



COMPARATIVE EVALUATION OF BONDING EFFICIENCY OF PEEK AND ACRYLIC RESIN WITH FACIAL SILICONE USING DIFFERENT BONDING AGENTS- AN IN VITRO STUDY

Dental Science

Dr. Manjulika Tyagi*

P.G Student, Department of Prosthodontics and Crown and Bridge Subharti Dental College, Swami Vivekanand Subharti university Meerut ,U.P India *Corresponding Author

Dr. Chandan Kumar Kusum

MDS Reader Department of Prosthodontics and Crown and Bridge Subharti Dental College, Swami Vivekanand Subharti university Meerut ,U.P India

Dr. Roma Goswami

MDS Professor and HOD Department of Prosthodontics and Crown and Bridge Subharti Dental College, Swami Vivekanand Subharti university Meerut ,U.P India

ABSTRACT

Aim: To comparatively evaluate the bonding efficiency of PEEK - silicone and acrylic resin-silicone using different bonding agents.

Settings and Designs: In vitro – comparative study **Materials and Methods:** For conducting the study, one hundred and forty four specimens (72 each of PEEK and 72 of acrylic resin) were prepared. PEEK specimens were CAD CAM milled while those of acrylic resin were made in heat cure resin. Out of 72 samples of PEEK and 72 of acrylic resin specimen, 24 were bonded to facial silicone without bonding agent, 24 were bonded using platinum primer and 24 were bonded to silicone using cyanoacrylate. Bond strength of each group was evaluated and compared using peel bond strength test using Universal testing machine. **Statistical Analysis Used:** One way ANOVA, Karl Pearson's correlation. **Results:** Comparison of mean bond strength among PEEK-silicone and acrylic-silicone groups shows that no significant difference was present between the control groups and also when primer was used as bonding agent. Acrylic-silicone was having significantly better bond strength than PEEK-silicone when cyanoacrylate adhesive was used. **Conclusion:** Similar to acrylic resin PEEK can also be used as biomaterial which can be bonded to silicone using primer as adhesive material.

KEYWORDS

PEEK, silicone, acrylic, peel bond strength

INTRODUCTION

The elastomers and polymers are often used as the primary materials of maxillofacial prosthesis.

⁽¹⁾ Silicone prosthesis generally require a matrix to encapsulate retentive clips, metal housings or magnets, for their attachment to implants. The materials most favorably used for fabrication of this matrix are acrylic resins.⁽²⁾ Polyetheretherketone (PEEK) is a tooth colored synthetic polymer which can be used as an alternative to PMMA.^(3,4,5) Properties such as thermal stability at high temperature, non-toxic and superior biocompatibility renders PEEK as the material of choice for many dental prosthesis.⁽⁶⁾ PEEK can also be used for CAD-CAM fixed and removable prosthesis because of its superior properties compared to acrylic.⁽⁷⁾ Studies have proven that PEEK has excellent bonding results with epoxy resins, cyanoacrylates and silicone adhesives.⁽⁸⁾

Many studies⁽⁹⁻¹¹⁾ have evaluated the bonding efficiency of PMMA resin with silicone using different adhesives but no study is available to know the bonding efficiency of PEEK with silicone. Hence the aim of this study was to evaluate the bonding efficiency of PEEK with silicone using different bonding agents and then compare it with that of acrylic resin and silicone.

MATERIALS AND METHODS

The present study was organized in the Department of Prosthodontics and Crown and Bridge, Subharti Dental College, Meerut.

The test specimens were divided into 6 groups. 3 groups were of PEEK and 3 of acrylic resin. All acrylic resin and PEEK groups were treated with either cyanoacrylate or primer or none depending upon their distribution in subgroup as given in Table1. All the test specimens of PEEK and Acrylic resin received surface alteration in form of retentive holes.

Preparation of Specimens(Figure1.)

(Acrylic Resin) 72 test specimens of heat cure acrylic resin of dimensions 75x10x3mm were fabricated using lost wax technique according to ADA/ANSI Sp.No.12(ISO 1567). Heat cure processing was performed according to manufacturer's instructions.

(PEEK)

72 CAD CAM milled specimens of PEEK of dimensions 75x10x3mm were polished and air abraded and then sterilized ultrasonically.

In then bonding area of each specimen, horizontal lines were marked at

a distance of 3 mm and vertical lines were marked at a distance of 2.5 mm. At the junction of these lines, 24 holes were made of diameter 1.5 mm and depth of 0.5 mm using a tungsten carbide round bur of diameter 1.5 mm with help of milling machine.(Figure2.) All the PEEK and acrylic resin specimens along with surface alteration were then packed and cured with facial silicone.

Preparation of mold for packing of silicone elastomer

The acrylic resin blanks which were fabricated were overlapped with another acrylic blank of the same dimension (75 mm×10 mm×3 mm) and the borders of the two were sealed to close the gap between the two blanks. Flasking was done with the first pour covering till the junction of the two blanks.

Later on second pour was done after applying separating media using dental. After this the flask was opened, dewaxing done and the overlapped acrylic blank from the second pour was removed. The lower member containing the acrylic blank with the required surface characteristic was overlapped with upper member of the flask which was packed with silicone.

Specimens of the control group were packed without the primer and cyanoacrylate and cured. The same procedure was carried out for PEEK specimens also. On all the acrylic resin and PEEK specimens with retentive holes, an adhesive tape was applied and covered an area of 50 mm× 10 mm while the remaining area of 25 mm×10 mm was left uncovered . Same procedure was carried with all the 72 acrylic resin and 72 PEEK specimens. The uniform layer of primer was applied over the specimens and left to dry for 30 minutes.

The silicone was mixed and applied into the mold with the help of spatula. Group A and Group D were packed with silicone without applying the primer and cyanoacrylate.

Curing of silicone was done in hot air oven at 100 C for 1hour according to manufacturer's instructions. For cyanoacrylate group, cured silicone strip was removed. A uniform layer of cyanoacrylate resin was applied on the specified area of acrylic resin and PEEK specimens. The silicone strip was then immediately replaced in its correct position on the blanks and a weight of 1 kg was placed on the specimens for about 15 minutes.

Test specimens bonded with silicone were then tested for peel bond strength using an UTM Machine.(Figure.3) All the test groups were put on 180° peel strength test on Hounsfield universal testing machine (HT-400) (Figure.4). The test was carried out according to the ASTM

D-903 specifications².

The free end of the unbonded part of strip was turned back at 180° was gripped in the upper clamp while the end part of acrylic resin and PEEK was clamped in the lower clamp. The force needed to cause bond failures was recorded. Peel strength (N/mm) was evaluated using the formula Peel strength = $F / W (1 + \lambda / 2 + 1)$ Where F = maximum force recorded (N); W = Width of specimens (mm); λ = Extension ratio of silicone elastomer (the ratio of stretched to primary length). After collecting the data, results were tabulated, statistically analyzed and compared (in Mpa).

RESULTS

The results obtained were statistically analyzed using ANOVA and Karl Pearson's test.

DISCUSSION

Different types of forces act on prosthesis margins and interface between silicone and substructure or matrix which can lead to tearing of silicone from margins and dislodgement of substructure or matrix from silicone prosthesis due to bond failure.⁽¹²⁾ The material of choice for matrix in these prostheses since long back has been acrylic resin.

It is because of advantages such as good handling property, the rigidity and relatively low in cost. The limitation of PMMA, its possibility to produce toxic reactions or irritations for the wearer⁽¹³⁻¹⁵⁾ and for dental technicians⁽¹⁶⁾ has led the researchers to search for other alternative materials having better properties. Polysulfone (PSF), nylon and polycarbonate (PC) are suggested for patients who are allergic to acrylic.⁽¹⁷⁻¹⁹⁾

However, shortcomings in some of their properties have confined their use.^(20,21) Biocompatibility, followed by good mechanical and physical properties is a primary requirement in all restorative materials that guaranteed their use over long periods of time.⁽²²⁾ Polyetheretherketone (PEEK) is emerging as a new and advanced biocompatible material which is now widely used for medical purposes⁽²³⁾ and has attracted more interest than any other material in the last few years.⁽²⁴⁻²⁶⁾

Hence, the aim of present study was to evaluate the bonding efficiency of PEEK with silicone and then comparing it with that of acrylic resin. The primers most commonly used for maxillofacial prostheses are A-330, A-306, A-304⁽¹⁰⁾.

A-304 was used in this study because of its ability to bond effectively to acrylic resin.⁽¹²⁾ The primers consist of an adhesive agent and an organic solvent that are believed to react with both, silicone elastomer and acrylic resin materials.⁽²⁷⁾ It consists of hydrophilic and hydrophobic groups, which react with functional groups of silicone elastomer.⁽²⁸⁾ In the present study surface alteration was done in the form of retentive holes as it has been proved in the previous study that surface characterization had increased the bond strength considerably.⁽²⁾

The mean bond strength of specimens of PEEK for control, primer and cyanoacrylate groups (i. e for group A, B, C) was 0.62MPa, 15.45MPa, and 4.49MPa respectively (Table.2). The difference among the intra group specimens was statistically significant. (Table.3) The primer group showed the maximum bond strength. It may be because of reason that A-304 contains methacryloxyethyl and most studies has shown that the bonding agents that contain methylacryl group (MMA) were able to establish a sufficient bond to PEEK.⁽²⁹⁻³²⁾ But still further studies are required at molecular level to assess the bonding of PEEK with platinum primers.

The mean bond strength within acrylic resin groups D, E, F was 0.61MPa, 14.44MPa and 5.97MPa respectively (Table.2). The difference among the intra group specimens of acrylic resin was statistically significant. (Table.4) Primer group i.e. group E showed the maximum bond strength which may be credited to its strong chemical affinity of acrylic resin with the primer.⁽³³⁾ Control groups A and D showed less bond strength with no statistical significant difference among them. (Table.5)

This infers that only surface alteration in form of retentive holes without adhesive agent was not able to produce comparable bond strength. All specimen showed mean bond strength more than 0.07 MPa which is considered to be minimum limit for clinical success.⁽³⁴⁾

³⁶⁾The differences in terms of bond strength within each group were due to variations in compositions of bonding agents and also due to surface alteration done in form of retentive holes.

The difference among intergroup specimens was not significant statistically except for group C and F which showed statistically significant difference which might be because of the reason that acrylic surface is amenable to adhesive bonding.

While for PEEK, due to its low surface energy and chemical inertness and different chemical composition its bonding with cyanoacrylate gave comparatively less mean bond strength. More studies are required to investigate the poor bonding of PEEK and silicone using cyanoacrylate. Cyanoacrylate has shown decreased bond strength in comparison to primers.

One of the reasons of this decrease in the bond strength could be due to the method of specimen fabrication, where in due to retentive holes, the depressions and elevations of the two materials could not have corresponded to each other while reassembling.⁽²⁾

Test showed that specimens of primer A-304, of both acrylic resin and PEEK showed either cohesive or adhesive failure, whereas the specimens of cyanoacrylate of both acrylic resin and PEEK showed adhesive failure. Generally, sufficient surface roughness is considered an important alteration for improving the bonding strength for plastic dental materials.⁽³⁷⁾ But because of hardness and inertness of PEEK, it generally is nonreactive and thus a limited number of surface roughening methods can be successfully employed with PEEK.⁽³⁸⁾

Due to the absence of standard laboratory conditions, accurate comparison of the results of different studies on bond strength of facial silicone to PEEK and acrylic surfaces was not feasible in this study. Several factors such as the variable geometry of the samples, different surface energy of materials and variability in packing and curing conditions can affect the bond strength values.⁽³⁹⁾

Future studies are recommended to assess the long-term clinical service and success of the bond of the facial silicone to PEEK surfaces in oral clinical conditions.

CONCLUSION

After considering the various aspects of the present study and correlating the results with literature, it could be concluded that similar to acrylic resin PEEK can also be used as biomaterial which can be used with silicone using primer as adhesive material.

However if cyanoacrylate adhesive is used, PEEK shows poor performance than acrylic resin.

Conflicts of interest

There are no conflicts of interest.

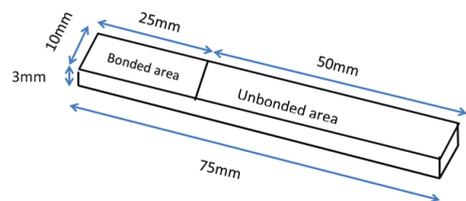


Figure.1 Specimen Dimensions

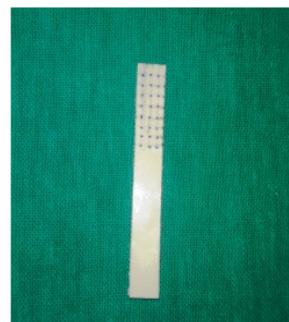


Figure.2 Markings made for retentive holes(PEEK)



Figure.3 Silicone bonded to PEEK (PS) and acrylic resin(AS)

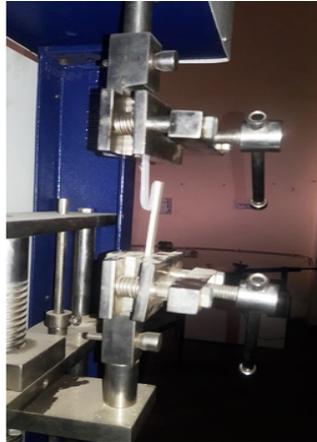


Figure.4 Testing specimens on Universal Testing Machine

Table.1 Groups of PEEK and Acrylic resin specimens

Group A	Bonding PEEK with silicone using no adhesive.
Group B	Bonding PEEK with silicone using silicone platinum primer.
Group C	Bonding PEEK with silicone using cyanoacrylate adhesive.
Group D	Bonding Acrylic resin with silicone using no adhesive.
Group E	Bonding Acrylic resin with silicone using silicone platinum primer.
Group F	Bonding Acrylic resin with silicone using cyanoacrylate adhesive.

Table.2 — Mean, standard deviation, median, maximum & minimum scores of bond strength of PS & AS in six groups (in MPa) PS- PEEK- Silicone AS-Acrylic-Silicone

S. NO.	P S			A S		
	Group A (control)	Group b (primer)	Group C (cyanoacrylate)	Group D (control)	Group E (primer)	Group F (cyanoacrylate)
Mean	0.6292	15.4500	4.4958	0.6125	14.4458	5.9708
S.D.	0.2985	1.8216	1.0277	0.2626	2.2872	1.4600
Median	0.600	15.000	4.350	0.600	14.200	5.650
Maximum	1.60	18.40	6.10	1.30	18.20	8.40
Minimum	0.30	12.80	2.40	0.20	11.00	3.40

Table.3 One way Anova-f test for comparing the bond strength among the group A, group B & group C

Source Of Variation	SS	DF	MS	F	P-Value	F CRIT
Between Groups	2836.816	2	1418.408	953.3503	5.47E-51*	3.129644
Within Groups	102.6592	69	1.487814			
Total	2939.475	71				

Table.4 One way Anova-f test for comparing the bond strength among the group D, group E & group F

Source Of Variation	SS	DF	MS	F	P-Value	F CRIT
Between groups	2335.188	2	1167.594	471.3124	5.85E-41*	3.129644
Within Groups	170.9354	69	2.477325			
Total	2506.123	71				

Table.5 – Comparison between groups (by unpaired”t” test) for bond strength among group A-F

S. No.	P Value Between Groups (by Independent ”t” Test	Significance
1	.0000* (P<.05)	Significant Difference
2	.0002* (P<.05)	Significant Difference
3	.8382** (P>.05)	No Significant Difference
4	.0000* (P<.05)	Significant Difference
5	.0999** (P>.05)	No Significant Difference
6	.0002* (P<.05)	Significant Difference
7	.0000* (P<.05)	Significant Difference
8	.0000* (P<.05)	Significant Difference
9	.0000* (P<.05)	Significant Difference

*SHOWS A SIG NIFICANT DIFFERENCE B/W GROUPS AT .05 LEVEL OF SIGNIFICANCE. i. e. p<.05 ** SHOWS NO SIGNIFICANT DIFFERENCE B/W GROUPS AT .05 LEVEL OF SIGNIFICANCE. i. e. p>.05

REFERENCES

1. Frangou MJ, Polyzois GL, Tarantili PA, Andreopoulos AG. Bonding of silicone extra-oral elastomers to acrylic resin: the effect of primer composition. The European journal of prosthodontics and restorative dentistry. 2003 Sep; 11(3):115-8.
2. Shetty US, Guttal SS. Evaluation of bonding efficiency between facial silicone and acrylic resin using different bonding agents and surface alterations. The journal of advanced prosthodontics. 2012 Aug 1; 4(3):121-6.
3. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. Journal of prosthodontic research. 2016 Jan 31; 60(1):12-9.
4. Costa-Palau S, Torrents-Nicolas J, Brufau-de Barberà M, Cabratosa-Termes J. Use of polyetheretherketone in the fabrication of a maxillary obturator prosthesis: a clinical report. The Journal of prosthetic dentistry. 2014 Sep 30; 112(3):680-2.
5. Ardelean LC, Bortun CM, Podariu AC, Rusu LC. Acrylates and Their Alternatives in Dental Applications. In Acrylic Polymers in Healthcare 2017. InTech.
6. Stawarczyk B, Beuer F, Wimmer T, Jahn D, Sener B, Roos M, Schmidlin PR. Polyetheretherketone—a suitable material for fixed dental prostheses?. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2013 Oct 1; 101(7):1209-16.
7. Troughton MJ. Handbook of plastics joining: a practical guide. William Andrew; 2008 Oct 17.
8. Hattori M, Sumita YI, Muthiah L, Iwasaki N, Takahashi H, Aimaizang Y, Yoshi S, Taniguchi H. Effect of fabrication process on the bond strength between silicone elastomer and acrylic resin for maxillofacial prosthesis. Dental materials journal. 2014 Jan 30; 33(1):16-20.
9. Sanohkan S, Kukiattakoon B, Peampring C. Tensile bond strength of facial silicone and acrylic resin using different primers. Journal of Oromaxillofacial Sciences. 2017 Jan 1; 9(1):48.
10. Al-Shammari FA. Effect of Different Primers on the Peel Bond Strength between Silicone Elastomer and Acrylic Resins. Journal of Advances in Medicine and Medical Research. 2015 Jun 8:1034-44.
11. Harsh Patel RK, Ponnanna AA, Arvind Singh Bithu KS. The Effect of Primer on Bond Strength of Silicone Prosthetic Elastomer to Polymethylmethacrylate: An in vitro Study. Journal of clinical and diagnostic research: JCDR. 2015 Mar; 9(3):ZC38.
12. Tanveer W, Wonglamsam A, Tanchareon S, Tirasriwat A, Srithavaj T, Shrestha B, Chotprasert N. Evaluation of peel bond strength between plexiglas acrylic (pmma) and maxillofacial silicone using three different primers. M Dent J. 2017; 37(3):263-72.
13. Kanerva L, Lauerma A, Estlander T, Alanko K, Henriks-Eckerman ML, Jolanki R. Occupational allergic contact dermatitis caused by photobonded sculptured nails and a review of (meth) acrylates in nail cosmetics. American Journal of Contact Dermatitis. 1996 Jun 1; 7(2):109-15.
14. Kanerva L, Jolanki R, Estlander T. 10 years of patch testing with the (meth) acrylate series. Contact dermatitis. 1997 Dec; 37(6):255-8.
15. Lung CY, Darvell BW. Minimization of the inevitable residual monomer in denture base acrylic. Dental Materials. 2005 Dec 1; 21(12):1119-28.
16. Kiec Swierczynska M. Occupational allergic contact dermatitis due to acrylates in Lodz. Contact Dermatitis. 1996 Jun; 34(6):419-22.
17. Haddad MF, Gioato MC, Santos DM, Pesqueira AA, Moreno A, Naves LZ, et al. Bonding of facial silicon with nanoparticles to an acrylic resin substrate. Int J Adhes Adhes. 2014; 54:206-13.
18. Stafford GD, Arendorf T, Huggett R. The effect of overnight drying and water immersion on candidal colonization and properties of complete dentures. Journal of dentistry. 1986 Apr 1; 14(2):52-6.
19. Tanoue N, Nagano K, Matsumura H. Use of a light-polymerized composite removable partial denture base for a patient hypersensitive to poly (methyl methacrylate), polysulfone, and polycarbonate: a clinical report. The Journal of prosthetic dentistry. 2005 Jan 1; 93(1):17-20.
20. Pfeiffer P, Rosenbauer EU. Residual methyl methacrylate monomer, water sorption, and water solubility of hypoallergenic denture base materials. The Journal of prosthetic dentistry. 2004 Jul 1; 92(1):72-8.
21. Pfeiffer P, Rolleke C, Sherif L. Flexural strength and moduli of hypoallergenic denture base materials. The Journal of prosthetic dentistry. 2005 Apr 1; 93(4):372-7.
22. Anusavice S, Shen and R CH, Rawls. Phillipsscience of dental materials. 2013; 12.
23. Kurtz SM. An overview of PEEK biomaterials. In PEEK biomaterials handbook 2012 Jan 1 (pp. 1-7). William Andrew Publishing.
24. Rae PJ, Brown EN, Orler EB. The mechanical properties of poly (ether-ether-ketone) (PEEK) with emphasis on the large compressive strain response. Polymer. 2007 Jan 12; 48(2):598-615.
25. Koutouzis T, Richardson J, Lundgren T. Comparative soft and hard tissue responses to titanium and polymer healing abutments. Journal of Oral Implantology. 2011 Apr; 37(sp1):174-82.
26. Hahnel S, Wieser A, Lang R, Rosentritt M. Biofilm formation on the surface of modern implant abutment materials. Clinical oral implants research. 2015 Nov; 26(11):1297-301.
27. Minami, H., et al., Effect of surface treatment on the bonding of an autopolymerizing soft denture liner to a denture base resin. Int J Prosthodont. 2004. 17(3): p. 297-301

28. Chang, P.P., et al., The effects of primers and surface bonding characteristics on the adhesion of polyurethane to two commonly used silicone elastomers. *J Prosthodont*, 2009. 18(1): p. 23-31.
29. Bauer J, Costa JF, Carvalho CN, et al: Influence of alloy microstructure on the microshear bond strength of basic alloys to a resin luting cement. *Braz Dent J* 2012;23:490-495
30. Uhrenbacher J, Schmidlin PR, Keul C, et al: The effect of surface modification on the retention strength of Polyetheretherketone crowns adhesively bonded to dentin abutments. *J Prosthet Dent* 2014;112:1489-1497
31. Marshall SJ, Bayne SC, Baier R, et al: A review of adhesion science. *Dent Mater* 2010;26:11-16
32. Stawarczyk B, Taufall S, Roos M, et al: Bonding of composite resins to PEEK: the influence of adhesive systems and air-abrasion parameters. *Clin Oral Investig* 2018;22:763-771
33. Mutluay, M.M. and I.E. Ruyter, Evaluation of bond strength of soft relining materials to denture base polymers. *Dent Mater*, 2007. 23(11): p. 1373-81.
34. Goiato MC, Haddad MF, Santos DM, Pesqueira AA, Moreno A. Hardness evaluation of prosthetic silicones containing opacifiers following chemical disinfection and accelerated aging. *Braz Oral Res* 2010;24:303-8.
35. Goiato MC, Ribeiro Pdo P, Pellizzer EP, Garcia Júnior IR, Pesqueira AA, Haddad MF. Photoelastic analysis of stress distribution in different retention systems for facial prosthesis. *J Craniofac Surg* 2009;20:757-61.
36. Haddad MF, Gioato MC, Santos DM, Pesqueira AA, Moreno A, Naves LZ, et al. Bonding of facial silicon with nanoparticles to an acrylic resin substrate. *Int J Adhes Adhes* 2014;54:206-13
37. Zhou L, Qian Y, Zhu Y, Liu H, Gan K, Guo J. The effect of different surface treatments on the bond strength of PEEK composite materials. *Dental Materials*. 2014 Aug 1;30(8):e209-15.
38. Tsuka H, Morita K, Kato K, Kawano H, Abekura H, Tsuga K. Evaluation of shear bond strength between PEEK and resin-based luting material. *Journal of Oral Biosciences*. 2017 Nov 1;59(4):231-6.
39. Baldan A. Adhesively-bonded joints and repairs in metallic alloys, polymers and composite materials: adhesives, adhesion theories and surface pretreatment. *Journal of materials science*. 2004 Jan 1;39(1):1-49.