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Effect of Different Primers on the Peel Bond Strength between Silicone Elastomer and Acrylic Resins

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Author's contribution

The author designed the study and wrote the manuscript.

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ABSTRACT

Introduction: Implant-supported extra-oral prostheses often require a retentive matrix to hold gold alloy clips and magnets, which act as retentive means. Silicone elastomers have a different structure to acrylic resins. Hence, primers are used to increase the bonding between silicone and acrylic resin.
Aim of Study: To investigate the effect of new platinum primers on the peel bond strength of silicone elastomer to acrylic resins.
Materials and Methods: Peel bond strength of Cosmesil 2004 to two acrylic resins was assessed using two primers (MED6-161 and MED160) and no primer (control group). Sixty samples were prepared and divided into six groups according to the combination of acrylic resin, silicone, primer and no primer. All samples were then exposed to load in a universal testing machine with a cross head speed of 25 mm/min until failure. Data was analysed using STATA 12.1 software. Values of mean peel force between light and auto-polymerising acrylic resins were compared using two-way ANOVA and tukey HSD test.
Results: The interaction between primers and acrylic resins had a significant effect on peel bond

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strength between Cosmesil 2004 and acrylic resins. MED6-161 primer significantly improved peel bond strength of Cosmesil 2004 to light-polymerising acrylic resin. However, MED-160 primer enhanced peel bond strength between Cosmesil 2004 and auto-polymerising acrylic resin.

Conclusion: The combination of primer and acrylic is important in improving the bond strength. However, further investigation of different primers, silicones and different surface treatments to achieve the optimum bonding is need.

Keywords: Bond; acrylic; silicone elastomer.

1. INTRODUCTION

The main causes of facial deformity are congenital abnormalities (e.g. hemifacial microsomia), surgical resection of tumour (e.g. squamous cell carcinoma) and trauma (e.g. road traffic accidents). These facial defects can be replaced with extra-oral prostheses, which can be made from a silicone elastomer retained by implants [1,2]. Implant supported extra-oral prostheses often require a matrix to encapsulate gold alloy clips or magnets, which act as the retentive mechanisms (Figs. 1.a-c).

This matrix can be fabricated from acrylic resins (such as heat-polymerising, auto-polymerising and light-polymerising acrylic resins). These materials differ chemically and physically from silicone elastomers [3]. According to the literature,the failure of the bond between silicone elastomers and the acrylic resis was considered as one of the main problems with implant retained extra-oral prostheses for a long time [4,5]. As one material is essentially rigid (i.e. cold cured acrylic resin) and the other is flexible (i.e. silicone elastomer for extraoral prosthesis), it is necessary to add additional components (primers) to the acrylic surface to increase the adhesion between the silicone elastomer and acrylic resin [6]. According to the literature, one of the main problems with extra-oral prosthesis for a considerable period of time has been the failure of the bond between silicone elastomers and the acrylic resins [7,8] As a result; different types of primers have been developed to enhance the adhesion between these materials. Platinum primers (i.e. A304, A330-G, A306; Factor II Inc., Lakeside, AZ, USA) and G-611 (Principality Medical, UK) are used to enhance the bond strength between platinum cured silicones and acrylic resins [9]. Various studies have investigated the effect of different types of primers on bond strength between silicone and acrylic resins by using three test methods. Al-Athel and Jagger [10] compared the peel, shear and tensile bond strength between denture lining material and poly methyl methacrylate. The results showed the mean bond strength of the peel test was 2.59 N/mm whereas the tensile strength and shear strength showed mean bond strength 1.22 N/mm² and 1.39 N/mm², respectively.

Fig. 1 a   Fig. 1b   Fig. 1c

Figs. 1 a-c. Ear prosthesis, acrylic sleeve and retentive bar in situ

The aim of this study was to evaluate the effect of new different primers on the peel bond strength between Cosmesil 2004 silicone elastomer and two acrylic resins. The Null hypothesisinposed that there is no statistical significant difference between the peel bond strengths of silicones using new different primers on auto-polymerising and light-polymerising acrylic resins.

2. MATERIALS AND METHODS

In this study, Cosmesil 2004 silicone elastomer (Principality Medical Ltd, Newport, UK), MED-160 and MED6-161 primers (NuSil Technology LLC, California, USA), light-polymerising and auto-polymerising resins (Bracon Limited, Etchingham, East Sussex, UK) were used to assess the peel bond strength of silicone elastomer to acrylic resin. Sixty samples were used in this study and were divided into six equal groups. Three groups of auto-polymerising resin; one group was not treated with primer, another group was treated with MED-160 primer and a third group was surface treated with MED6-161 primer. Similarly, for the three light-polymerising resin groups; the first group was not treated with primer, the second group was treated with MED-160 primer and the third group was surface treated with MED6-161 primer. The number of the samples correlates with previous work [3]. An aluminum mould with teflon plate inserts was used to fabricate the acrylic/silicone samples. This mould was custom made, which consisted of a metal base with several pillars. These pillars stabilise and accurately locate the position of fourteflon layers and the top and bottom aluminum plates. The outer two teflon covers sandwich the inner two teflon plates, which contain acrylic samples and silicone samples (Fig. 2).

Fig. 2. Teflon plate which holds acrylic / silicone samples

2.1 Preparing the Acrylic / Silicone Samples

The process of fabricating the acrylic / silicone samples involved several steps, which are discussed in the following section. Specific variations in the fabrication of the different materials used were applied for optimal curing results.

2.2 Preparation of Auto and Light-Polymerising Acrylic Resin Samples

The auto-polymerising acrylic resin samples were prepared by mixing powder and liquid (1.3:1 ratio) in a glass jar. The mixture was then poured into the teflon inserts of the mould, which was securely closed using G clamps. These moulds were placed in a hydroflask containing warm water for 10 minutes for curing. Once the samples were cured, they were removed from the flask and excess material was trimmed using 100-grit sand paper. Acrylic samples were then kept in water. Samples with air bubbles were excluded (Fig. 3).

Fig. 3. Auto-polymerising acrylic resin samples

The light-polymerising acrylic resin samples (Bracon Limited**,** Etchingham, East Sussex, UK) were prepared by adapting the resin sheet into teflon mould spacer, andthe mould was secured by plastic pins. Then, the mould was placed in a light curing machine (Lampada, Bracon Limited, Etchingham, East Sussex, UK) for two minutes in the absence of aluminum cover. Both sides of the samples were thoroughly cured. Once cured the samples were removed from the mould and excess removed in a similar fashion to the auto-polymerising resin samples (Fig. 4). Samples were then stored in water.

2.3 Surface Preparation of Acrylic Samples

Both sets of acrylic samples were treated using Hatamleh and Watts [3] method (Fig. 5). In short, one part of the surface (25 mm) was roughened using 60-grit silicone carbide abrasive paper and then they were cleaned with water. The rest of the surface of the acrylic samples were separated with polyurethane sheets (50 mm X 10 mm X 3 mm) (Fig. 6).

Acrylic samples were then cleaned with acetone to degrease the surface prior to packing the silicone into the mould, and were then left to dry for 24 hours. Finally, the acrylic resin surfaces were brushed either with MED-160®primer or MED6-161®primer following manufacturer's instructions and then left to dry for thirty minutes. Control samples were not treated with primers.

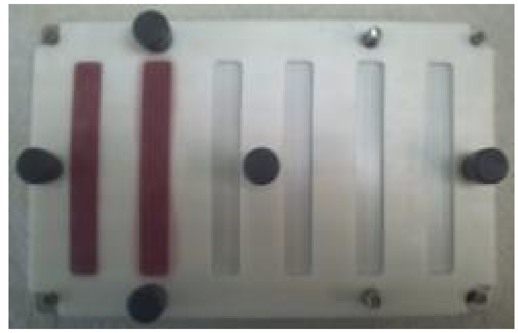


Fig. 4. Light-polymerising acrylic samples within the mould

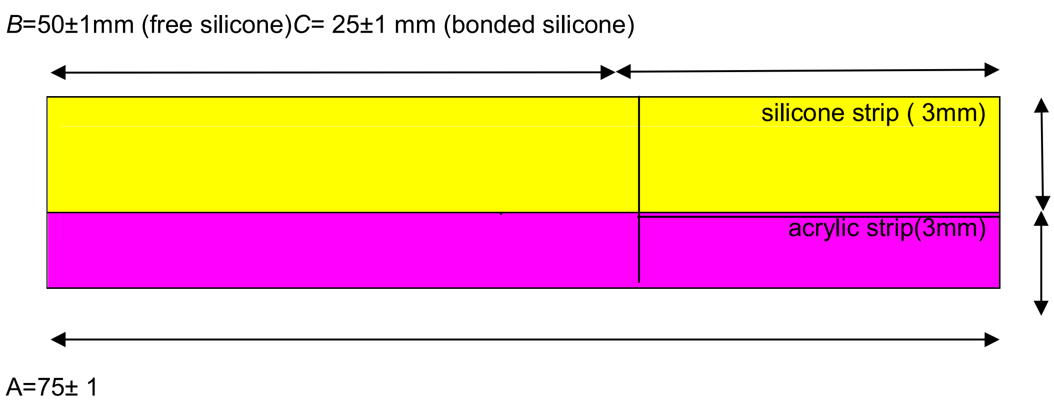


Fig. 5. Peel bond specimen preparation (dimensions in mm) [3]

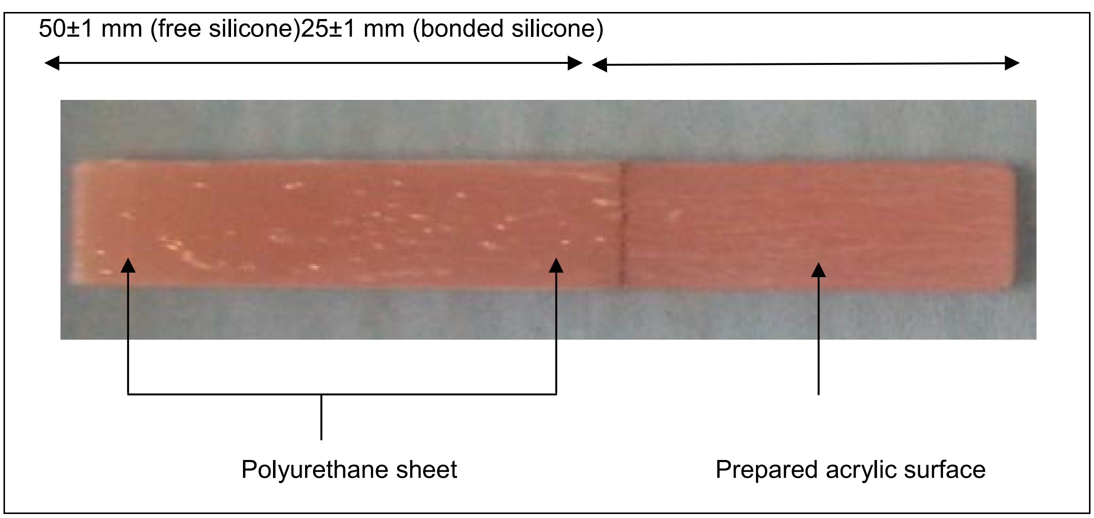


Fig. 6. Specimen preparation of the current study

2.4 Packing Cosmesil 2004 (HTV) Silicone on to the Acrylic Samples

Cosmesil 2004 (Addition cured silicone or platinium cured silicone) comes into two part, the first part is a base paste (polyvinyl siloxane, silanol and filler) and the second part is a catalyst paste (polyvinyl siloxane, platinum catalyst and filler). The addition reaction, platinum catalyst-dependent, occurs when two pastes are mixed together resulting in cross-linking between two pre-polymers. Silicone was prepared by mixing equal parts of part a (poly dimethyl siloxane) and part B (catalyst). The mixture was manually mixed with a spatula and then with an automated speed machine. Silicone was then packed carefully over acrylic samples already positioned in the mould to avoid trapping air bubbles and cured in an oven at 100ºC for 1.5 hours. Next, samples were finished and stored at 23±1ºC. Samples with air bubbles were excluded. For instance, samples 1 and 5 in Fig. 7 were excluded because of the presence of bubbles.

2.5 Peel Test

All acrylic / silicone samples were tested after seven days of fabrication according to the American Society for Testing and Materials (ASTM) specification number D903-98(2010) [11]. The samples were peel tested using a universal testing machine at 25 mm/min cross head speed at 180 degrees (Figs. 8 and 9).

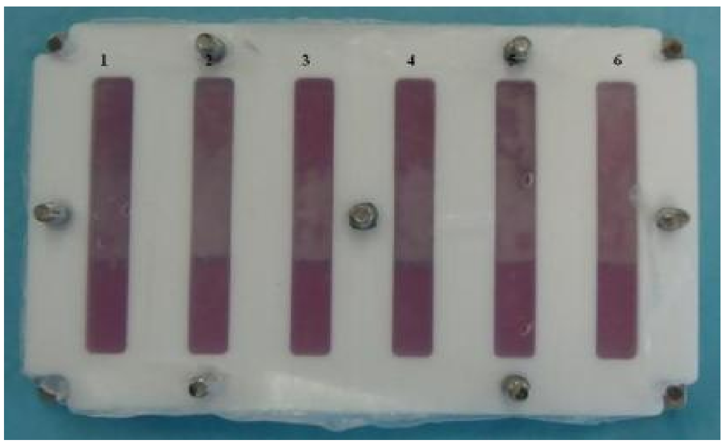


Fig. 7. Acrylic / silicone samples within the mould, four samples were used and two samples with air bubbles were excluded

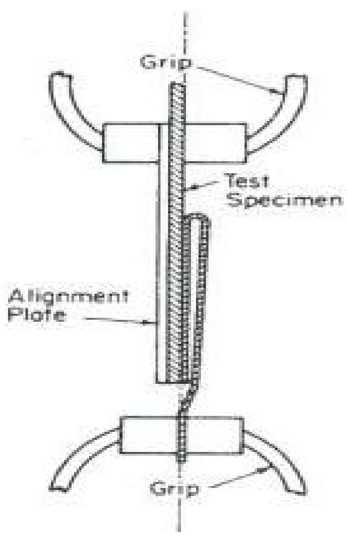


Fig. 8. ASTM specification D903-98 (2010) [6]

Fig. 9. Specimen under test

2.6 Statistics Analysis

Data was analysed using STATA 12.1 software. Peel force data were summarised by providing mean, standard deviation, minimum and maximum values. Comparisons of peel force values between samples were made using two-way ANOVA and tukey HSD test to show any comparison between groups with a cut off significance at $p < 0.05$.

3. RESULTS

The effects of two different primers on the peel bond strength of two types of acrylic resin and Cosmesil 2004® silicone elastomer were evaluated. The results of the study are as follows:

3.1 The Effect of Both Type of Acrylic Resin Used and Primer and Their Interaction on Peel Bond Strength

The Table 1 demonstrated that the peel bond strength was significantly influenced by primers and type of acrylic resin used (P<0.001) and there was a strong interaction between primers and type of acrylic resin (P<0.01). For acrylic resin, the light-polymerising resin had a higher value of mean peel bond strength than auto-polymerising resin (Table 1). For example, for light-polymerising resin samples the peel bond strength of MED-160, MED6-161 or control group was 9.41±1.44 N, 11.83±1.95 N or 1.68±0.82 N, respectively (Table 1). On the other hand, the peel bond strength for auto polymerising resin samples was 9.60±4.13 N (for MED-160 group), 6.88±1.92 N (for MED6-161 group) or 0.31±0.29 N (for control group). For primers, the peel bond strength was statistically higher in both MED-160 and MED6-161 as compared to the control samples for both auto and light polymerising resins (Table 1).

The Table 2 indicated that there were a highly significant differences between control and primers group (*highely Siginificant P<0.001). However, there was no siginificant differences between MED160 and MED6-161 primers for both auto and light polymerising resins (P>0.001). *highely Siginificant (P<0.001)

3.2 Types of Peel Bond Failure

All failures were adhesive as silicone samples were peeled away from acrylic samples without tear or snap of silicone elastomers as a result of load (N) applied as shown in Fig. 10. Analysis of peel bond strength of a set of tested samples is demonstrated in Fig. 11. This line chart demonstrates that 10 samples of acrylic/silicone, which were treated with MED6-161® primer, were exposed to the load and reached a complete failure at 200 seconds. For example, sample number 3 (green line) starts peeling after 60 seconds and showed complete failure at 200 seconds.

Similarly, 10 samples of acrylic/silicone, which were surface treated with MED6-161 showed peeling after 60 seconds and adhesive failure occurred at the same periods at 200 seconds (Fig. 12).

Table 1. Mean and standard deviation of peel bond strength (N)

Acrylic resins	Primers	Mean	SD	Min	Max
Auto-polymerising acrylic resin	Control	0.31	0.29	0.01	0.92
	MED-160	9.60	4.13	5.22	16.87
	MED6-161	6.88	1.92	4.15	10.75
Light-polymerising acrylic resin	Control	1.68	0.82	0.65	3.14
	MED-160	9.41	1.44	7.32	11.66
	MED6-161	11.83	1.95	9.89	15.00

The mean values of peel bond strength were demonstrated in the Table 1

Table 2. Comparison between control and primers groups

Acrylic resins	Groups	P value	Groups	P value	Groups	P value
Light	Control		Control		Primer 160	
	Primer 160	0.000*	Primer 6-161	0.000*	Primer 6-161	0.089
Auto	Control		Control		Primer 160	
	Primer 160	0.000*	Primer 6-161	0.000*	Primer6-161	0.098

Light polymerising resins (P>0.001)

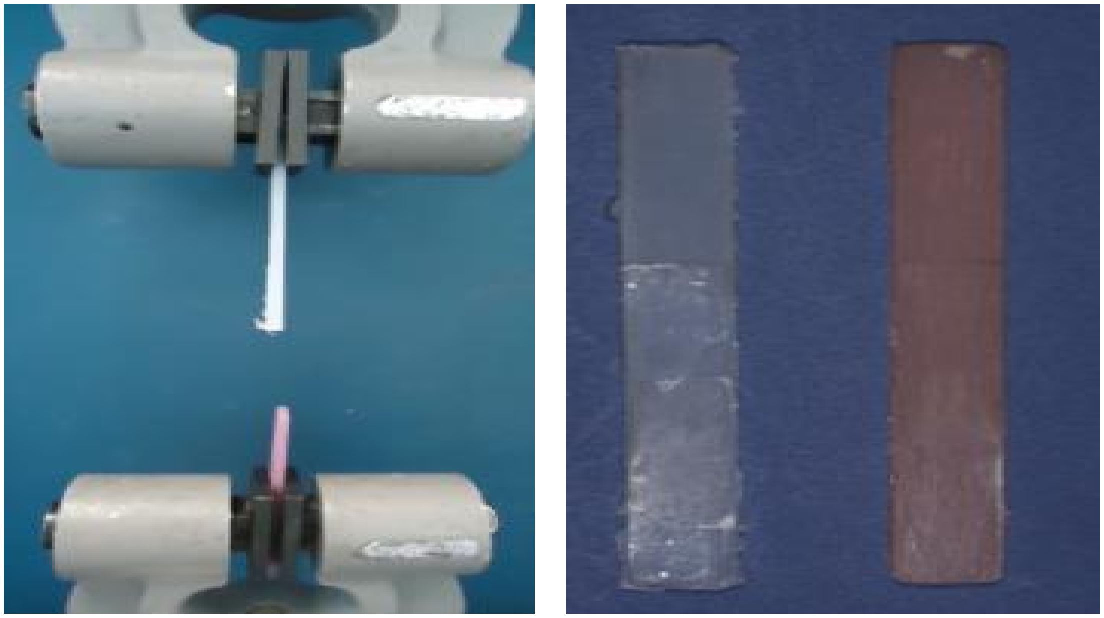
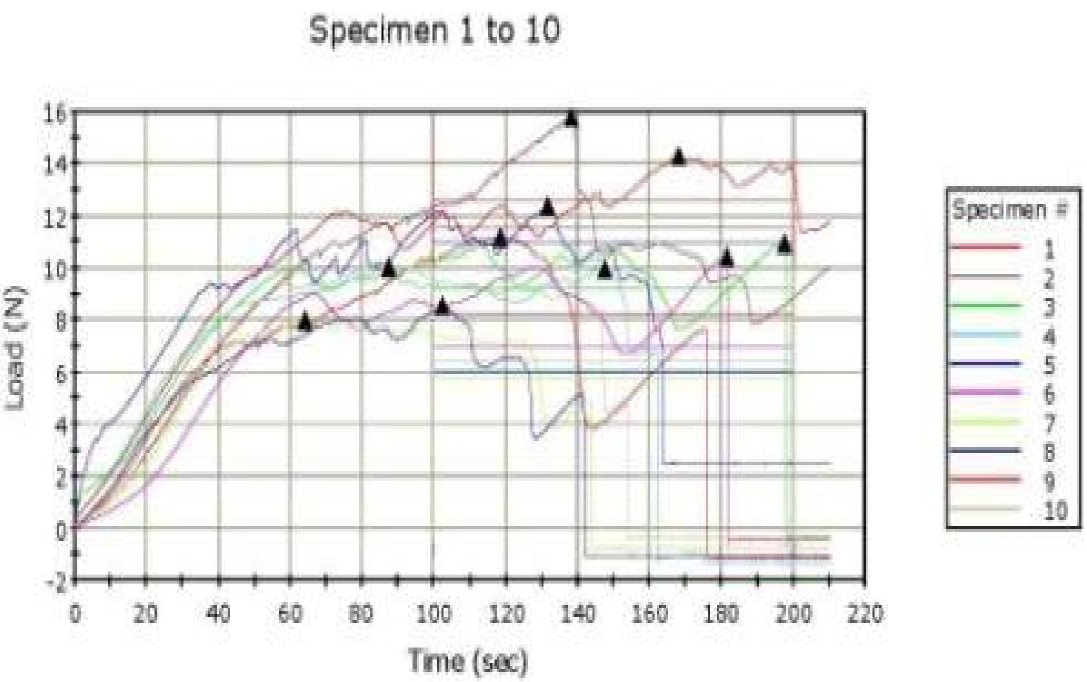


Fig. 10. Adhesive failure between Cosmesil silicone and acrylic resin



▲ = Maximum force to peel silicone away from acrylic resin

Fig. 11. Acrylic / silicone samples which were treated with MED-160 primer exposed to load (N)

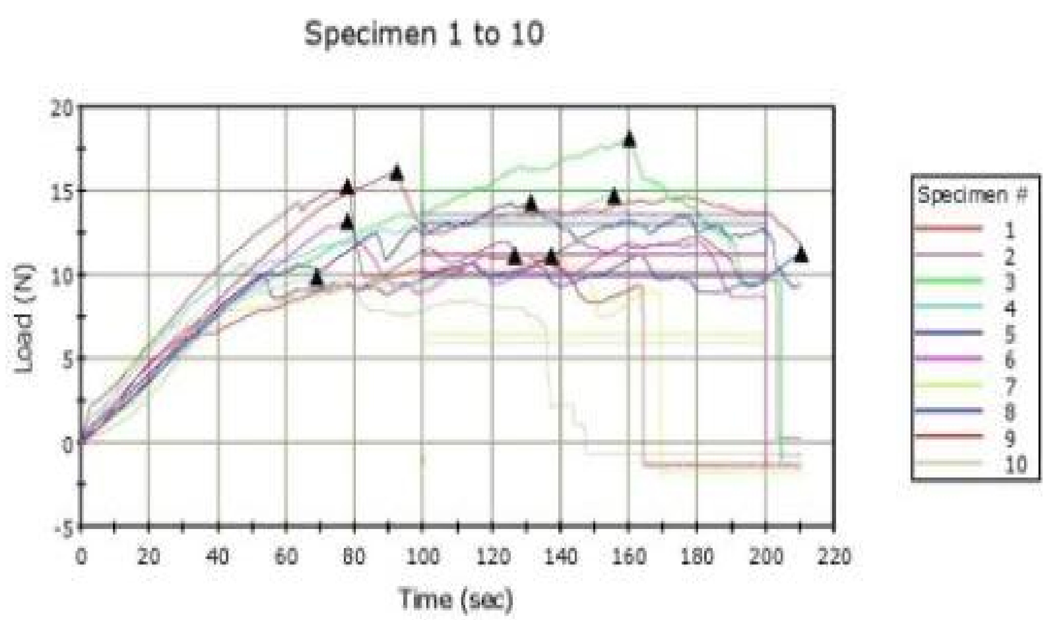
4. DISCUSSION

The successful outcome of implant retained extra-oral (e.g. auricular, nasal and orbital) prostheses requires achieving a good bond between silicone and acrylic substrates which hold gold clips and magnets [3]. This bond must be strong enough to resist the forces when patients remove their prosthesis [12]. On the other hand, the bond between two dissimilar materials is weak and this is the reason why primers are used to increase the bond between silicones and acrylics [13]. The optimum bond strength can be achieved using a combination of silicone and primer (i.e. platinum primer with platinum silicone) [3]. Overall, the bond between silicone and acrylic resin can be tested using different test methods such as peel, shear and tensile [10]. The aim of this study was to evaluate the bonding effects of two new primers between Cosmesil 2004 and two acrylic resins (i.e. light-polymerising and auto-polymerising acrylic resins). The results of the study indicated that there are significant differences between control group and the 2 primers used to bond Cosmesil 2004® to light-polymerising and auto-polymerising acrylic resins.

Implant retained extra-oral prostheses are often peeled away from skin tissue when patients remove them for cleaning and air ventilation for defect area. These prostheses often require a retentive matrix to hold clips or magnets, which act as the retentive mechanisms. The silicone peels away from the acrylic sleeve as the force is applied to remove the prosthesis [14]. Accordingly, the peel test was used in this study and we demonstrated that the peel bond strength was influenced by the type primers and type of acrylic resin used.

The MED-160® and MED6-161® primers which designed to use with platinum cured silicones (i.e. Cosmesil 2004®) were placed on the market (2006) and there were no published papers regarding their use. The main ingredients of such primers are Naphtha (85%), VM&P Tetra-n-propyl silicate (5%), Tetrabutyltitanate (5%), Tetra (2-methoxyethoxy) silane (5%).

In this study the control groups for both auto-polymerising and light-polymerising acrylic resins were not coated with primers and were used to compare the bond strength to the samples treated by primers. We demonstrated that surface treatment of light-polymerising or auto-polymerising resins with either MED-160® primer or MED6-161® primer significantly improved peel bond strength than control group (see Table 1).



▲ = Maximum force to peel silicone away from acrylic resin

Fig. 12. Acrylic / silicone samples which were treated with MED6-161 primer exposed to load (N)

The results of this study are in accordance with Taft et al. [14] study which showed that surface treatment of light-polymerising and auto-polymerising acrylic resins with 1205® primer had a higher peel bond strength (40.2±8.2 and 35.7±5.3 N) compared to no primer group (28.6±4.8 N and 26.9±11.0 N). Overall, peel results values of Taft et al. [14] were higher than those of the current study and this could be partially explained by different surface preparation used (pumice), primers (1205 and 2260), acrylics, silicones as well as the design of the bonded and free tested samples.

As well, the present results were supported by Shetty and Guttal [15] study which reported that primers enhanced peel bond strength between Cosmesil M511 and heat–polymerisng acrylic resin as compared to control group (no primer). For example they found that A330-G® primer with different surface treatments (retentive holes, beads and smooth surfaces) had significantly greater peel bond strength (6.50±0.52 MPa, 5.63±0.40 MPa and 5.21±0.76 MPa, respectively) compared to control samples (0.32±0.28 MPa, 0.25±0.20 MPa and 0.15±0.23 MPa). In addition, they demonstrated that G611® primer showed similar results as compared to control groups where the peel bond strength was 5.83±0.73 MPa (retentive holes), 5.38± 0.43 MPa (beads) and 5.11±0.82 MPa (smooth surface).

Furthermore, a strong interaction between the resins used and primers was observed. A significant improvement in peel bond strength was demonstrated when light-polymerising resins were surface treated with MED6-161® primeras compared to auto-polymerising resins exposed to the same primer (Table 1). Similarly, the peel bond strength was enhanced when auto-polymerising resins were coated with MED160® primer as compared to light-polymerising resins exposed to the same primer (Table 1).

These results are supported by Taft et al. [14] who demonstrated a similar interaction between resin and primer. Here, they showed that light-polymerising resins treated with 1205® primer improved peel bond strength (40.2±8.2 N) as compared to auto-polymerising resin which was treated with that particular primer (35.7±5.3 N). As well, Taft et al. [14] showed that when light-polymerising resin samples were treated with 2260 primer® this significantly reduced peel bond strength (18.3±6.8 N) than when auto-polymerising resins samples were treated with similar primer (26.1±5.6 N). Though, values of both reports (current study and Taft et al. [14]) are different possibly due to inherent differences in the type of materials used, surface treatments and the length of the bonded and free tested samples.

Failure mode as a result from peel test could either be adhesive failure or cohesive failure. The separation between silicone elastomer and acrylic resin without tear and snapping of silicone when peeled from acrylic resin is known as adhesive failure whilst tear or snap of the silicone elastomer when peeling is indicated as cohesive failure [16]. The adhesive failure means that the strength of silicone materials is stronger than the bond between silicone and acrylic resin while cohesive failure indicated that the bond between tested materials is higher than silicone strength [9].

An investigation was undertaken to assess the parameters needed to undertake peel test and the results showed that only adhesive failure between Cosmesil 2004 and acrylic resins occurred after adjusting the time between 0-220 second with speed 25 mm/min. Accordingly, all acrylic / silicone samples were exposed to tension and showed adhesive failure for primers groups and control groups (see Table 1). These results were consistent with Taft et al. [14] who found that all acrylic/silicone samples failed adhesively.

However, Hatamleh and Watts [3] and Shetty and Guttal [16] showed that failure mode was a combination of adhesive and cohesive failures. In other words, the chosen combination of primer and silicone resulted in either a greater or a lower bond strength than the chosen silicone.

The current research assessed the bond strength of silicone to acrylic using peel test. Patients who have facial defects and are often rehabilitated with a prosthesis. One of the challenges for a successful outcome is the bond between the acrylic substrate (encompassing the clips and magnets) and the silicone elastomer. The current study suggested that MED6-161 and MED160 primers improved peel bond strength between silicone and acrylic. The null hypothesis was rejected as there were a significantly differences between MED-160 and MED6-161 primers to bond Cosmesil 2004 and light and auto-polymerising acrylic resins. However, further investigation of different primers, silicones and different surface treatments to achieve the optimum bonding is need.

5. CONCLUSION

This study concluded the following points:-

1. There is an interaction between MED6-161 primer and light-polymerising acrylic resin, and MED-160 primer and auto-polymerising acrylic resin improved peel bond strength between Cosmesil 2004 and acrylic resin.
2. The correct combination of primer and acrylic resin may improve the serviceability of implant-retained facial prosthesis.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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I would like to thank Dr. Trevor Coward and Professor Michael Fenlon, for their support and advice to carry out the research. I would like to show appreciation to Mr. Richard Mallett, the director of research lab in the Department of Biomaterials, Biomimetics and Biophotonics at Guy's Hospital for providing help to use universal testing machine. I would like to show my gratitude to all staff in the Maxillofacial Department at Guy's Hospital and in particular Mr. Colin Haylock for providing help to prepare all laboratory equipments.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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