International Journal of Basic & Clinical Pharmacology
Punia V et al. Int J Basic Clin Pharmacol. 2026 Sep;15(5):953-959
https://www.ijbcp.com
pISSN 2319-2003 | eISSN 2279-0780

DOI: https://dx.doi.org/10.18203/2319-2003.ijbcp20262866

Original Research Article

Assessing the effect of layering gingival shade composite resin thickness on the flexural strength of denture base polymer resin material processed by CAD/CAM and injection moulded technique

Vikas Punia*, Vaishnavi Ghuge, Anand Porwal, Abhijit Sethia, Palak Salgia, Jehan Dordi, Apexa Tuvar

Department of prosthodontics and crown & bridge, Darshan Dental college and Hospital, Udaipur, Rajasthan, India

Received: 17 June 2026
Accepted: 16 July 2026

***Correspondence:**
Dr. Vikas Punia,
Email: drvikas81@gmail.com

ABSTRACT

Background: Acrylic resin denture base as materials for dentures, do not mimic the gingival esthetics. Gingival composite resin used for fabrication of denture; it enhances the denture esthetics but affects the material's flexural strength. The study aimed to investigate the flexural strength of denture base polymer resin material CAD/CAM milling and injection molding, as well as the impact of gingival shade composite resin thickness.
Methods: Two types of denture acrylic resins were used as base materials: CAD/CAM pre-polymerized PMMA resin and injection molded acrylic resin. Specimens of both groups, each size 32×10×3 mm, were fabricated. The denture base material was layered with a Gingiva-shade composite resin in thicknesses of 1.0 mm and 1.5 mm, creating subgroups for each material type (n=10). After conditioning of samples, a UTM was used to conduct a 3-point bending test measured the flexural strength and results were analyzed statistically
Results: The compression strengths of the injection-molded acrylic resin samples varied between 125.4±3.115 MPa and 114.3±5.074 MPa, whereas the compression strengths of the CAD-CAM prepolymerized acrylic resin varied between 129.4±3.84 MPa and 119.4±8.16 MPa. All test groups maintained flexural strength values above the ISO 20795-1 minimum requirement of 65 MPa, clinical acceptability for denture fabrication.
Conclusions: CAD/CAM PMMA denture bases exhibited superior flexural compared to injection-molded, both pre and post aging and in different thickness of GSCR layering.

Keywords: CAD/CAM, Gingival shade composite resin, Injection molding

INTRODUCTION

The acrylic denture base resin offers limited aesthetics since it lacks the natural appearance of healthy gingiva. Aesthetics of dental prosthesis should complement the soft tissues around the teeth, particularly in the anterior area.[1] Therefore, aesthetically pleasing full or partial dentures that can imitate the gums and mucosa would be a great solution. Gingival shade composite resins (GSCR) have been created more recently to restore the gingiva's look in detachable/removable, tooth-supported and implant-supported prostheses.[2] The most effective denture base material for creating full dentures has been found to be polymethyl methacrylate. There are various methods for creating complete dentures. Compression molding, injection molding and CAD/CAM milling are the most often used denture processing methods.[3] Modern technological developments have enabled the use of digital methods, including as three-dimensional (3D) printing, computer-aided design and manufacturing (CAD/CAM) and others, to manufacture denture bases.[4] Digital techniques make it possible to create a denture base in a single block or disc to use the appropriate adhesive to attach prefabricated teeth to the denture base.[5] Faster

denture manufacturing and fewer stages in the process, which can lower the likelihood of processing errors, are the benefits of digital approaches.[2]

The impact of layering gingival shade composite resin on CAD/CAM polymethyl methacrylate is an area of less research. This in vitro study aimed to determine the flexural strength of CAD/CAM acrylic denture base resin materials by substituting layers of varying thicknesses of gingival shade composite resin for denture base polymers following thermocycling, as well as to analyze the bond strength of these materials to denture base resins. It's important to evaluate the relevance of the gingival shade composite layering over the CAD/CAM acrylic resin.

METHODS

Two types of denture acrylic resins were used as base materials: CAD/CAM pre-polymerised PMMA resin and injection molded acrylic resin. Pilot research was conducted to identify the sample size. A total of 30 specimens were manufactured of each group and then split into three subgroups, each with a sample size of 10. The size of each specimen was 32×10×3 mm and were fabricated in accordance with ISO standards 1567 and 20795-1:2013. A gingival-shade composite resin (GSCR) (Beautiful II Shofu dental, Pvt. Ltd, India.) was used to replace different thicknesses (1.0 mm and 1.5 mm) of acrylic resin denture resin materials (Figure 1).

For the fabrication of CAD/CAM pre-polymerized PMMA resin samples STL (Standard Tessellation Language) files of above-mentioned dimensions, which were created using Exocad software, in the CAD unit. In the CAM unit (Arum 5X-500, Arum Dentistry.), which is a 5-axis CNC (computer numerical control) milling machine a CAD/CAM pre-polymerized PMMA resin (Noble Cam) pucks were used and dry milling was done. And total of 30 sample was obtained which further subdivided into 3 sub-groups The test specimens of dimensions 32 x 10 x 3mm (control group), 32×10×2 mm for the application of 1 mm of gingival shade composite resin (GSCR) and 32×10×1.5 mm thickness for the application of 1.5 mm of GSCR were obtained.

For the fabrication of Injection Moulded specimens, a conventional heat cure acrylic resin (MAARC Pvt. Ltd) and injection molding flask (Valplast Pvt. Ltd. Faridabad, India.) was used. And total of 30 samples obtained which further subdivided into 3 sub- groups The test specimens of dimensions 32 x 10 x 3mm (control group), 32×10 x 2 mm for the application of 1 mm of gingival shade composite resin (GSCR) and 32×10×1.5 mm thickness for the application of 1.5 mm of gingival shade composite resin (GSCR) were obtained (Figure 2).

A 3 mm control specimen was used to create a silicone mold, ensuring a uniform 3 mm thickness for the gingival resin bonding and layering processes. After roughening up the surfaces of the denture base resin specimens with sandpaper, a thin layer of primer (Universal Shofu dental primer) was applied to cover the surfaces and then photopolymerized for 1 minute (photopolymerizing unit by Dentsply Sirona). Using a silicone point applicator, the gingiva-shade composite resin was applied to the denture acrylic resin specimens in increments of 1.0 mm and 1.5 mm using the silicone mold. This process continued until the total specimen thickness of around 3 mm was restored.

For conditioning of the test specimen, All the test specimens were aged with the thermal cycle in 5-55℃ in the distilled water bath with the dwell time of 30 secs. The specimens are placed in cold water of about 50 ℃ for 15 sec and then it is placed in hot water of about 55℃ for 15 sec. The transition time from hot to cold temperature is of 1 sec. 10,000 cycles simulate the aging of 1 year.[6,7] After conditioning has been completed, all the test specimens were immersed in denture cleanser solution (3.8 % sodium perborate) for 10 mins at room temperature to check the effect of denture cleanser on the test specimens. After 10 minutes, specimens were thoroughly washed and the specimens were stored in distilled water for 24 hours. This procedure was repeated daily for 180 days (Figure 3).[8]

Flexural strength=3FL=2BH2, where F is the maximum load applied on the specimen, L is the distance between the supports, B is the width at the center of the specimen and H is the height at the center of the specimen. A universal testing equipment and a bespoke fixture were used to conduct the 3-point loading test at a crosshead speed of 5 mm/min, in compliance with ISO 20795-1:2013. The test specimens were tested for flexural strength before and after aging procedure. The values were obtained and subjected to statistical analysis. One way ANOVA of calculated values was performed, followed by Tukey HSD multiple comparison test. Independent "t" test and paired "t" test of mean values were performed to make comparisons. The level of significance was set upto $p \leq 0.05$ (Figure 4).

RESULTS

The results are shown in table 1. Data was tabulated and subjected to statistical analysis. One way ANOVA of calculated values was performed, followed by Tukey HSD multiple comparison test. Independent "t" test and paired "t" test of mean values were performed to make comparisons. The level of significance was set up to $p \leq 0.05$.

Intra group comparison of the mean flexural strength before and after conditioning of test specimen of CAD/CAM pre polymerized PMMA resin group. by applying Student's Paired 't' test there is a significant difference in between mean values of flexural strength before and after conditioning of test specimen of CAD/CAM pre polymerized PMMA resin group in CP-1 (Control group 3 mm PMMA), in CP- 2 (2 mm PMMA+1 mm GSCR) group and in CP-3 (1.5 mm PMMA+1.5 mm GSCR) groups respectively. CP-3 shows highest difference

of mean values of flexural strength before and after conditioning of CAD/CAM pre polymerized PMMA resin group A as compared to groups CP- 2 and CP-1 (Figure 5).

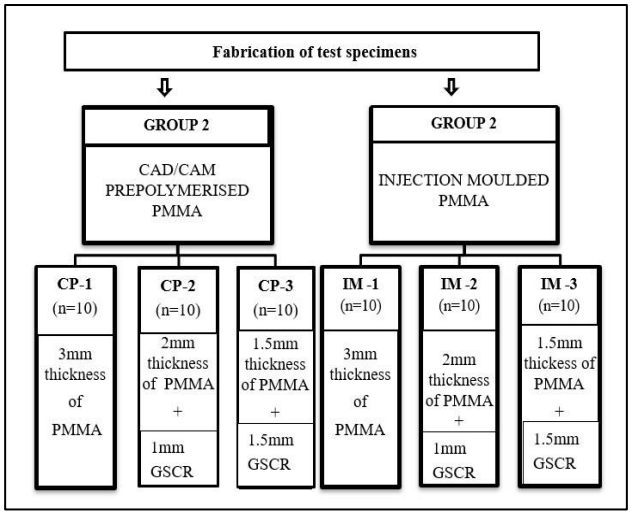

Figure 1: Group division of injection moulded and CAD/CAM milled PMMA test specimens.

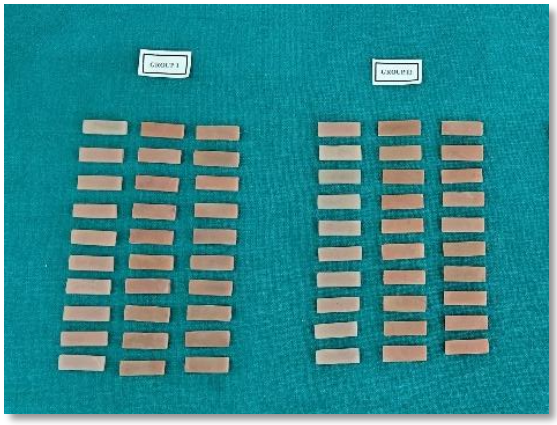

Figure 2: CAD/CAM Pre polymerised PMMA resin and Injection molded PMMA resin layered with gingiva colored composite resin.

Figure 3: Conditioning of the test specimen.

Figure 4: Evaluation of Flexural strength of the test specimen.

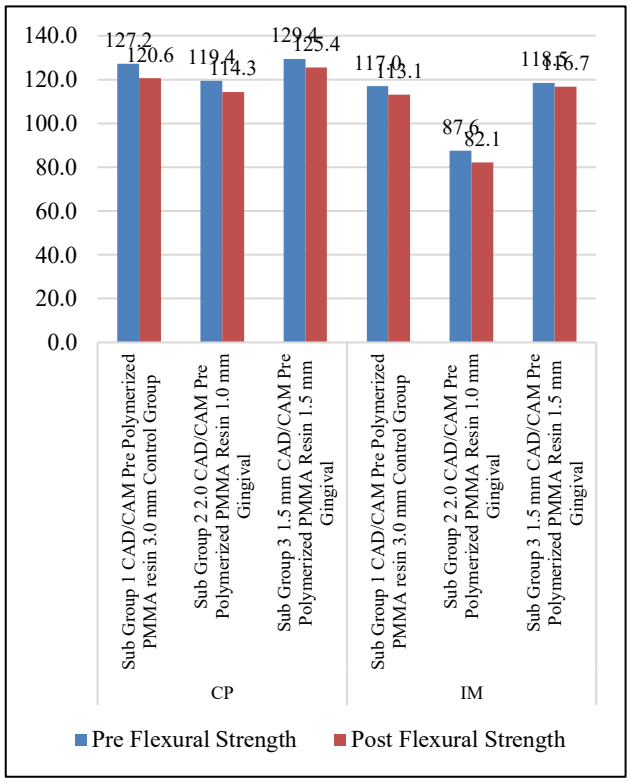

Figure 5: Intra and inter group comparison of before and after aging of CAD-CAM pre polymerized and Injection molded PMMA resin group.

The mean values of flexural strength before and after conditioning of test specimen of injection molded PMMA resin group in IM-1 (Control group 3mm PMMA), in IM-2 (2 mm PMMA+1 mm GSCR) group and in IM- 3 (1.5 mm PMMA+1.5 mm GSCR) groups respectively. IM-3

shows highest difference of mean values of flexural strength before and after conditioning test specimen of injection molded PMMA resin group A as compared to groups IM-2 and IM-1.

Table 1: Inter group comparison of flexural strength for before and after aging of CAD-CAM pre polymerized and Injection molded PMMA resin group.

Flexural strengths		N	Mean	Std. deviation	P value
Before	CP-1	10	127.19	3.758	0
	IM-1	10	116.95	3.003	
After	CP- 1	10	120.59	4.59	0.002
	IM- 1	10	113.13	4.59	
Before	CP- 2	10	119.37	8.168	0
	IM -2	10	87.62	10.153	
After	CP- 2	10	114.3	5.074	0
	IM- 2	10	82.06	8.771	
Before	CP- 3	10	129.39	3.842	0
	IM- 3	10	118.54	3.219	
After	CP- 3	10	125.44	3.115	0
	IM- 3	10	116.73	4.123	0

*Significant at 0.05 level.

DISCUSSION

Conventional complete denture therapy is the most common treatment option for edentulous patients.[1] Compression molding, pouring a fluid resin and injection molding are three common denture processing methods. For many years, the standard procedure has been packing and pressing, which involves compression molding in a conventional flask.

Due to its reduced processing time, the fluid resin (pour) technology gained popularity. On the other hand, problems including air entrapment, misaligned denture bases and shifting prosthetic denture teeth have been discovered as a result of processing speeds being too high. Before Ivoclar made the injection molding process commercially available in 1970, Prior had described it in 1942.[3] A denture foundation may now be made in a single block using digital technologies and prefabricated teeth can be attached with the right glue. The use of digital technology streamlines the denture manufacture process and reduces the number of steps required.[2]

The amount of residual monomer and the mechanical qualities are closely related to the polymerization condition, according to a study by Jafar Gharechahi and colleagues on the flexural strength of acrylic resin denture bases produced by two distinct ways in heat-cured acrylic resins. Because of its plasticizing qualities, residual monomer might affect the flexural strength of denture bases. Given the concept and the high flexural strength of the SR Ivocap specimens in this investigation, it can be inferred that the polymerization was more thorough and there was less residual monomer in these specimens than in the conventional processing method.[9] Additionally, dual polymerization and small particle sizes may be responsible for the injection-molded resin's favorable mechanical and physical characteristics.[6] The acrylic base of the denture may undergo a fatigue process as a result of intraoral forces, creating tiny flexural stresses that could lead to the development of tiny cracks. Denture fractures will eventually result from the spread of these cracks over time because dentures typically break when they are loaded beyond their optimum capacity.[10]

In the last 20 years, CAD/CAM technology has been broadly used in the dental field for manufacturing various prostheses due to its advantages such as increased efficiency, automaticity and accuracy of the entire treatment flow.[4] The use of pre polymerized blocks of polymethyl methacrylate (PMMA), computer software and 5-axis milling. CAD/CAM dentures have become a rapidly expanding part of the dental market.[4] Brian C. Aguirre and et al, compared the flexural strength of denture base acrylic resins processed by conventional and CAD-CAM methods computer-aided design and computer aided manufacturing (CAD-CAM) has evolved to include the fabrication of complete dentures.

The production of the resin puck includes high pressure and heat, resulting in a condensed acrylic resin and minimized shrinkage, porosity or free monomer. These bases are milled from prepolymerized resin pucks, which promise superior strength and fit and reduced bacterial adhesion.[11] An ideal dental prosthesis would have an aesthetic that is complementary to the surrounding soft tissues, particularly in the frontal area, where the teeth are located. The best material for the base of detachable dentures is poly methyl methacrylate. Traditional acrylic denture resin, on the other hand, lacks the realistic look of healthy gums, limiting its aesthetic appeal. So, to satisfy the aesthetic need, dentures, whether full or partial, should be able to mimic the characteristics of natural gingiva and mucosa.[8]

The impact of layering gingival shade composite resin on CAD/CAM polymethyl methacrylate is the subject of less research. The goals of this in vitro study were to ascertain the flexural strength of denture base resins made using

computer-aided design (CAD/CAM) and to understand the bond strength of gingival shade composite resin and denture base polymers after thermocycling. It's important to decide the relevance of the gingival shade composite layering over the CAD/CAM acrylic resin. In CAD/CAM pre-polymerized group, Layering GSCR on denture bases may cause a minor decrease in flexural strength, but all pre- and post-conditioned values still exceed the ISO minimum of 65 MPa, indicating suitability for clinical use. CP-3 consistently showed the highest flexural strength values, both before and after conditioning. Even with 1 mm GSCR layering, mechanical performance remains within acceptable limits, which supports the clinical feasibility of esthetic gingival customization.

Edmond Armand et al, tested how adding layers of gingiva-shade composite resin affected the strength of the polymer used to make denture bases. Flexural strength values were greater in the prepolymerized CAD-CAM acrylic resin groups compared to the heat polymerized resin groups, according to the study's results. These results could be explained by the prepolymerized acrylic resin's reduced porosity, increased condensation and higher degree of polymerization with low residual monomer content.[12] According to study by Rutika C. Patankar and et al, the impact strength and flexural modulus were observed to be significantly improved in CAD/CAM resin as compared to the conventional heat cure resins. Thus, it can be stated that CAD/CAM denture base resin has superior mechanical properties compared to the injection molding technique and compression molding technique.[13]

The flexural and impact strengths as well as the flexural modulus of CAD/CAM and conventional heat-cured polymethyl methacrylate were examined by Al-Dwairi and colleagues. The acrylic base of the denture may undergo a fatigue process as a result of intraoral forces, creating tiny flexural stresses that could lead to the development of tiny cracks.[14] Denture fractures will eventually result from the spread of these cracks over time because dentures typically break when they are loaded beyond their optimum capacity.[6] Based on their mechanical qualities, 3D-printed, CAD/CAM and traditional denture base materials were compared by Vladimir Prpic and colleagues.[2] CAD/CAM materials showed higher flexural strength values than compression-molded denture base materials did.[15] Since CAD/CAM PMMA blocks are made under high heat and pressure conditions with condensed acrylic resin and minimal shrinkage, porosity or free monomers, the higher flexural strength values of CAD/CAM materials, confirmed by the present study results.[16]

The Intra group comparison of the mean flexural strength before and after conditioning of test specimen of CAD/CAM pre polymerized PMMA resin group done by applying Student's Paired 't' test there is a significant difference in between mean values of flexural strength before and after conditioning of test specimen of CAD/CAM pre polymerized PMMA resin group in CP-IA (Control group 3 mm PMMA), in CP-IB (2 mm PMMA + 1 mm GSCR) group and in CP-IC (1.5 mm PMMA+1.5 mm GSCR) groups respectively. CP-IC shows highest difference of mean values of flexural strength before and after conditioning of CAD/CAM pre polymerized PMMA resin group A as compared to groups CP- IB and CP-IA. The Intra group comparison of the mean flexural strength before and after conditioning test specimen of Injection molded PMMA resin group done by applying Student's Paired 't' test there is a significant difference in between mean values of flexural strength before and after conditioning of test specimen of Injection molded PMMA resin group in IM-IIA (Control group 3 mm PMMA), in IM-IIB (2 mm PMMA + 1 mm GSCR) group and in IM-IIC (1.5 mm PMMA+1.5 mm GSCR) groups respectively. IM-IIC shows highest difference of mean values of flexural strength before and after conditioning test specimen of Injection molded PMMA resin group A as compared to groups IM-IIB and IM-IIA.

There is a significant difference between the mean values of flexural strength before and after conditioning test specimens of CAD-CAM pre polymerized and injection molded PMMA resin in all CP-IA. IB. IC and IM-IIA. IIB. IIC groups, according to a comparison of flexural strength before and after conditioning of CAD-CAM pre polymerized and injection molded PMMA resin. In the present study a comparison of flexural strength before and after conditioning of CAD-CAM pre polymerized and Injection molded PMMA resin was done. The results showed significant difference in between mean values of flexural strength before and after conditioning test specimens of CAD-CAM pre polymerized and Injection molded PMMA resin in all CP-IA, IB, IC and IM, IIA. IIB. IIC groups i.e. between the control groups and different thickness of gingival shade composite resin layering group.

The CAD-CAM pre polymerized group showed higher flexural strength in all the groups before and after conditioning of test specimen. In CAD/CAM pre-polymerized group and the injection molded group, Layering GSCR on denture bases may cause a minor decrease in flexural strength, but all pre- and post-conditioned values still exceed the ISO minimum of 65 MPa, indicating suitability for clinical use.[17,18] CP-3 consistently showed the highest flexural strength values, both before and after conditioning. Even with 1.5 mm GSCR layering, mechanical performance remains within acceptable limits, which supports the clinical feasibility of esthetic gingival customization.

This research confirms previous findings that CAD/CAM denture bases outperformed all other groups in terms of flexural. Their superior clinical performance should make them the material and processing technique of choice for denture producers, outperforming all other denture base materials. A greater degree of polymerization is one of the main elements that determines resin strength, this may explain why the CAD/CAM samples in this investigation had higher flexural values.[19] A highly concentrated resin mass with few porosities is created by pre-polymerizing the

CAD/CAM resin blocks to an extremely high degree utilizing technology that is more advanced than traditional procedures.[20] Autopolymerizing resins, on the other hand, have lower densities and strengths and greater porosities because of this. Flexural may vary because to variations in polymer and monomer compositions.

CONCLUSION

Within the limitation of this study following conclusions can be drawn denture esthetics achieved without compromising the strength. The thickness of layered GSCR affects flexural strength can guide clinicians in achieving aesthetic customization without significantly compromising the mechanical performance of the denture base material.

The study helps to select whether injection-molded or CAD/CAM-milled denture bases retain better mechanical strength when layered with GSCR. Study provides the guidelines for layering thickness of GSCR thereby preventing premature fracture or deformation of prostheses during function.

Future studies can explore other important properties such as bond strength between composite and denture base resin, impact resistance and wear resistance. Multiple layering thicknesses beyond 1.0 mm and 1.5 mm, as well as different gingival shades or composite formulations, can be studied. Clinical trials or in vivo evaluations would help validate laboratory findings of layering of GSCR on denture performance, patient comfort and esthetics. Future study could include other denture base fabrication techniques such as 3D printing and newer composite materials can be used. Further studies can be done using various surface conditioning methods and primers on the adhesion and mechanical strength of layered composite which can affect the results.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Punia V, Ghuge V, Porwal A, Sethia A, Salgia P, Dordi J, et al. Assessing the effect of layering gingival shade composite resin thickness on the flexural strength of denture base polymer resin material processed by CAD/CAM and injection moulded technique. Int J Basic Clin Pharmacol 2026;15:953-9.