INC, USA) was used in this investigation (6). Artificial aging was used to replicate the intraoral environment that will subject the prosthetic to fluctuating conditions of temperature and stressful situations within patient using time (3). Our approach for preparing specimens and measuring bond strength depended on JIST 6506 (1989) due to it is the only recent test and utilizes a single maxillary or mandibular anterior tooth for evaluation, with detachment occurring most frequently in the maxillary incisors (19). In this study, the influence of several techniques of surface modification for ridge lap region of acrylic teeth (mechanically T-Hole or sandblasting with 250 aluminum oxide, chemically using fusion liquid adhesive, and a combination of them) on the degree of SBS improvement has been examined and assessed.

I-Mechanical treatment

The T. Hole exhibited statistically higher bonding strength in all thermoplastic resin types (14). The hole diameter must be big enough to bind prosthetic teeth well. A too-small hole may not be able to adequately attach the prosthetic teeth to the denture base. Because karadent thermoplastic resin is viscous, the manufacturer suggests drilling wider holes. As demonstrated in this research, there is a highly significant variation between T. hole group and the control group. This might be because the vertically and horizontally made grooves produced tight mechanical jointing between the synthetic teeth and the thermo-plastic material applied in injecting the mold. This observation matched with that of (Tashiro, S., et al.,2020), T-shaped holes were proven to be a good mechanically attachment design for developing the high strength value of bonding artificial teeth to thermoplastic resins for injection molding (8).

Alumina-blasting therapy enhanced SBS when applied to tooth surfaces. which increased SBS by increasing total bonding area (9). As a result, mechanical changes for the artificial teeth ridge lap area are essential for creating a strong connection of the teeth to the denture base. The aluminum oxide group sandblasted with 250µm Al2O3 particle size exhibits considerably greater binding strength than the untreated specimens in this experiment. This elevation might be related to the abrasive action induced by the particles of aluminum oxide pummeling the surface, which raises the overall surface energy and roughens it by developing irregularities and undercuts, resulting in micromechanical retention pits and, as a result, increased bond strength. This group results agrees with (Krishna, V.P., et al., 2014) Finding that sandblasting acrylic teeth enhanced the bond strength with denture base material (9).

II-Chemical treatment

Surface conditioning of the ridge lap area of tooth was utilized for increasing the bond strength of artificial teeth to denture base resins by accelerating polymerizable material diffusion from the denture base and forming a more extensive interwoven polymer network (6). As a consequence of the surface deterioration by placing a drop of fusion liquid over the tooth ridge lap SBS differed significantly from the unmodified control group. The TCS fusion liquid includes corrosive elements that may harm or destroy the surface, according to the manufacturer's SDS. A connection between the tooth and resin will occupy this deformation on the tooth ridge lap. Unlike (Mahadevan, V. et al., 2015) they observed no difference in shear bond strength between treated and untreated surfaces (5).

III-Combination treatment (chemo-mechanical)

The (chemo-mechanical) treatment enhanced SBS compared with control and other individual treatments. The groups treated with T. holes + fusion liquid exhibited substantially different binding strengths than the ones treated with T. holes alone. These results coincide with those of (Meng GK, et al., 2010) who reported that utilizing diatoric recessed adhesives prior to injection enhances the bonding force between denture bases and acrylic teeth (20). Bond strength was much stronger in the fusion liquid + alumina blasting group than in the alumina blasting alone group. Micro-retentive areas may have increased the total adhesion area, resulting in greater SBS. These micro-retentive voids were filled by adhesives that bridged the tooth ridge lap to the denture base resin, raising the SBS. According to (Saavedra G, et al., 2007) sandblasting outperforms no surface treatment in shear bond testing. Chemical and mechanical adjustments produced the best adhesion (21).

IV-Evaluating the impact of accelerated aging on SBS of all groups

After 100 hours of artificial ageing, the influence of aging on all groups was extremely clear. All study groups found a substantial reduction in SBS. the control group that exhibited the largest reduction in SBS (25.80%). This is Due to recurrent expansions and contractions produced by temperature changes, the bond strength of two different materials decreases after 100 hours of artificial aging (22). Both T. Hole and Alumina-blasting mechanical treatment groups exhibited equal percentage reductions of (12.36% and 13.24%), respectively. concentrating Water molecules in the region of the bond and seep into the pores of the bonding sites, leading to higher tension accumulating at the bonding sites as a consequence of the samples' expansion (11). Our results contradicted (Pande N, et al., 2018) findings that heat cycling had no influence on SBS between teeth and denture bases (22). The combined surface treatment had the lowest percentage reductions in SBS, with T. Hole + fusion liquid having the lowest at 9.27 %. Unlike (AlZaher et al., 2020),) they show that Heat cycling lowers shear bond strength in all treated groups, but this is more evident in groups that have undergone chemical and mechanical surface preparation in combination (18).

Conclusion

- The problem statements with thermoplastic resins that cannot support chemical bonding were solved by thermoplastic monomer-free semi-rigid microcrystalline polymer.
- SBS of tooth to thermoplastic denture base material was improved by the combination chemo-mechanical treatment.
- Ageing had less of an effect on combination therapy than on individual treatments.

Conflicts of Interest

The authors reported that they have no conflicts of interest.

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Table (1): Levene's test and One-ay ANOVA test

Test's Situation	Testing Homogeneity of Variances		ANOVA- Testing Equality of Means	
	Levene Statistic	Sig. (*)	F-test	Sig. (*)
Groups Before ageing	4.975	0.000 (HS)	400.091	0.000 (HS)
Groups After 100hrs of ageing	5.586	0.000 (HS)	431.929	0.000 (HS)

(*) **HS: Highly sig. at P<0.05**

Table (2): mean shear bond strength ±SD (N) and significance of specimens with different surface treatments at 0 and 100 hrs. of ageing

Different small letters significant differences between two groups (before and after) at p-value

Treatment groups / Time	mean±SD		Mean differences	p-value
	Before aging (0 hours) n=10	After aging (100 hours) n=10		
Control	80.63±12.76 $^{a\ F}$	59.83±11.66 $^{b\ F}$	25.80%	0.001 **(HS)**
T. Hole shape	237.79±10.37 $^{a\ B}$	206.4±10.49 $^{b\ B}$	13.20%	0.0001(**HS**)
Sandblasting	140.56±12.9 $^{a\ E}$	119.94±10.18 $^{b\ E}$	14.66%	0.001(**HS**)
Fusion liquid	109.43±10.37 $^{a\ D}$	87.75±10.83 $^{b\ D}$	19.81%	0.0001(**HS**)
T. Hole +Fusion liquid	295.67±12.16 $^{a\ A}$	268.27±8.95 $^{b\ A}$	9.27%	0.0001(**HS**)
Sandblast +Fusion liquid	204.73±12.48 $^{a\ C}$	181.11±10.47 $^{b\ C}$	11.54%	0.0001(**HS**)

<0.05.

Horizontally identical superscripted different capital letters significant differences among treatment groups in each column at p-value <0.05. ANOVA and Tukey`s test.

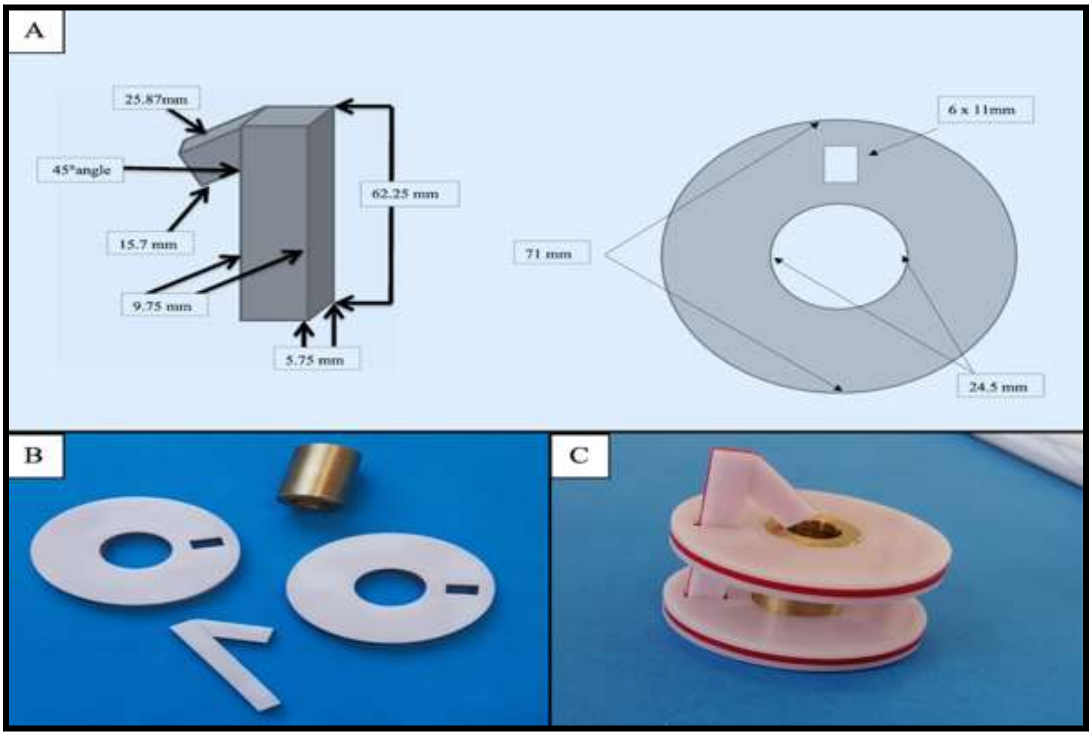

Figure 1: Acrylic Pattern Preparation

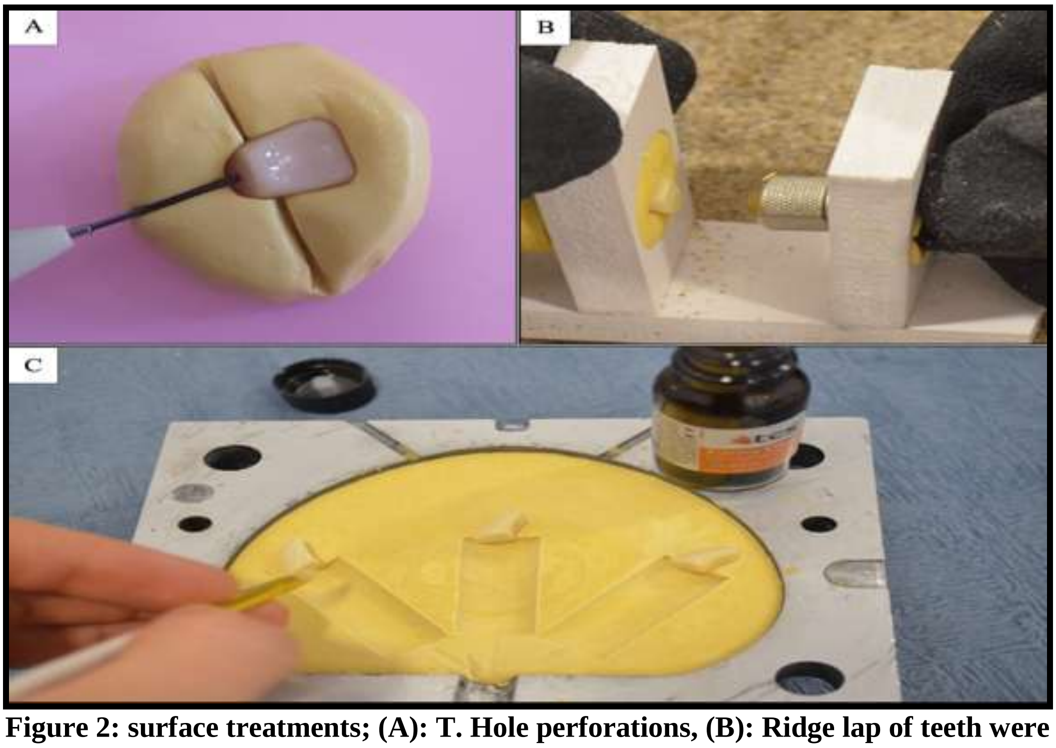

Figure 2: surface treatments; (A): T. Hole perforations, (B): Ridge lap of teeth were abraded with aluminum oxide particles (250 µm) (C): Applying Fusion liquid

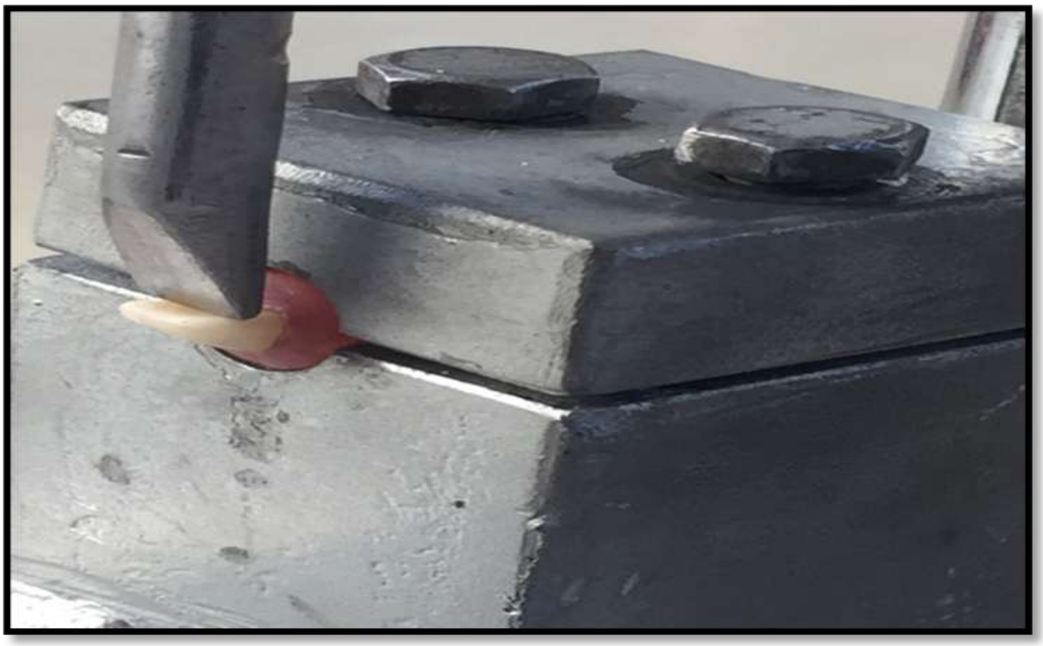

Figure 3: Testing Shear Bond Strength

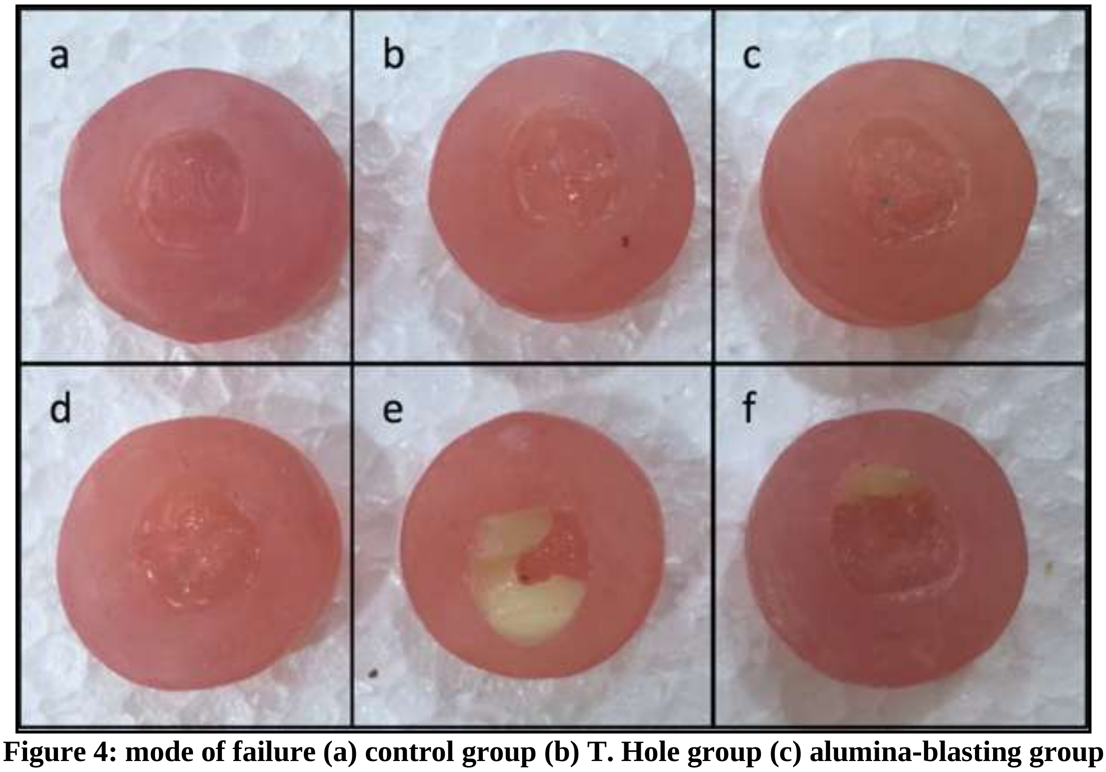

Figure 4: mode of failure (a) control group (b) T. Hole group (c) alumina-blasting group (d) fusion liquid group (e) T. Hole+ fusion liquid group (f) alumina-blasting + fusion liquid group.

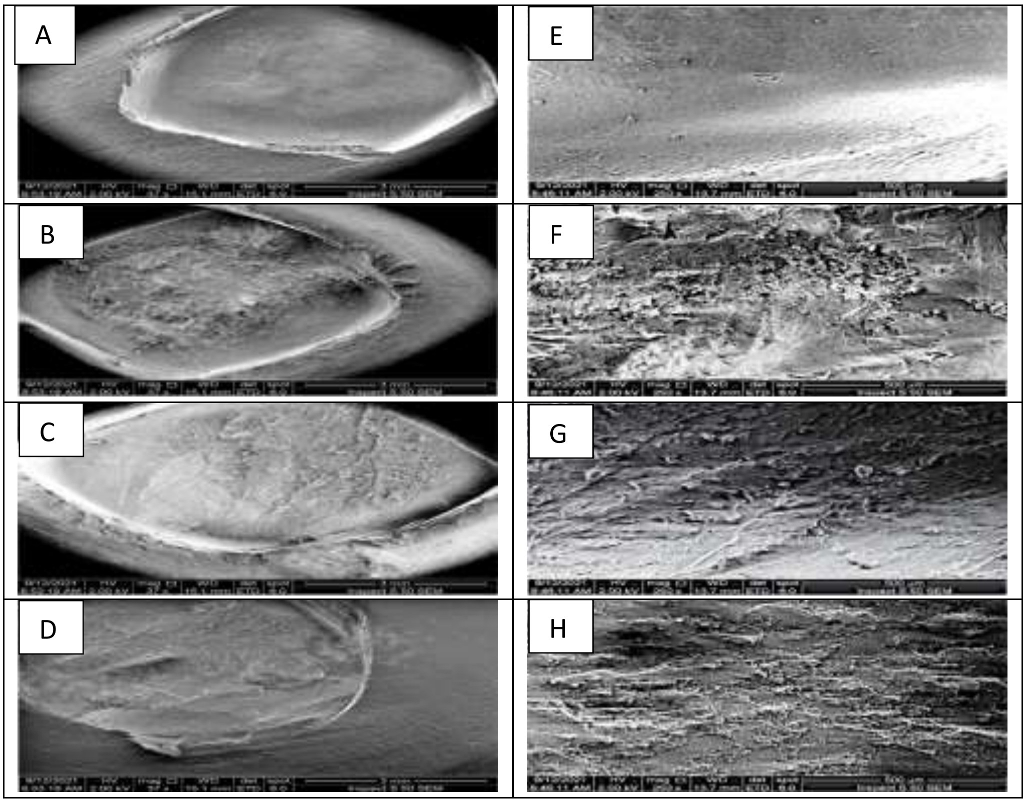

Figure 5: SEM images of fractured surfaces of the studied groups

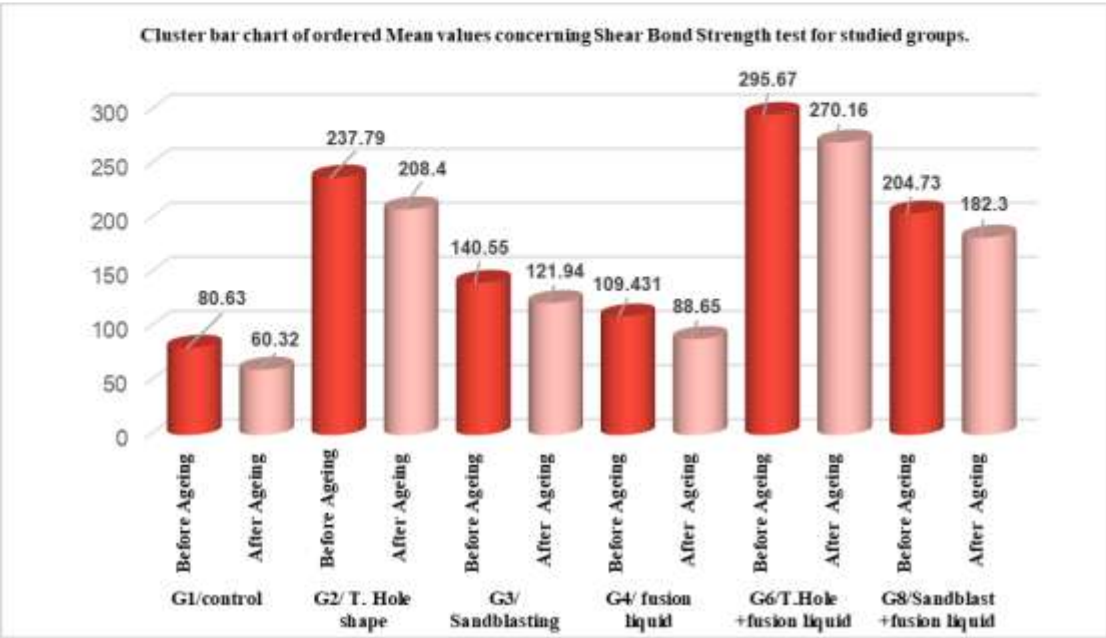

Figure 6: Cluster Bar Chart Shows the Means of SBS Before and After 100 Hrs of Artificial Ageing

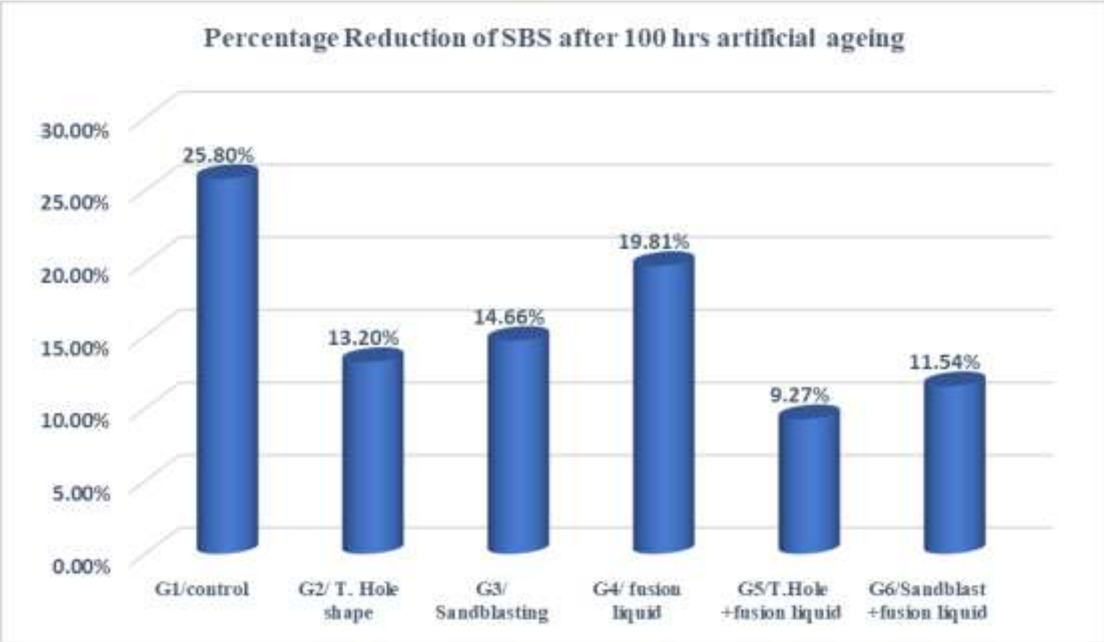

Figure 7: Percentage Reduction in SBS After Accelerated Artificial Ageing