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Evaluation of adaptation of different resins to secure implant supported over denture housings: A scanning electron microscopic study

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Abstract
Eighty heat polymerized polymethyl methacrylate (PMMA) denture base specimens (30×11×8mm) were prepared. Four materials used to retain the housings in the PMMA denture base blocks were autopolymerizing acrylic resin, composite resin, pattern resin and heat polymerizing acrylic resin. The PMMA block containing housing was then seated on a ball abutment-implant analog. Universal testing machine was used to detach the acrylic block-housing assembly from the ball abutment implant analog assembly. Scanning electron images were made to inspect the PMMA denture base-retaining material-housing interfaces for any adhesive failure. Chi square test was used to compare the results of SEM analysis. Highest percentage of adhesive failure of 55% was found in the composite resin group (Group B) at the acrylic denture base-housing retaining material junction (junction 1). Heat polymerizing acrylic resin group (Group D) exhibited 100% adhesive failure at the retaining material-housing junction (junction 2).

Keywords: denture resins, repair resins, implant supported overdenture, attachment housing

Introduction

Overdentures supported by implants have a higher rate of success than overdentures supported by the roots of natural teeth [1]. Implant supported overdenture can be converted from implant-tissue supported prosthesis (RP-5) to a completely implant supported prosthesis (RP-4) to fixed prosthesis. The implant-supported overdenture may be the treatment of choice when there are unfavorable ridge relations, an inadequate number of implants, poor implant distribution or alignment, a desire for easy removal to provide abutment and prosthesis hygiene, or financial limitations that may prevent the use of fixed implant prosthesis [2]. It may also be a practical form of treatment for satisfied denture wearers who desire additional stability for their prostheses. Successful implant therapy requires detailed planning and precise execution to ensure a successful and predictable outcome.

Implant-supported overdenture housing can be incorporated into the intaglio surface of denture as an indirect procedure during the laboratory processing of the denture or as a direct clinical procedure in the mouth. Direct clinical placement of the attachment requires minimal chair side time, easily accomplished and does not require additional laboratory procedures or component parts.

Autopolymerized PMMA resin is used to secure the attachment housings in the overdenture base. Autopolymerized resin bonds well with the denture base resin, as both of them are PMMA resins. In addition, different kinds of hard relining materials are also used for housing retention in overdentures [2].

Inadequate bonding between overdenture components and acrylic resin may weaken the prosthesis. In addition, gaps that form as a result of adhesion failure can lead to microleakage between the retaining material and the housing. These gaps may serve as reservoirs for microorganisms and can increase staining and accelerate discoloration. These gaps may exist at microscopic level long before the actual clinical attachment failure can be observed by the clinician following the long term use of the implant supported overdenture.

Therefore the current study aims at evaluating and comparing the effectiveness of autopolymerizing acrylic resin, composite resin, pattern resin and heat polymerizing acrylic resin in retaining the housing to the denture base resin using scanning electron microscopic images of the two junctions; denture base-resin (junction 1) and resin-housing (junction 2).

Materials and Methods

80 specimens were prepared to evaluate the adaptation of 4 resins to secure implant supported overdenture housings.

A stainless steel bar measuring 30×11×8mm was fabricated. This served as a metal pattern for the production of the acrylic blocks. Silicon putty impression material base and catalyst was mixed according to the manufacturer's recommendation and the metal bar pressed into this impression material to create a mould. 80 such moulds were obtained. After the removal of metal bar, the mould was filled with molten wax to make 80 wax patterns. These wax patterns were then invested in a conventional denture investment flask using dental stone type III and dewaxed. Heat-polymerizing denture base resin polymer and monomer was mixed in a ratio of 3:1 by vol. (2:1 by wt.) and packed in a dental flask at the dough stage and bench cured according to ADA specification no. 12. The flasked specimens held in clamp, were processed by submerging in water at 73± 1ºC for one and half hour followed by 100ºC for 30 minutes. After completion of acrylization, the flask was bench cooled at room temperature for 30 minutes and then kept under running tap water for 15 minutes. All the 80 acrylic blocks were trimmed and polished using the standard protocol.

Stainless steel housings (Adin) of dimensions of 4mm in diameter × 3mm in height were used in this study. A 7(±0.5) mm diameter × 5(±0.5) mm depth hole was drilled at the center of each acrylic denture block using a drill press.[3] The stainless steel housings were seated in the denture blocks by direct attachment transfer technique using 4 different resin retaining materials: (1) autopolymerized acrylic resin (2) composite resin (3) pattern resin and (4) heat polymerized acrylic resin.

Housing retaining material was filled upto two-third of the hole created at the center of each acrylic denture block. The stainless steel housing was placed inverted on a glass slab. The denture block was then inverted and placed over the stainless steel housing such that the housing seats inside the hole. The denture block was pressed against the glass slab for 10 minutes under finger pressure. This simulated the clinical direct housing attachment transfer technique (Pick-up technique) [3]. Once the retaining material was set the excess material was removed with a tungsten carbide bur and the repaired surface was finished using 200- and 600- grit abrasive paper. The surface was then checked for any voids. Samples if found with voids were rejected and fabricated again. A total of 80 such samples were fabricated.

All the 80 acrylic denture blocks were randomly divided into four groups (20 in each group) according to the retaining material used.

GROUP A –autopolymerizing acrylic resin.

GROUP B –composite resin.

GROUP C –pattern resin.

GROUP D–heat-polymerizing acrylic resin. The heat-polymerized resin, used for housing retention, was polymerized in a curing pressure pot under 0.6 MPa at 100^{0}C [4].

Fabrication of implant analog - aluminium matrix block

An anodized aluminium matrix of 10×10×50 mm dimension was fabricated. A dental implant analog (ADIN) was then mounted at 90^0 in this anodized aluminium matrix. A 2mm hex ball abutment was torqued to 35 Ncm with a manual torque wrench into this implant analog [5].

A standard white plastic cap was placed inside the stainless steel housing. This plastic cap helps to accurately fit the implant ball abutment inside the housing. The acrylic block containing the metal housing was then seated on the ball abutment-implant analog.

Testing adaptation

The tests were carried out at Indian Institute of Science, Bangalore.

The acrylic block-aluminium matrix assembly was placed in the micro Universal Testing Machine (UTM) such that the acrylic specimen was held by the upper grip and the implant analog fixture/aluminium matrix was held in the lower grip of the UTM. A pulling force of 5.5N was applied at 50mm/min speed to detach the acrylic block-housing assembly from the ball abutment-implant analog assembly [6, 7]. A study conducted by Jefferies *et al*. to compare the detachment forces of two implant overdenture attachment types also demonstrated that a speed of 50mm/min is closer to the speed of the movement of the denture away from the ridge and retentive components when dislodging forces were applied to the denture. The authors have also stated that an applied force of 5.5N represented a general force value where the applied force exceeded the maximum frictional force resulting in detachment of the attachment components [7].

After the detachment of the housing from the ball abutment, each specimen was placed under a Scanning electron microscope to evaluate the adaptation of the retaining material to the housing and acrylic denture block. The acrylic denture base-resin retaining material junction and the resin retaining material-housing junctions were examined at 4 positions per junction, radially across each specimen at ×500 magnification. Scanning Electron Microscopic images at ×500 magnification were made to detect any microcracks that might have formed during detachment at acrylic denture base-resin retaining material junction (Junction 1) and the resin retaining material-housing junctions (Junction 2). Depending on the location of the microcracks, it was observed whether the loss of retention was an adhesive or a cohesive failure.

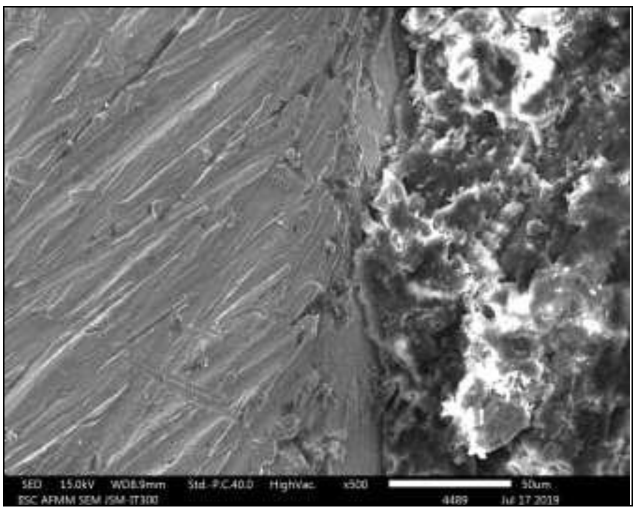

Fig 1: SEM image of Group A (autopolymerizing acrylic resin) exhibiting adhesive failure at Junction 1

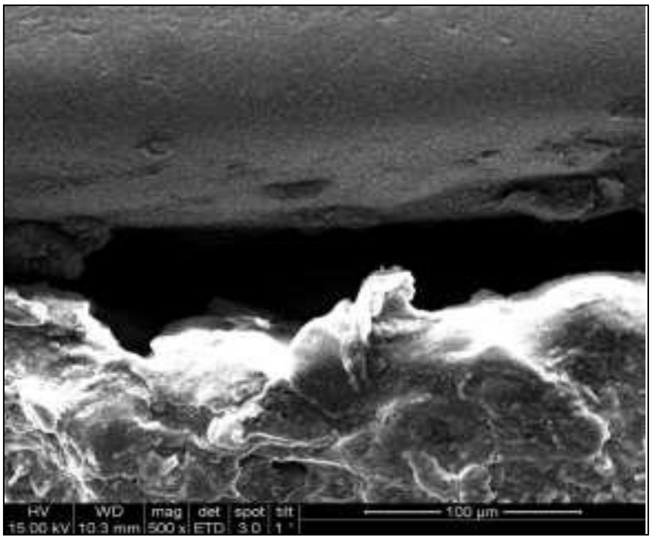

Fig 2: SEM image of Group A (autopolymerizing acrylic resin) exhibiting adhesive failure at Junction 2

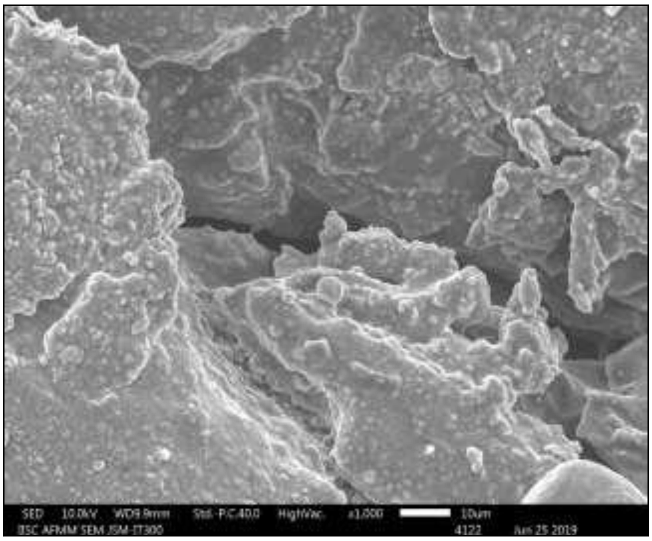

Fig 3: SEM image of Group B (Composite resin) exhibiting adhesive failure at Junction 1

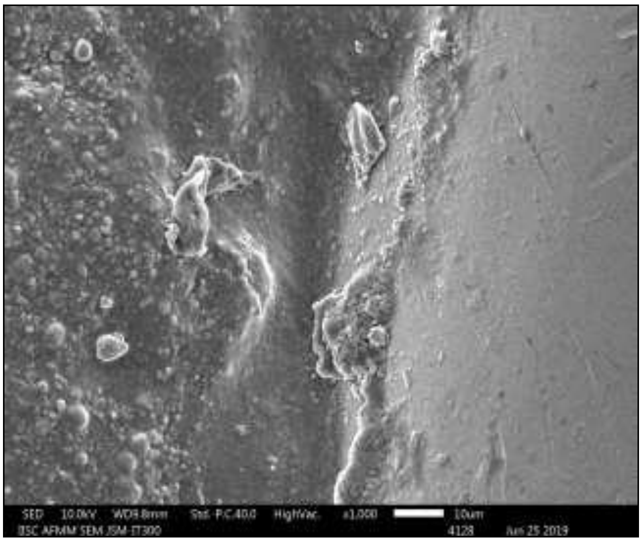

Fig 4: SEM image of Group B (Composite resin) exhibiting cohesive failure at Junction 2

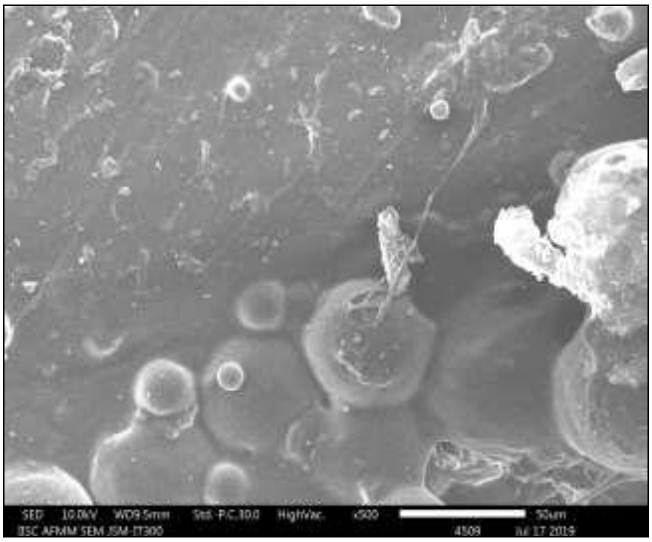

Fig 5: SEM image of Group C (Pattern resin) exhibiting adhesive failure at Junction 1

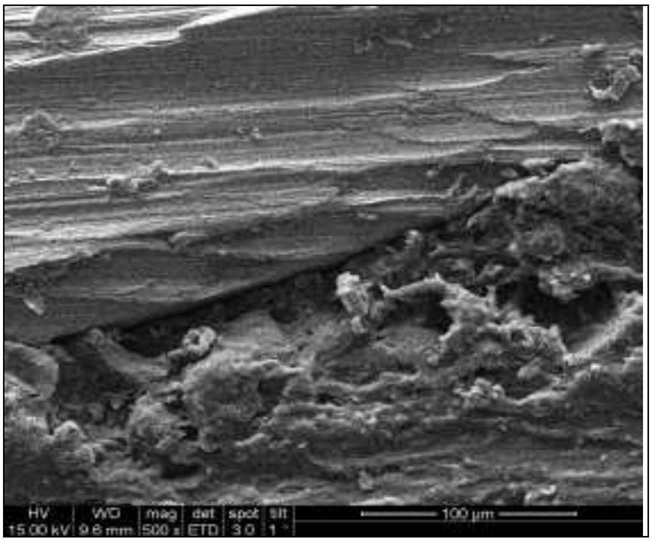

Fig 6: SEM image of Group C (Pattern resin) exhibiting adhesive failure at Junction 2

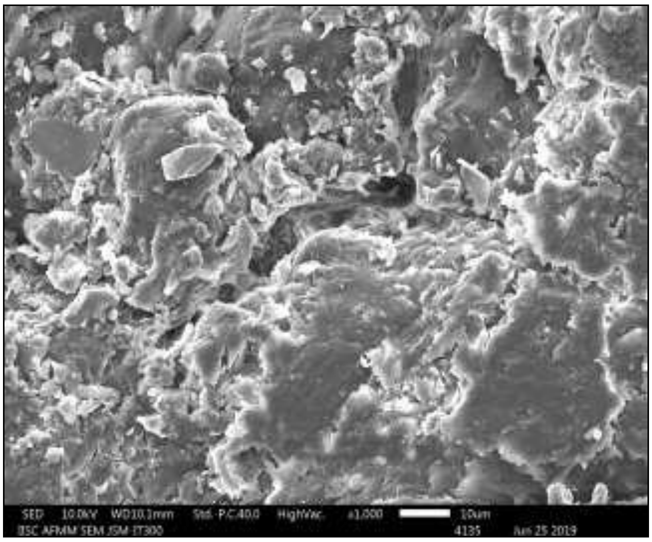

Fig 7: SEM image of Group D (Heat polymerizing acrylic resin) at Junction 1

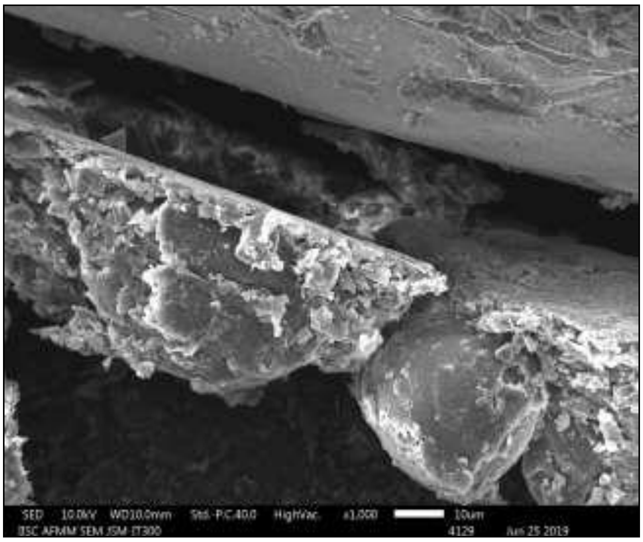

Fig 8: SEM image of Group D (Heat polymerizing acrylic resin) exhibiting adhesive failure at Junction 2

The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data and Microsoft word and Excel were used to generate graphs, tables etc**.** Results on categorical measurement were presented in number (%). Level of significance was fixed at p=0.05 and any value less than or equal to 0.05 was considered to be statistically significant. Chi square analysis was used to find the significance of study parameters on categorical scale.

Results

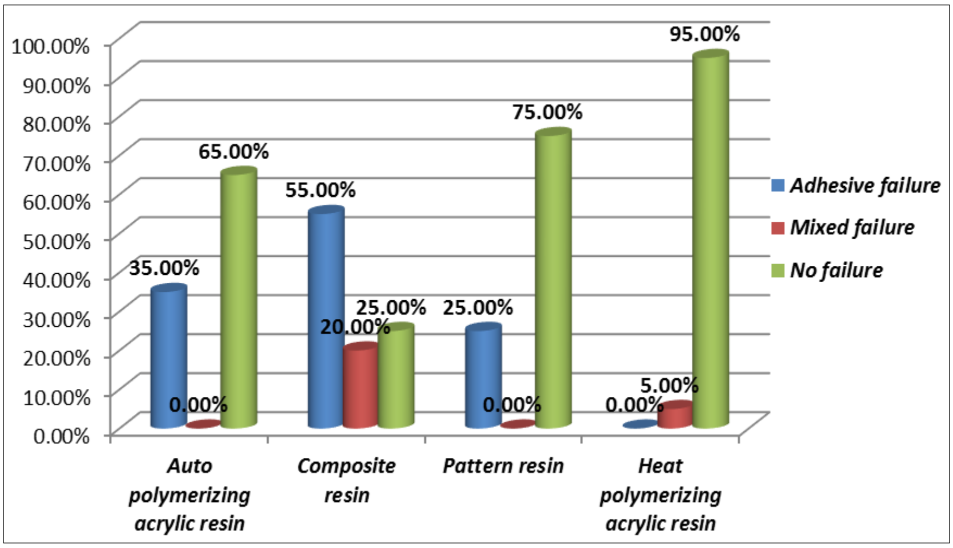

Table 1: Comparison of the results of SEM analysis at junction 1 among different groups using chi square test.

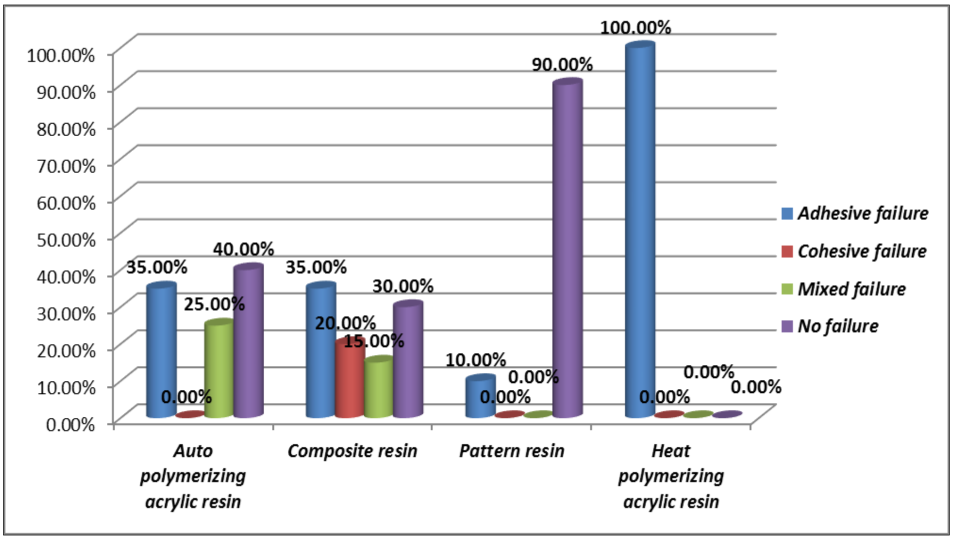

Table 2: Comparison of the results of SEM analysis at junction 2 among different groups using chi square test

SEM analysis at the Acrylic denture base-retaining material junction (Junction 1) among different groups was compared using chi square test. 28.7 % of the samples exhibited adhesive failure, 5% of the samples exhibited mixed adhesive and cohesive failure and 65% of the samples exhibited no failure at all. The result of this comparison is tabulated in table 1. There was a statistically significant difference found between the groups.
(P<0.001). Highest percentage of adhesive failure (55%) was found in the composite resin group (Group B), followed by 35 % in autopolymerizing group (Group A) and 25 % in pattern resin group (Group C). Adhesive failure was not observed in the heat polymerizing acrylic resin group (Group D) at Junction 1.
SEM analysis at the Retaining material-Housing junction (Junction 2) among different groups was compared using chi square test. 45 % of the samples exhibited adhesive failure, 5 % of the samples exhibited cohesive failure, 10% of the samples exhibited mixed adhesive and cohesive failure and 40% of the samples exhibited no failure at all.
The result of this comparison is tabulated in TABLE 2. There was a statistically significant difference found between the groups (P<0.001). Adhesive failure was observed in all the samples of Heat polymerizing acrylic resin group at Junction 2. 35 % of the samples in autopolymerizing group (Group A) exhibited adhesive failure, followed
by 35 % in composite resin group and 10 % in pattern resin group. Cohesive failure was observed only in the composite resin group at Junction 2.

Discussion
Polymethyl methacrylate (PMMA) is the most popular material used for the fabrication of denture bases since 1937. Its colour, optical characteristics and dimensional properties remain stable under normal intraoral conditions [8]. PMMA is a hard resin with a Knoop hardness no. of 18 to 20. It has a tensile strength of approximately 60 MPa, density of 1.19g/cm3 and modulus of elasticity of approximately 2.4 GPa. These physical properties have proven to be adequate for the application of PMMA as a denture base material [9]. However, the denture base may be thin around the implant attachment housings, and PMMA base fractures have been reported. Atleast 2mm of denture base acrylic should be present between the teeth and borders of the denture around the attachment housing [5]. The stainless steel housings used were of dimensions of 4mm in diameter × 3mm in height. Hence, holes of 7(±0.5)mm diameter × 5(±0.5)mm depth were drilled at the center of each acrylic denture block to maintain atleast 2mm of acrylic resin around the housings.
The bond between the resin-denture base and resin-housing is important for the success and longevity of an overdenture [3]. At the acrylic denture base-resin retaining material junction (Junction 1), highest percentage of adhesive failure (55%) was found in the composite resin group (Group B), followed by 35 % in autopolymerizing group (Group A) and 25 % in pattern resin group (Group C). Adhesive failure was not observed in the heat polymerizing acrylic resin group (Group D) at Junction 1. The adhesion of the retaining materials to the denture base depends on the diffusion of the monomers into the Polymethyl Methacrylate of denture base [10]. The monomer consists of methyl methacrylate and dibutyl phthalate as a plasticizer. The monomer has the ability to swell and penetrate into the swollen surface layers. Dibutyl phthalate in the monomer liquid and diethyl phthalate in the powder increase the solubility of the PMMA beads of the denture base powder resulting in increased bonding between the material and the denture base [9].
Autopolymerizing acrylic resin, heat polymerizing acrylic resin and pattern resin contain methyl methacrylate monomer. Methyl methacrylate monomers penetrate the surface of the denture base and polymerize [9]. The heat polymerizing acrylic resin used as the retaining material had the same chemical composition as that of the denture base. This could probably help in better bonding thereby minimizing adhesive failure when heat polymerizing acrylic resin was used as the housing-retaining material. Studies conducted by Mutuay *et al*. also demonstrated that the materials with similar chemical composition as that of the denture base exhibited better bonding [10].
The percentage of adhesive failure at Junction 1 in the autopolymerizing acrylic resin group was greater as compared to the pattern resin group (Table 1). This may be due to greater polymerization shrinkage of autopolymerizing acrylic resins (2%) as compared to pattern resin (0.37%).
Composite resins when used as the housing retaining material exhibited greatest adhesive failure at Junction 1 amongst all the materials tested. This could probably be due to the difference in chemical composition between composite resin and denture base. Vergani *et al*. conducted a study to evaluate the bond strength between composite resin and acrylic resin denture teeth. The authors stated that chemical bonding can occur between composite resin and acrylic resin if there is sufficient cross linking [11]. Therefore, the absence of methyl methacrylate monomer in composite resins could probably have resulted in decreased bonding to the acrylic denture base due to inadequate cross linking.
At the resin-housing junction (Junction 2), the adhesion of the materials to the metallic housing is mechanical rather than chemical in nature. The percentage of adhesive failure at junction 2 was 45 % as compared to 28.7% at junction 1 (Table 2). The mechanical retention between the housing and the retaining material is by means of an undercut in the housing. However this may not be sufficient in absence of any surface treatment of the housing to increase its surface roughness. Domingo *et al*. in their study concluded that the flexural strength of autopolymerizing acrylic resin with silane treated attachment housings was significantly higher than with untreated attachment housings [3].
Adhesive failure resulting in microcracks were observed at junction 2 in all the heat polymerizing acrylic resin samples. The samples of heat polymerizing acrylic resin group (Group D) were subjected to heat for the polymerization of the heat polymerizing acrylic resin retaining material. Microcracks could have been formed due to release of stress caused by heat for polymerization of the material [8]. Also there is a significant difference in the coefficients of thermal expansions of the heat polymerizing acrylic resin and stainless steel housing. 26 Only the samples of heat polymerizing acrylic resin group (Group D) were subjected to heat for the polymerization of the heat polymerizing acrylic resin retaining material. This could have resulted in adhesive failure at the retaining material-housing junction (Junction 2) in Group D. Studies conducted by Ozkir *et al*. to evaluate the adaptation of different materials to secure the implant attachment housings also demonstrated adhesive failure at the housing-retaining material junction in all the groups after thermocycling. The authors have stated that this could be due to the difference in coefficient of thermal expansion between the housing and the materials [4].

Thermocycling is carried out in experimental set up to duplicate the conditions that the dentures are exposed to during function. This was not done in the current study. No mechanical test was conducted to evaluate the bond strength of the resins to the PMMA and housing. Therefore further studies need to be conducted to strengthen the result of the current study.

Conclusion

Within the limitations of the study the following conclusions were drawn:

1. SEM analysis at the Acrylic denture base-Retaining material junction (Junction 1) revealed highest percentage of adhesive failure of 55% with composite resin (Group B). No adhesive failure was observed with heat polymerizing acrylic resin (Group D) at Junction 1.
2. SEM analysis at the Retaining material-Housing junction (Junction 2) revealed 100% of adhesive failure with heat polymerizing acrylic resin (Group D) which was highest. Pattern resin (Group C) exhibited 10% of adhesive failure at Junction 2 which was the least.
3. Pattern resin showed promising results at both the junctions. Therefore its function as a housing retaining material should be investigated further.

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