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 – 5, Issue – 2, April - 2022, Page No. : 564 - 573

Effect of different surface treatments on the metal housing and its impact on the flexural strength of high impact denture base material – A comparative in-vitro study

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Citation of this Article: Danish Siddique**,** Anupama N M, Surendra Kumar G P, Fahadah Ubaid, "Effect of different surface treatments on the metal housing and its impact on the flexural strength of high impact denture base material – A comparative in-vitro study", IJDSIR- April - 2022, Vol. – 5, Issue - 2, P. No. 564 – 573.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background: The attachment of the housings in mandibular overdenture needs more space resulting in thinning of the overdenture with increased risk to fracture. Evidence regarding the effects of different surface treatments on the housings and its impact on the bond strength and flexural strength of overdenture is lacking.

Aim: To compare and assess the effects of sandblasting, Sulphuric acid chemical treatment and both on the housings and its impact on the flexural strength of the overdenture.

Materials and methods: Forty high impact resin specimens of dimension 64mm × 10mm × 4mm were fabricated. They were divided into 4 groups. In group 1, no surface treatment was done on the housings. Group 2, housings were surface treated with sandblasting; Group 3, housings were chemically treated with Sulphuric acid for 60 seconds; Group 4, housings were both sandblasted and chemically treated with Sulphuric acid. All the housings were then retained using autopolymerising acrylic resin (APAR) and the samples were stored in artificial saliva for 14 days at 37^{o} C. all the samples were tested using Universal Testing Machine (UTM) and the flexural strength (MPa) were analysed using Mann-Whitney u-test ($P \leq 0.05$). SEM analysis of the attachment housings was done to study the surface changes caused due to the various surface treatments.

Result: Group 3 (Sulphuric Acid) had significantly highest Flexural Strength as compared to Group 1, 2 & 4 at P<0.001. This was followed next by group 2 (Sandblasted) showing significantly higher mean Flexural Strength as compared to group 1 at P=0.001 and finally group 4 (Both Sandblasting and Acid) showing significantly higher mean Flexural strength as compared to group 1 at P=0.004. However, Group 2 did not significantly differ when compared to group 4 [P=0.89].

Conclusion: The metal housing treated with Sulphuric acid and retained with autopolymerising resin showed the highest flexural strength.

Clinical implication: The surface treatment of overdenture housing attachment with suphuric acid and sandblasting can be used chairside to improve the bonding between housing and acrylic denture base.

Keywords: UTM, ISOD, MMA, PMMA, SEM.

Introduction

It is well recognized that many struggle to use dentures, particularly the lower denture, because of mobility and discomfort, and these difficulties have been shown to be linked with social, psychological and functional disabilities, a situation which can deteriorate further as the ridges reduce in size over time.[1] The McGill consensus recommended a 2-implant overdenture as the standard of care for edentulous mandibles because at least 2 implants are deemed necessary to provide retention, support, and stability for mandibular overdentures.[2-3] The implant supported overdenture can be attached with splinted attachments such as bars or unsplinted attachments such as locator, ball anchors, double crowns and magnets. The selection of an appropriate attachment is based on the required retention, jaw morphology, oral function, and patient's willingness for recall.[3-5]

An attachment system is "a particular type of retentive mechanism using compatible matrix and patrix corresponding components. Matrix refers to the receptacle component of the attachment system, and patrix refers to the portion involving a frictional fit which engages the matrix".[3] The simplest type of stud attachment for clinical application is the ball attachment which is most commonly used for 2-implant mandibular overdentures.[3-5] For ball attachment, the recommended inter implant distance is 19 mm and 29 mm. According to previous studies, the ball attachments transfer less stresses to both implant and produces less denture movement, provides better retention and reduces oral mucous pressure during mastication along with additional advantages such as lower cost, more straightforward design, easier maintenance, and adequate retentive force.[3-6]

Polymethyl methacrylate (PMMA) is the most commonly used material for denture base fabrication; however, its mechanical properties limit denture performance.[7] Studies have shown that using high impact denture base material significantly increases the fracture resistance. ISOD has a female part or housing component for attachment of implant to the denture.[7-8] These housing can be secured using indirect (laboratory) or 0direct technique (intra-oral chair side). The direct method for attachment of housing using ball attachment is superior during a long-term evaluation period compared to indirect technique.[7-8] The denture has to be relieved to provide enough space to accommodate these housings and the dimensions of the housings are important as a decrease in the denture base thickness can increase the potential for fracture.[9-11]

Various types of retaining materials are used for attachment of housings like, acrylic resin-based relining materials, an autopolymerising composite resin

retaining, an autopolymerising PMMA, and heat-polymerized PMMA retaining materials.[10] Studies have shown that flexural strength of PMMA denture base was higher when PMMA-based acrylic resins were used as the housing retaining material.[11-12] One of the favored treatments is to pick up implant attachment housings into the denture using chairside techniques with self-cured repair resin.[13] The attachment housings on the denture will then snap onto the implant abutments and help with the retention of the prosthesis. A lot of research has been done regarding denture base repair methods. Successful repair of implant overdentures for attachment housing pickup does not only entail optimal bonding of the denture base resin and the repair material but also the adhesion between the repair material and the attachment housing.[14] No true chemical bond is formed between different acrylic resins.[15] To overcome this problem, cross-linking agents are added to hard denture relining materials to improve their mechanical properties.[15-16] The introduction of the metal housing greatly changes the dynamic of the repair; thus, it is desirable for patient care to use the strongest method available to pick up attachments.[17] Studies have shown that surface modification of the housing by sandblasting increases the flexural strength in dentures repaired with self-cure acrylic leading to less chances of prosthesis fracture and could possibly be an easy and cost-effective way to improve the strength of the denture.[17] However, no in-vitro studies have been done to compare the effects of various surface treatments of the attachment housing including sandblasting, suphuric acid and both on the flexural strength of high impact acrylic overdenture base material. Therefore, the purpose of this study was to evaluate and compare the effect of different surface treatments of the metal housing on the flexural strength of high impact overdenture base material. The null hypothesis in this study is that the various surface treatment of the attachment housing will have a similar effect or no significant difference on the flexural strength of high impact acrylic denture base material repaired with self-cure acrylic resin.

Materials and methods

Three metal dies of dimensions 64 mm × 10 mm × 4 mm were taken for the production of the bar shaped specimens. Two 6 mm diameter hollow were drilled to a depth of 3 mm, which were at a distance of 29 mm from each other. These metal dies were invested in a flask using type 3 dental stone (Kala Bhai kalstone) according to manufacturer's instructions (Figure 1a). Once the stone was set, the flask was separated and metal dies were removed to create a mold space. High impact acrylic denture base resin (Dentsply; TREVALON HI) powder was mixed with the liquid according to the manufacturer instruction and was packed into the mold space. The specimens were polymerized in a hot water bath for 2 hrs. at 74ºC, followed by heating at 100°C for 1 hour. The samples were removed and contoured using tungsten carbide bur at 15000 rpm and the final finishing was done using 200 and 600 grit abrasive paper. The surfaces were not polished as they were considered the intaglio surfaces of the denture (Figure 2). Specimens with processing and finishing flaws like porosity, over trimming were excluded from the test specimen groups.

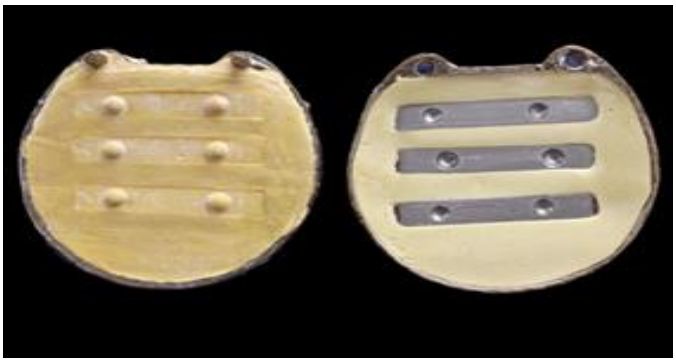


Figure 1: Metal moulds invested in type 3 dental stone.

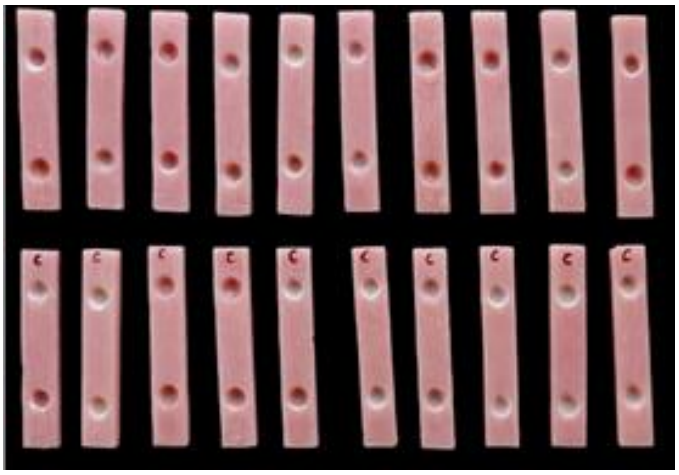


Figure 2: Finished acrylic samples prior to attachment of housing.

A total of 40 PMMA high impact resin (TREVALON HI) specimens were fabricated with the thickness maintained at 4mm. The samples were divided into 4 groups based on the surface treatment of implant ball attachment housings (ADIN IMPLANT; 4.5 mm diameter and 2.6 mm height) as follows:

Group 1: No surface treatment of the housing

Group 2: Sandblasting of the housing

Group 3: Dispersed in Sulphuric acid

Group 4: Sandblasting and Sulphuric acid dispersion.

Each group had 10 acrylic specimens with 20 housings.

Surface treatment of the implant housing

Group 1: No surface treatment was done on 20 housings.

Group 2: Using Pen blaster, an abrasive blasting system, 20 implant housings were sandblasted with silica-modified 110 μm aluminum oxide (BEGO Korox 110). A blast pressure of 2.8 bar was used for sandblasting. This was done to assure an adequate high level of energy to create the triboplasma. The surface was sandblasted at right angles from a distance of 1 cm for 15 seconds(s) all around the housing. It was then washed under slow running water and air dried before attachment of the housing to the acrylic specimens with auto polymerizing resin (Figure 3a).

Group 3: Sulphuric acid (concentration 97%) was taken in a dappen dish and housing was held with tweezer with its jaws covered with Teflon tape (PTFE) and the external surface of the housing was immersed in the acid for 60 seconds. It was then washed under running water and air dried before attachment to the specimens with auto polymerizing resin (DPI) (Figure 3b).

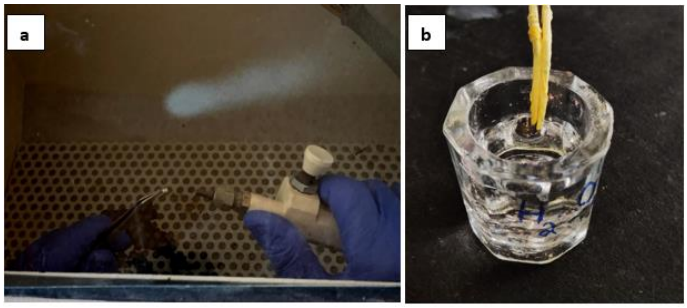


Figure 3 a: Housing is treated with aluminum oxide using pen blaster,

b. Housing external surface treated with Sulphuric acid.

Group 4: The housing was first sandblasted and the steps similar to group 2 was followed till the housing was air dried. It was then immersed in Sulphuric acid and the steps similar to group 3 was followed and the housings were attached using autopolymerising resin.

Attachment of the housing using Autopolymerising acrylic resin (DPI)

Eighty housings (4.5 mm diameter and 2.6 mm height, ADIN IMPLANT) were attached using autopolymerising acrylic resin to forty bar shaped specimens fabricated by compression molding technique. After cleaning and drying of the drilled PMMA surface, liquid methyl methacrylate monomer (DPI) was brushed on the exposed surface for 180 s to enhance adhesion of the repair material and the denture base resin. Self-cured acrylic was applied in the hollow space created using “salt-and-pepper” technique. Once the resin filled three-fourth of the hole, block was inverted and placed over the housings secured in the center of glass slab-simulating clinical attachment

pick-up. The block was pressed against a glass slab for 10 min. Additional self-cured resin was placed on the repaired side to fill any voids. Once set, the repaired surface with the attachment housing was refinished with abrasive paper (Figure 4).

All the specimens were immersed in artificial saliva at 37ºC in incubation chamber for 14 days. The samples were kept in dry conditions for 1 hour before the mechanical testing was to be done. Using Universal Testing Machine (UTM), a three-point flexure test [International Organization for Standardization (ISO) standard 1567] was utilized to test the flexural strength of the specimens placed in a test rig with vertical supports 50 mm apart. The plunger tip was 3.2 mm in diameter. A force was applied using a Mecmesin Multi Test 10-i system with Win Test software and a 500- lbf load cell at a cross head speed of 5mm/minute (Figure 5a). The fracture force (F) was recorded in newtons (N) and the flexural strength (FS) was calculated as per the following formula to yield MPa units: FS=3PL/2bd2. Where 'P' was maximum load, 'L' was length of specimen, 'b' was specimen width and 'd' was specimen thickness. The specimens fractured at the attachment site of housing and acrylic resin (Figure 5b) which is the common fracture site for mandibular overdentures.

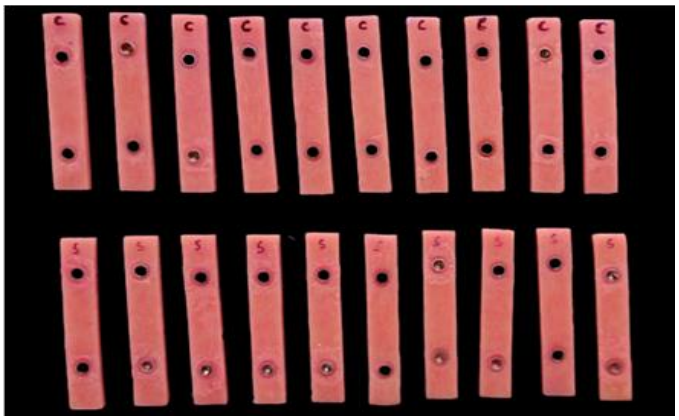


Figure 4: Final acrylic samples with attached implant housings.

The housings were further examined under Scanning Electron Microscope (SEM) imaging to analyze the surface change followed by sandblasting, Sulphuric acid treatment and both (Figure 6 a,b,c and d).

To perform the statistical analysis Statistical Package for Social Sciences (SPSS) version 20. [IBM SPASS statistics (IBM corp. Armonk, NY, USA released 2011)] was used. Descriptive statistics of the explanatory and outcome variables was calculated by mean, standard deviation for quantitative variables. Inferential statistics like One-way ANOVA test and Tukey's Post hoc Test was applied to check the statistical difference of fracture resistance, displacement between the groups. The level of significance was set at 5%.

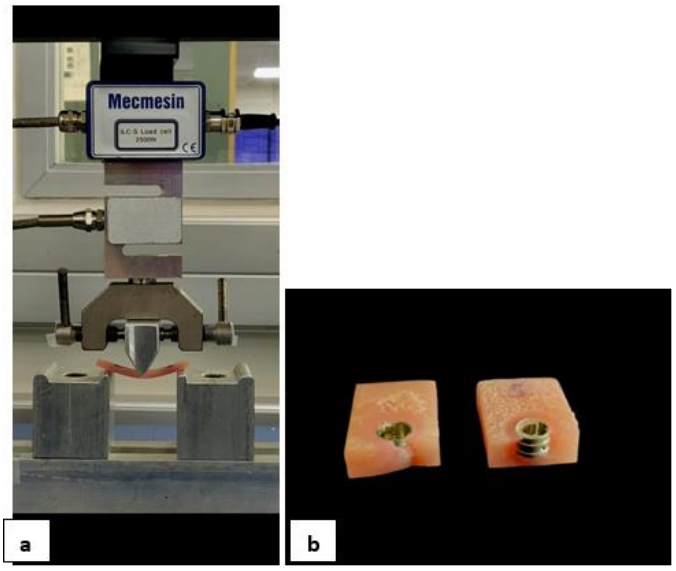


Figure 5 a: acrylic sample tested using Mecmesin UTM. b. Fractured acrylic samples at the housing attachment site.

Results

The mean difference in the Flexural Strength between 4 groups was statistically significant at P<0.001 [Table 1] illustrates the comparison of mean Flexural Strength between 4 groups.

The test results demonstrate that the mean Flexural Strength for Group 1 (No Treatment) was 144.13 ± 8,67,

for Group 2 (Sandblasted) was 163.20 ± 11.48, for Group 3 (Sulphuric Acid) was 184.73 ± 5.29 and for Group 4 (Sandblasting and Sulphuric Acid) was 160.12 ± 11.99.

Table 1: Comparison of mean Flexural Strength (in Mpa) between 4 groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	10	144.13	8.67	129.96	158.24	<0.001*
Group 2	10	163.20	11.48	149.72	178.16	
Group 3	10	184.73	5.29	177.30	194.72	
Group 4	10	160.12	11.99	143.82	178.92	

Discussion

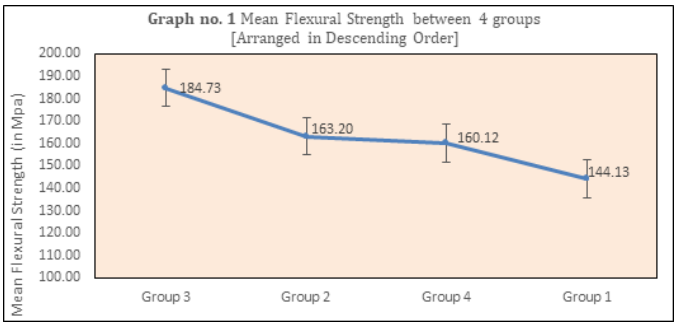
Various bonding methods and techniques have been developed for base metal alloys that have significantly improved the integrity of the resin/metal interface in oral environment such as electrolytic etching, chemical etching, silica coating, sandblasting with oxides of different granulation and conditioning with acid substances.[19-21]Abrasion of the metal surface with airborne particles has been claimed to improve the wettability of the metal surface, causing micro mechanical roughness that increases the surface area for bonding.[17-19] The null hypothesis in this study that there is no significant difference on the flexural strength of high impact acrylic denture base material repaired with self-cure acrylic resin after the various surface treatment on the housing was rejected.

The test results showed that Group 3 (Sulphuric Acid) had significantly highest Flexural Strength as compared to Group 1, 2 & 4 at P<0.001. This was followed next by group 2 (Sandblasted) showing significantly higher mean Flexural Strength as compared to group 1 at P=0.001 and finally group 4 (Both Sandblasting and Acid) showing significantly higher mean Flexural strength as compared to group 1 at P=0.004. However, Group 2 did not significantly differ when compared to group 4 [P=0.89].

The metal housing in this study was treated with sandblasting using Pen blaster unit with 30µm aluminum oxide particles as per manufacturer's instructions. According to Pfeiffer in 1993, the use of 30µm grain size produces the same adhesive strength as the 110 µm grain size but is less abrasive.[12]

Table 2: Multiple comparison of mean difference in Flexural Strength (in Mpa) b/w 4 groups using Tukey's Post hoc Test

(I) Groups	(J) Groups	Mean Diff.(I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	-19.07	-30.79	-7.35	0.001*
	Group 3	-40.60	-52.32	-28.88	<0.001*
	Group 4	-15.99	-27.71	-4.27	0.004*
Group 2	Group 3	-21.53	-33.25	-9.81	<0.001*
	Group 4	3.08	-8.65	14.80	0.89
Group 3	Group 4	24.60	12.88	36.33	<0.001*



This infers that Sulphuric acid group showed significantly highest mean Flexural strength, followed group Sandblasting group & both treatment group and least was with no treatment group. Agarwal et al in their study reported that sandblasting the attachment housing

with 30 µm silica modified aluminum oxide produces a roughened surface and effectively increased the bonding between titanium and self-cure acrylic resin.[17] The review of literature on surface processing of metals by Pawel Lochynski et al revealed that stainless steel may be electrochemical polished with baths containing Sulphuric acid, orthophosphoric acid, triethanolamine and ethylene glycol, oxalic acid, and acetanilide.[25] The housings in group 3 were chemically treated with Sulphuric acid by immersing it for 60 seconds in a petri dish. In this study, it was believed that metal surfaces were affected by surface treatments and was confirmed with SEM analysis (Figure 7 a-d) of the housing surfaces. Group 4 housings were subjected to both sandblasting and Sulphuric acid treatments.

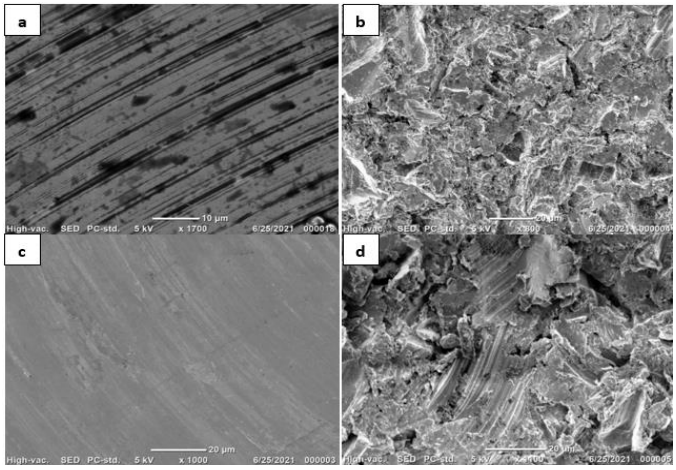


Figure 6: SEM analysis of external surface of the overdenture housings. a. Surface of untreated housing showing presence of oil and impurities, b. Sandblasted surface showing rough irregularities, c. The Sulphuric acid treatment on the housing shows oil and impurity free etched rough surface, d. The housing surface treated with both sandblasting and acid shows rough irregularities and acid etched areas.

Vallittu et al stated that wetting the repair surface with MMA dissolved the surface structure of polymethyl methacrylate (PMMA) and a duration of 180 seconds of wetting with MMA enhanced adhesion, compared with shorter durations of wetting.[24, 27] The housing pickup surface was pretreated with MMA for 180 seconds before attachment of the housing to enhance the bonding in this study. Gianluca et al concluded that high-impact denture base resins could be the material of choice when there is a history of repeated fracture or where the fracture is more likely to occur.[28] Fahadah et al reported that the specimens fabricated by compression molding technique using autopolymerising acrylic resin housing retaining material showed the highest flexural strength.[7] Therefore, in this study high impact denture base resin was used for the fabrication of specimens using compression moulding technique and autopolymerising acrylic resin was used to retain the housing.

Ozkir et al in his study stated that thermocycling should be used during testing of the specimens because higher thermal expansion and contraction of the metal housings might increase stresses leading to microcracks at the housing and retaining material junction though denture base and housing retaining material junction was intact.[10] Hence this study had several limitations including the standardized rectangular bar shaped specimens fabricated in this study were different from the overdenture used in clinical situation. The thickness of the specimens was taken 4 mm according to the clinical situations but may also differ from patient to patient. Since it's an in-vitro study, the specimens were stored in artificial saliva for two weeks to simulate the oral environment, but other factors like masticatory load, parafunctional habits, and oral temperature may also influence the flexural strength.

Clinical implication

The surface treatment of implant overdenture housing can be done chairside with Sulphuric acid, sandblasting or both prior to its attachment to the acrylic denture base

which will increase the flexural strength and therefore decrease incidence of fracture at the attachment site.

Conclusion

Within the limitations of the study, it can be concluded that, Sulphuric acid treatment of the metal housing for 60 seconds prior to its attachment can increase the bond strength with the housing material and increase the flexural strength of the overdenture.

Sandblasting of housing with 110-micron Aluminum oxide prior to its attachment increases the flexural strength of overdenture.

Surface treatment with both Sulphuric acid and sandblasting increases the flexural strength compared to no treatment but is less in comparison with either of the surface treatment alone.

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