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Evaluation of Peel Bond Strength between Self Cure Acrylic Resin Material and Two Different Commercially Avaliable Maxillofacial Silicone Material Using a Primer - An in Vitro Study

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Abstract:-

Background: A combination of acrylic resin and silicone elastomer are sometimes used in the fabrication of facial prostheses to provide structural support when a large prosthesis is required, a framework for retention, or housing for bar attachment clips on facial implants may also be used for extra support for the prosthesis. However, peeling off of the maxillofacial silicone elastomer from contact with the acrylic resin can be a problem in such facial prostheses. Therefore, the bonding process between silicone elastomer and acrylic resin has been investigated, and the use of a primer has been suggested to obtain suitable bond strength. Purpose: The aim of this study was to evaluate 180^0 peel bond strength between self cure acrylic resin and two different commercially available maxillofacial silicone material using a primer.Methodology: A total of 20 samples were fabricated using self cure acrylic resin on a stainless mold after which they were sandblasted and cleaned. The specimens were then divided into 2 groups (sample A and sample B) with 10 specimens in each group. Each sample in both the groups were coated with a thin uniform single coat of A-304 Platinum primer using a brush. The acrylic strips were then aligned back on the stainless steel mold. Silicone material from Technovent (Part A and Part B) was mixed according to manufacturers recommendations in the ration 10:1 and placed in vaccum chambers to eliminate air bubbles. The material was then packed into the mold space and allowed to set at room temperature. The specimens were tested using universal testing machine. Modes of failure was visually analysed and grouped into adhesive, mixed and cohesive depending on the way the silicone materials tears off from the surface of the acrylic. Results: Results calculation was done using Students unpaired t test. A statistical package SPSS VERS.21.0 (Armonk, NY, IBM Corp.) was used to do the analysis, where $p<0.05$ was considered as significant. The peel bond strength was calculated to be 1.37N/mm for sample A (M P Sai) and 1.105N/mm for sample B (Technovent). Adhesive failure was observed for all the specimens with silicone material in group I (MP Sai) and for 90% of specimens in group II (Technovent), whereas one specimen had cohesive failure for silicone material (Technovent).Conclusion: From the current study the following conclusions were drawn, the primer A-304 provided better peel bond strength with sample B when compared to sample A respectively. Majority of the samples in both the groups showed adhesive mode of failure using the platinum primer A-304. Autopolymerising acrylic provided comparable peel bond strength with both the maxillofacial silicone material used in the study.

***Keywords**:- Bonding, Maxillofacial Prosthesis, Maxillofacial Silicone Material, Primer, 180 Degree Peel Bond Test.*

I. INTRODUCTION

Maxillofacial prosthesis is concerned with the restoration and/or replacement of stomatognathic and associated facial structures by artificial substitute that may/may not be removable [1].

For retention of facial prostheses, mechanical factors such as adhesions, crowns, and magnets as well as anatomic factors such as hard and soft tissue residue in trauma or post-surgery defect, concavities and protrusions in auricular or orbital region, zygoma support, and external auditory pathway have been utilized. After evaluating the adjacent anatomical tissues, various methods have been tested depending on the shape and size of the defect, the systemic condition, and age of the patient. The most commonly used retention methods include adhesives and implants.

Craniofacial retained implant silicone facial prosthesis needs the retentive housing to secu1re various attachments such as bar clips or magnets. The rigid housing is usually made from auto-polymerizing acrylic resin to which the maxillofacial silicone is attached[2]. The attachment between silicone and acrylic housing base can be chemically or mechanically improved by various means, however research is mainly focused towards chemical bonding between silicone and acrylics.

Extra-oral facial prostheses used in combination with implants entail a retentive matrix to grasp the bar clips or magnets in place with the prosthesis. The retentive matrix is generally made from acrylic resin which can be either heat-polymerizing, auto-polymerizing, or light-cured materials, to which the facial silicone elastomer material is attached. Hence, sufficient bond strength is required to ensure a durable and functional prosthesis. During usage, maxillofacial silicone prosthesis may result in bond failures between the silicone and denture base, colour deterioration and loss of mechanical properties (i.e. tear and tensile strengths) [3]

In order to overcome such a limitation, the association of acrylic resin and facial silicone has been proposed. In this technique, the retention device of the implant is embedded in acrylic resin and then covered with silicone. Nevertheless, the resin/silicone bond is not safe, and the silicone may tear or separate from the resin when patients remove their prosthesis [4, 5].

Clinical studies have indicated the application of primers and adhesives on the resin/silicone interface to enhance the bonding between the two materials.

During function, silicone facial prosthesis faces numerous physical and mechanical failures, including bond failures between silicone and acrylic housing, color changes, wear and tear of silicone prosthesis margins. Though, silicone elastomers have undergone much improvement in terms of improved physical and mechanical properties; debonding of silicone away from the retentive housing is still a consistent problem[6].

Surface roughness is believed to increase the surface area for bonding between silicone and acrylic resin. Various methods have been used to prepare surface of acrylic prior to application of primers, such as beading with rotating burs, sand blasting, holes and rubbing with SiC paper over acrylic substrate[7].

It is common knowledge that silicone elastomers are difficult to bond to acrylic or VLC resins; hence manufacturers have developed primers to enhance the bond. Hence the current study was aimed to investigate the peel bond strength between self cure acrylic resin and two different commercially available maxillofacial silicone material using a primer.

AIM OF THE STUDY

To evaluate 180^0 peel bond strength between self cure acrylic resin and two different commercially available maxillofacial silicone material using a primer.

OBJECTIVES

1. To determine the peel bond strength between maxillofacial silicone material Technovent and self-cure acrylic using primer.
2. To determine the peel bond strength between maxillofacial silicone material MP Sai and self-cure acrylic using primer.
3. To compare the peel bond strength Technovent and MP Sai with acrylic using a primer.
4. To determine the common mode of bond failure in the primer used.

II. METHODOLOGY

MATERIAL

Self cure acrylic strips were fabricated as substrate for primer application using DPI-RR cold cure material.A-304 platinum primer was used on the surface of acrylic. Two maxillofacial silicone material were used that is Technovent and MP Sai silicone, where Technovent material is supplied as Part A and Part B systems and M P Sai material supplied as single tube system, both of them are RTV. The materials are listed in Table 1.

STUDY DESIGN

A total of 20 samples were considered, which were divided into 2 groups with 10 specimens in each group as described in Table 2. Fabricated acrylic resin strips were surface treated with sand blasting method using Korox 110 powder, after which they were coated with a thin uniform single coat of A-304 Platinum primer using a brush. Universal testing machine (ZWICK/ROELL) was used to perform 180 degree peel bond test.

MATERIAL	BRAND NAME	MANUFACTURER
SILICONE	1. Technovent	Factor 11 , Inc.Lakeside, AZ,USA
	2. MP Sai	M P Sai Enterprise Pvt Ltd Manpada, Thane
PRIMER	A-304 Platinum primer	Technovent/ Factor 11 , Inc.Lakeside, AZ,USA
ACRYLIC	DPI-RR cold cure Material	Dental Products of India, The Bombay Burmah trading Corp. Ltd.
SANDBLASTING POWER	KOROX 110 (fig 5)	Wilheim-Herbst-Strabe 1 Made in Germany

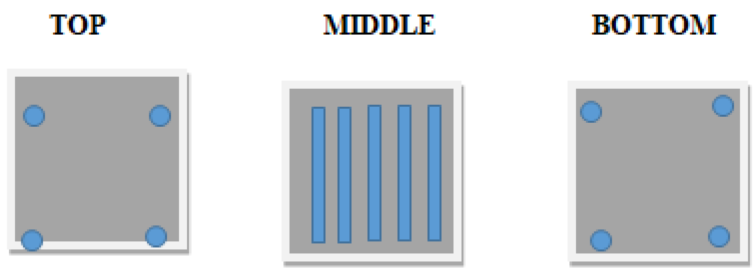
Table 1: Description of materials used in this study

SILICONE MATERIAL	PRIMER	ACRYLIC MATERIAL	SAMPLE
SAMPLE A-Technovent-Factor 11, Inc. Lakeside, AZ,USA	A-304 Platinum primer	DPI-RR cold cure material	N=10
SAMPLE B-(MP Sai-M P Sai Enterprise Pvt Ltd Manpada, Thane)	A-304 Platinum primer	DPI-RR cold cure material	N=10

Table 2: Description of the specimens used in this study (sample A and sample B)

MOLD FABRICATION

Three piece stainless steel mold was designed to standardize the fabrication of both silicone material samples and the acrylic resin samples. The upper mold helps to exert force while packing the material and the lower mold holds the material in place while the middle lid of the mold was designed to accommodate 5 sets of specimens of 75mm×10mm×4mm each.



SPECIMENS FABRICATION

Self cure acrylic resin powder and liquid was dispensed and mixed in a flexible bowl according to manufactures instructions, the material was then packed onto the prefabricated mold at dough stage. The packed material was allowed to set at room temperature, 20 samples of acrylic strips were fabricated in the similar manner after which it was retrieved and their surface of 25mm was marked initially and then prepared by sandblasting using Korox 110 powder while the unbonded area of 50mm was covered with adhesive tape using 3M scotch plaster tape. The acrylic specimens were then cleaned with acetone to remove any debris of acrylic or aluminium oxide powder and left to dry for 15 mins.

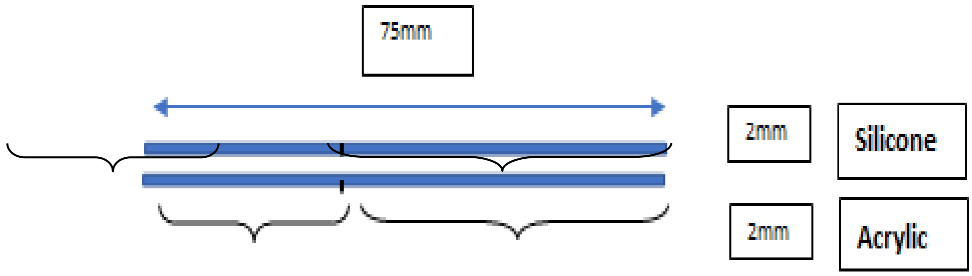


Fig 9. Dimensions of acrylic and silicone specimen with dimensions of bonded and unbonded areas

SAMPLE A and SAMPLE B FABRICATION

A uniform layer of single coat of primer was applied using a brush over self cure acrylic strips along the marked area of 25mm and left to dry for 30mins(fig 1). The acrylic strips were then aligned back on the stainless steel mold. Silicone material from M P Sai was dispensed onto the glass slab and manipulated for the required consistency. Similarly silicone material from Technovent (Part A and Part B) was mixed according to manufacturers recommendations in the ration 10:1 and placed in vaccum chambers to eliminate air bubbles. Both the material were then packed into the mold space and allowed to set at room temperature (fig 2). The set specimen thickness was 4mm where 2mm was acrylic and 2mm was silicone material. The silicone material was bonded to acrylic at one end that is along the 25mm of the length of the acrylic sample and free at another end.

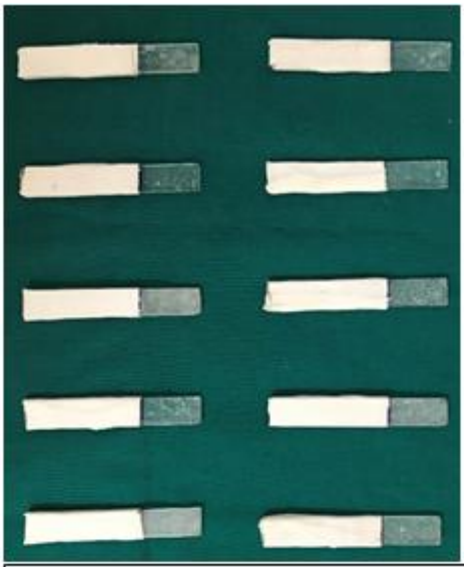


Fig1: Prepared acrylic samples

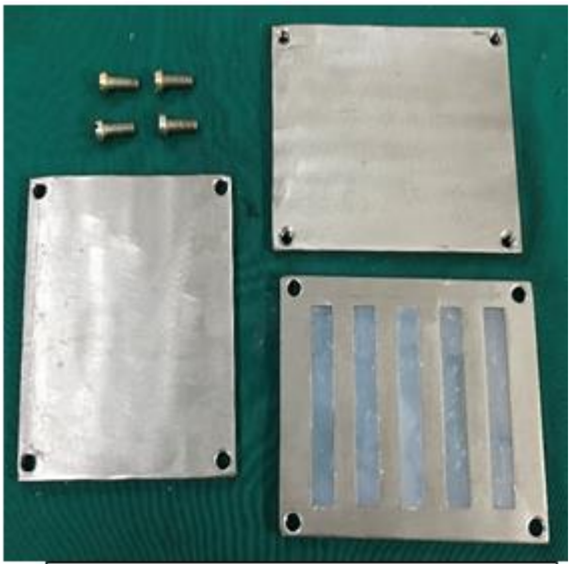


Fig2: Packed acrylic samples with silicone using primer into the mold space

SPECIMENS TESTING

The specimens were tested using universal testing machine by holding the rigid acrylic strip in lower clamp and the unbound silicone is turned back at 180˚ and gripped in upper clamp. The cross head speed was adjusted at 10mm/min and specimens were pulled at 180˚ to peel the silicone material off the acrylic (fig 3). The force required to induce bond failure was registered and peel strength (PS) (N/mm) was calculated using

$$\mathbf{PS} = \boldsymbol{F}/\boldsymbol{W}\left(\frac{\mathbf{1}+\boldsymbol{\lambda}}{\mathbf{2}} + \mathbf{1}\right)$$

Where F indicates maximum force (N), W is the width of individual specimen (mm) and λ is extension ratio (ratio of stretched to unstretched length) of silicone material.

BOND FAILURE DETECTION

Modes of failure was visually analysed and grouped into adhesive, mixed and cohesive depending on the way the silicone materials tears off from the surface of the acrylic. The surface of self cure acrylic interface was visually assessed and modes of failure were categorized as adhesive (peeling of silicone material), mixed (silicone material snaps off from acrylic surface) and cohesion (tearing of silicone material) (fig 4).

Fig 10.Visual assessment of three different types of bond failures seen during the peeling of silicone from acrylic surface.

Fig3: The unbound silicone is turned back at 180˚ and gripped in upper clamp

Fig4: The visual examination of peeling of silicone from the acrylic samples

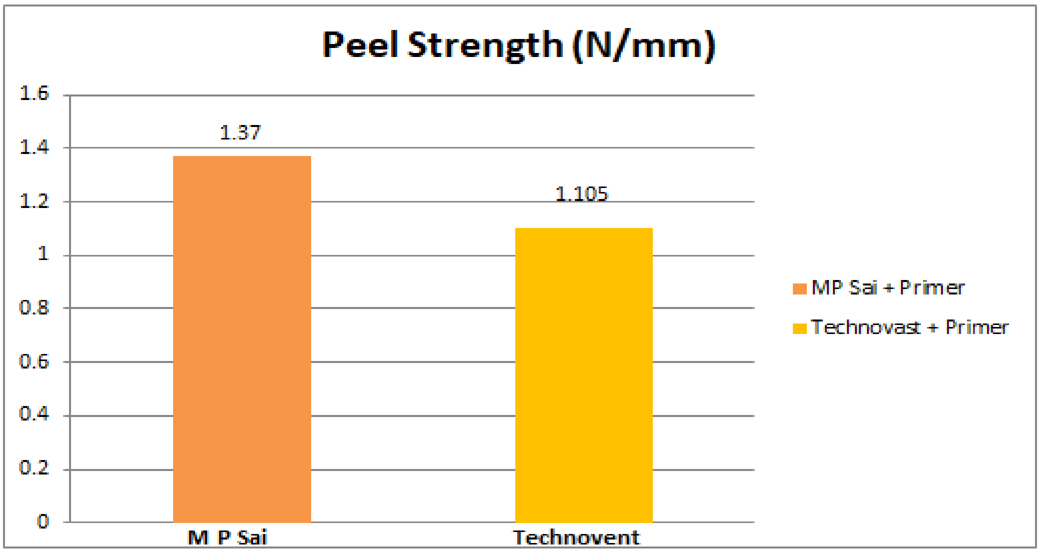
III. RESULTS

Results calculation was done using Students unpaired t test. A statistical package SPSS VERS.21.0 (Armonk, NY, IBM Corp.) was used to do the analysis, where $p<0.05$ was considered as significant. Self cure acrylic resin was mixed in a flexible bowl using manufactures instructions, the material was then packed to the prefabricated stainless steel mold at dough stage. The packed material sets at room temperature after which it was retrieved and their surface was prepared by sandblasting (20 samples) using Korox 110 powder while the un bonded surface was covered with adhesive tape (3M scotch).The acrylic specimens were then cleaned with acetone to remove any debris of acrylic or aluminium oxide powder and left to dry for 15 mins. A uniform layer of single coat of primer was applied using a brush over self cure acrylic strips (25mm) and left to dry for 30mins.

The acrylic strips were then aligned back on the stainless steel mold. Silicone material (Technovent and MP Sai silicone) was mixed according to manufacturer's instructions and placed in vaccum chambers to eliminate air bubbles. The material was then injected into mold space and allowed to cure at room temperature. The cured specimen thickness was 6mm where 3mm was acrylic and 3mm was silicone material. The silicone material was bonded to acrylic at one end and free at another end.

The specimens were tested using ZWICK/ROELL universal testing machine by holding the rigid acrylic strip in lower clamp and the unbound silicone was turned back at 180˚ and gripped in the upper clamp. The cross head speed was adjusted at 10mm/min and specimens were pulled at 180˚ to peel the silicone material off the acrylic. The force required to induce bond failure was registered and peel strength was calculated using a formula. The recording of peel obtained were recorded as shown in Graph 1 and Graph 2 for Sample B (MP Sai) and Sample A (Technovent) respectively and also the values are shown in table 4 and table 5 for Sample B (MP Sai) and Sample A (Technovent) respectively.

The peel bond strength was calculated to be 1.37N/mm for sample B (M P Sai) and 1.105N/mm for sample A (Technovent) as shown in Graph 1 and depicted in table 3. The mode of failures were visually analysed and grouped as adhesive, cohesive and mixed. Adhesive failure was observed for all the specimens with silicone material in group I (MP Sai) and for 90% of specimens in group II (Technovent), whereas one specimen had cohesive failure for silicone material (Technovent) as shown in table 6.



Graph 1: Mean Peel Strength values after Peel Bond Test

Table 3: Comparison of mean values of peel strength (N/mm) for two different silicone materials

Groups	N	Mean	SD	P value
M P Sai	10	1.3762	0.078	P = 0.001*
Technovent	10	1.105	0.035	

Level of significance at P < 0.05; SD – Standard Deviation
*statistically significant using unpaired ‘t’ test

Table 4: Description of the values for peel bond strength used in this study (sample B)

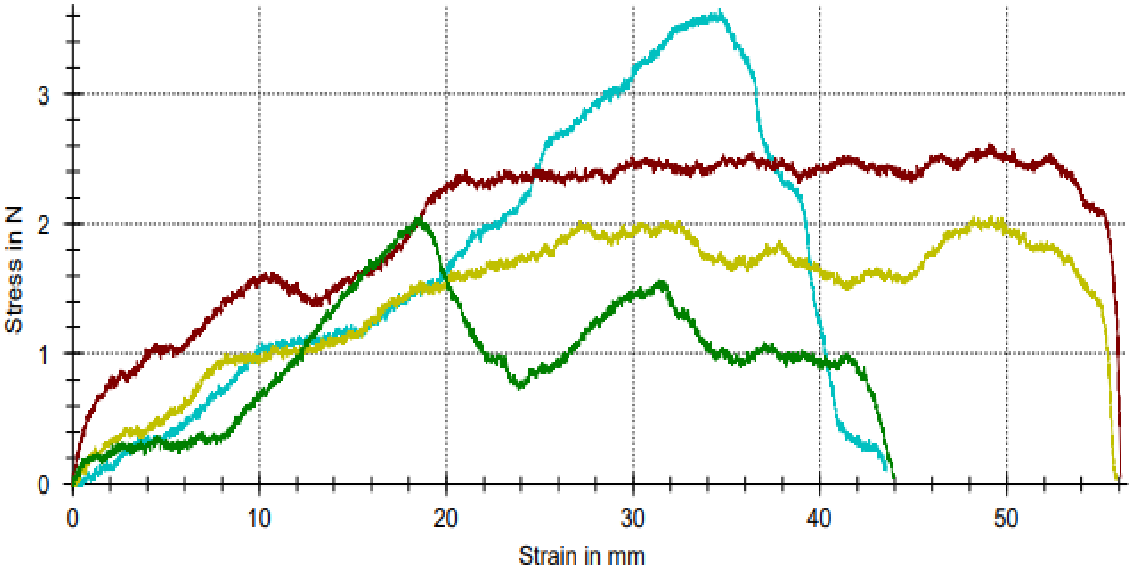
M P SAI					
sample	**Fmax**	**Tensile strength (N/mm)**	**Elongation @ Break (%)**	**thickness (mm)**	**width (mm)**
M1	**3.65**	**0.365**	**69.2**	**2**	**10**
M2	**2.06**	**0.206**	**89.6**	**2**	**10**
M3	**2.62**	**0.262**	**94.4**	**2**	**10**
M4	**2.05**	**0.205**	**73.3**	**2**	**10**
M5	**2.08**	**0.201**	**70.1**	**2**	**10**
M6	**2.11**	**0.205**	**86.6**	**2**	**10**
M7	**3.33**	**0.206**	**84.2**	**2**	**10**
M8	**2.89**	**0.212**	**89.6**	**2**	**10**
M9	**3.15**	**0.253**	**92.1**	**2**	**10**
M10	**2.17**	**0.207**	**83.6**	**2**	**10**

Table 5: Description of the values for peel bond strength used in this study (sample A)

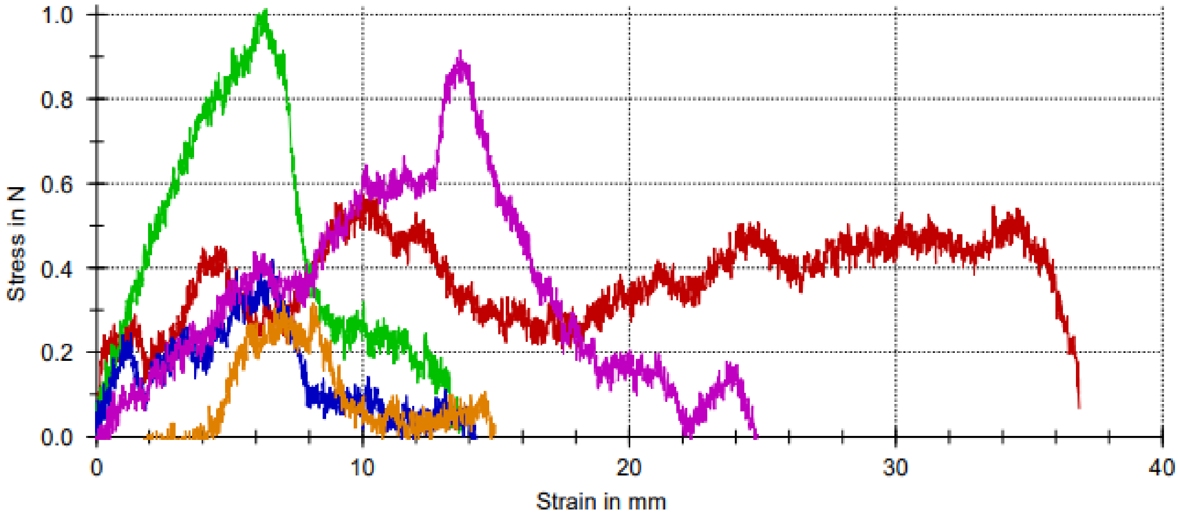
TECHNOVENT					
sample	**Fmax**	**Tensile strength (N/mm)**	**Elongation @ Break (%)**	**thickness (mm)**	**width (mm)**
T1	**0.58**	**0.0576**	**61.5**	**2**	**10**
T2	**1.01**	**0.101**	**22.7**	**2**	**10**
T3	**0.42**	**0.042**	**23.6**	**2**	**10**
T4	**0.32**	**0.0324**	**22.1**	**2**	**10**
T5	**0.92**	**0.0917**	**41.3**	**2**	**10**
T6	**0.62**	**0.0988**	**55.6**	**2**	**10**
T7	**0.58**	**0.112**	**24.9**	**2**	**10**
T8	**0.89**	**0.0966**	**58.7**	**2**	**10**
T9	**0.83**	**0.109**	**38.5**	**2**	**10**
T10	**0.75**	**0.106**	**49.5**	**2**	**10**

Table 4: Mode of failures as observed in all the specimens in both groups

Mode of Failure	MP Sai + Primer	Technovent + Primer
Adhesive	10 (100%)	9 (90%)
Mixed	0	1(10%)



Graph 2: Graph showing the peel bond strength in samples with M P Sai silicone.



Graph 3: Graph showing the peel bond strength in samples with Technovent silicone.

IV. DISCUSSION

The current study showed that the use of acrylic-primer combination influenced bond strength between silicone elastomer and acrylic resin. A total of 20 samples were considered, which were divided into two groups (sample A and sample B) with 10 samples in each group. Acrylic samples were fabricated and sandblasted in selected area to receive two different commercially available silicone elastomeric material (Technovent and M P Sai). Sample A group received Technovent and sample B received M P Sai silicone material. The sand blasted area was treated with A-304 primer. The fabricated samples were tested for their peel bond strength in a universal testing machine. Thus, the null hypothesis that bond strength of maxillofacial silicone elastomers is not affected by the addition of primer was rejected.

The materials used in this study are those that are often used in maxillofacial prosthetic treatment. The bonding of silicone on an acrylic plate was reported to be poor when bonded without a primer. The differences in terms of bond strength within two groups using two different silicones with a primer are due to variations in compositions and their chemical affinity with the primer and acrylic resin. The peel bond strength of specimens treated with primer A-304 with two different commercially available silicones ranged 1.37N/mm for sample B (M P Sai) and 1.105N/mm for sample A (Technovent) respectively. The values recorded for bonding of M P Sai silicone with acrylic was better than that recorded by Technovent with acrylic using the primer. The peel bond strength between silicone and acrylic without a primer was not investigated. The 180˚ peel force that occur during removal of prosthesis can stimulate the horizontal component of de-bonding forces, leading to bond failures.

The primer in its composition consists of an adhesive agent and an organic solvent that is believed to react with both, silicone elastomer and acrylic resin materials. It acts as an intermediate layer composed of hydrophilic and hydrophobic groups, which react with functional groups present in silicone elastomer. In addition, primers activate the surface of resins by etching or promoting covalent coupling and hydrogen bonding, enhancing the surface energy and wettability of the resin substrate, and penetration of the polymeric ingredients into the surface layer[35].

In addition, the bonding between the silicone and acrylic resin may be affected by the chemical affinity between the silicone material and primers. The chemical affinity is also related to the composition of the materials that will be used. According to the manufacturer, the auto-polymerized acrylic resin (DPI-RR cold cure Material) basically has two components powder and liquid[36,37]. The powder is composed of polymethylmethacrylate and benzoyl peroxide and liquid has methylmethacrylate, EDMA/Crosslink/ and an inhibitor. The Technovent silicone material is a two-component material and M P Sai is a one component silicone material. Dimethylsiloxane polymer, reinforcing silica, and a platinum catalyst are the elastomeric components present in M.P Sai and Technovent silicone material. The curing component is made up of a dimethylsiloxane polymer, an inhibitor, and a siloxane crosslinking agent. No strong bond between them was noted when no primer and adhesive was applied as the composition of two materials is different[15,36,38].

The peel-testing, produces stresses in horizontal plane and the debonding proceeds through a line of junction, whereas in case of shear testing, interfacial area is stressed, with tear resistance of the silicone elastomer plays an important role to prevent bond failures. In present study peel bond strength was calculated considering both the elastic deformation (λ) of prepared silicone, and the applied primer bonding. This formula calculates the amount of absorbed energy required for deformation of the silicone and the energy used to peel the silicone away from acrylic resin depicted in graph 1 and graph 2 for the above study[39]. Therefore, the absorbed energy is also affected by the hardness and dimensions such as thickness and width of the specimen; whereas the energy used to peel the silicone from acrylic, is affected by the area of bonding and interfacial thickness of adhesive primer. Thus, if peeling of flexible silicone occurs with a minimum strain, the elastic energy present in the unattached tab can only be neglected. In previous studies, peel bond strength was calculated (the highest peel force was considered per unit of width), where the extension ratio was not taken into account[40].

Few previous studies have debated over the effects of the fabrication process or post-fabrication conditions on silicone-acrylic bonding where they have stated that the fabrication process may or may not affect the bond strength of the same. In a study conducted by Polyzois, where he investigated the effects of microwave and dry heat fabrication processes on bond strength, he found that bonding was affected by the type of silicone elastomer and not by the fabrication process used. In Polyzois's study, however, the effect of using metal flasks was not evaluated which can be a drawback[13].

In a study conducted by Taft et al. the results showed that surface treatment of light-polymerising and autopolymerising acrylic resins with 1205 primer had a higher peel bond strength compared to no primer group. In general, peel result values of Taft et al were higher than those of the current study and this may be because of the use of different surface preparation (pumice), primers (1205 and 2260), acrylics, silicones as well as the design of the bonded and free tested samples[41].

In a study conducted by Shetty and Guttal , where they detailed that the use of primers enhanced the peel bond strength between Cosmesil M511 and heat–polymerisng acrylic resin as compared to control group which had no prime. They found that the use of primer A330-G with different surface treatments such as retentive holes, beads and smooth surfaces had remarkably greater peel bond strength than when compared to control samples. In addition to that they had also concluded that G611 primer showed similar results as compared to control groups, with additional retentive holes made, additional beads on the acrylic samples and smooth surface acrylic samples. [27].

A significant improvement in peel bond strength was seen in a study demonstrated by Al-Shammari et al where they used light-polymerising resins which were surface treated with MED6-161 primer which was compared to auto-polymerising resins exposed to the same primer. The study revealed that the peel bond strength was improved when autopolymerising resins were coated with MED160 primer as compared to light-polymerising resins exposed to the same primer[24].

The peel bond strength was influenced by the mode of surface preparation and the type of primer used in each group. Many studies have been done to modify the surface preparation technique to attain higher bond strength. Amin et al had reported in his study that the bond strength between silicone and acrylic had decreased after sandblasting[34]. Similarly, Miami et al found that surface preparation of the denture resin surface with air abrasion was not very effective in providing long term bond strength[35]. In contrast, Polyzois and Frangou stated that, 80 Grit, SiC provided higher bond strengths as compared to other grits of SiC paper[14]. In a study conducted by Tanveer et al, primers (A-306, A-304 and A-330) were applied after surface preparation with 80 Grit SiC paper to increase the surface area of rigid Plexiglas acrylic. Therefore, surface treated specimens bonded with primer A-330 had exhibited the highest peel bond strength of 4.05N/mm while for specimens primed with A-304 and A-306 had shown low peel bond strength between 1.63-3.18N/mm[20].

The current research assessed the bond strength of silicone to acrylic base using peel test. Patients with any kind of facial defects are often rehabilitated with a maxillofacial prosthesis. For a successful outcome of a maxillofacial prosthesis the bond between the acrylic substrate (encompassing the clips and magnets) and the silicone elastomer is very critical. The current study evaluated 180^0 peel bond strength between self cure acrylic resin and two different commercially available maxillofacial silicone material M P Sai and Technovent with a platinum primer A 304. However, further investigation using different primers with different silicones and different surface treatments of acrylic has to be done to achieve the optimum bonding that is need.

V. CONCLUSION

Within the limitations of this in-vitro study following conclusions were drawn:
1. The primer A-304 provided better peel bond strength with sample B when compared to sample A respectively.
2. Majority of the samples in both the groups showed adhesive mode of failure using the platinum primer A-304.
3. Autopolymerising acrylic provided comparable peel bond strength with both the maxillofacial silicone material used in the study.

Clinical significance

This study provides prosthodontists information that may be helpful in the fabrication of maxillofacial prostheses. Results indicate that acrylic–silicone bonding may be improved by treating with primer such as A-304 Platinum primer, followed by attachment of silicone from MP Sai and Technovent. It is recommended that the chosen primer be placed on the acrylic surface for 30 minutes prior to the addition of the silicone. The foregoing combination appears to create improved bonding at acrylic–silicone interfaces.

VI. SUMMARY

Maxillofacial prosthesis has been used to rehabilitate mutilated patients by repairing soft tissues losses and extensive bone damage[48]. The aesthetic appearance, self-esteem, comfort as well as the quality of life of these patients have been improved with the use of facial prosthesis[10,11,12]. Hence to deliver a good prosthesis the prosthesis should be stable enough therefore it should bond efficiently to the acrylic or any other material used as base of housing the silicone.

Bond strength between acrylic and silicone varies significantly due to various reasons. Bond strength obtained without using a primer is found to fail as reported by various studies. Therefore, bond strength increases when a primer is used to bond acrylic with silicone. However the confirmation of required bond strength of silicone elastomer and acrylic plate has not been reported. It has been found in various other studies that more than 0.4 MPa is needed for tray and impression bonding[43]. Use of various compositions of acrylic plate and primer might cause different chemical or physical reactions between the acrylic plate and primer or between the primer and silicone elastomer. The current study evaluated 180^0 peel bond strength between self cure acrylic resin and two different commercially available maxillofacial silicone material M P Sai and Technovent with a platinum primer A 304. The results of the present study suggest that the primer A-304 provided better peel bond strength with sample B(M P Sai) when compared to sample A(Technovent) respectively.

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