



Evaluation of Flexural Strength of CAD/CAM Fixed Restoration

Dr.Surabhi Halder ¹

¹ Senior Lecturer, Department of Prosthodontics Crown and Bridge, Priyadarshini Dental College and Hospital, Thiruvallur, Tamil Nadu.

Abstract

With the evolution of CAD/CAM in prosthodontics, the fixed dental prosthesis is no exception. CAD/CAM technologies have emerged at a faster rate in the recent years showing greater success rates compared to other restorations. The present in-vitro study was conducted to comparatively evaluate the flexural strength of CAD/CAM milled PMMA resin and rapid prototype 3-D printed resin for long term provisional restorations. CAD/CAM milled PMMA resin (group no.1, n=10) and Rapid prototype 3-D printed resin (group no.2, n=10) were fabricated and grouped based on the type of material. All the twenty samples (group no.1, n=10) and (group no.2, n=10) were subjected to 3-point bend test using a universal testing machine at a cross head speed of 1.0 mm/min until fracture. The flexural strength values were obtained in megapascals. The values obtained from test samples were tabulated and statistically analysed using student t-test. CAD/CAM milled restorations showed greater flexural strength when compared to 3-D printed resin restorations and hence CAD/CAM restorations are preferred for long span provisional fixed prosthesis.

Keywords: Fixed, CAD/CAM, PMMA resin, flexural strength, milled restorations, 3-D printed resin, provisional, universal testing machine, prosthodontics.

1. Introduction

Provisional Restorations are of paramount significance in fixed dental prosthesis especially when long term treatment cases before the definitive restoration are delivered. These restorations are also responsible in the treatment plan. Several materials are used in the construction of provisional restoration namely autopolymerised resin, Bis-acryl resin, visible light cure resin, Bis-GMA (bisphenol-A glycidyl methacrylate and TEGDMA (triethylene glycol dimethacrylate). Among these materials heat cure polymethyl methacrylate remains the material of choice¹. Heat cure PMMA can be successfully utilized as a long term provisional restoration as it has adequate flexural strength and wear resistance, however they are susceptible to fracture in situations with less inter occlusal space and also their colour stability is considered inferior as they tend to attract external stains².

Over the years, CAD/CAM technology has evolved to a greater extent by which dental biomaterials can be fabricated utilizing both the additive and subtractive methods. CAD/CAM manufactured PMMA based polymers have chemical properties similar to those of conventional PMMA, in addition they are dense, highly cross linked, more homogeneous, lack of subsurface voids and porosities attributed to the higher flexural strength associated with CAD/CAM milled PMMA³.

In addition to subtractive methods, Rapid prototyping 3-D printing is also an emerging technology. Additive manufacturing is defined by the American society for testing and materials as the process joining materials to make objects from three dimensional (3-D) model data usually layer upon layer opposed to subtractive manufacturing technologies. One of the attractive feature of additive manufacturing is that there is no wastage of material. Traditionally additive manufacturing was first introduced in 1980s to manufacture prototypes, models and casting patterns⁴. Typical methods for polymer include polymer diffused modelling (FDM), digital light processing (DLP) and stereolithography (SLA). In fused deposition modelling a liquefied filament is extend from the nozzle and the material is fused on a scaffold when the nozzle is moved¹.

The digital light processing (DLP) method involves the polymerization of the photosensitive liquid resin in which the laser is controlled by a light micromirror. Stereolithography (SLA) is the method in which the same liquid is polymerized by a single laser beam. The digital light processing (DLP) makes use of entire liquid resin at once making it faster than that of Stereolithography (SLA). The resolution of digital light processing and stereolithography is higher than that of fused deposition modelling (FDM). The present study is carried out using digital light processing (DLP) because of its accuracy and advantages¹.

The flexural strength of the interim prosthesis is the critical property, particularly in long term interim prosthesis with short height pontics and connectors and when the patient exhibits parafunctional habits such as bruxism and clenching. Flexural strength or modulus of rupture is defined as the force per unit area at the point of fracture when the test specimen is subjected to flexural loading. Higher flexural strength is essential to achieve clinical success with interim prosthesis².

Several studies^{4,5,6,7} had compared the flexural strength of conventional PMMA, CAD/CAM PMMA resin and Bis acryl composite resin material among all the provisional restorative materials. These studies concluded that CAD/CAM interim materials showed higher flexural strength and hence were considered stronger compared to other materials. Very few studies^{8,9,10} comparing CAD/CAM interim materials with 3-D printed rapid prototyping materials are available thus in the view of the above, the aim of the present in vitro study was to evaluate and compare the flexural strength of the CAD/CAM milled PMMA and rapid prototyping of 3-D printed resin for long term fixed restorations. The null hypothesis of the present study was that there would be no significant differences between the flexural strength of CAD/CAM milled PMMA resin and rapid prototyping 3-D printed resin.

2. Materials and Methods

Two stereolithographic files were virtually designed using MESHMIXER software to the required dimensions both of (25mm × 2mm × 2mm). A 10 mm thick CAD/CAM PMMA blank (Ruthinium disc, Ruthinium pvt. ltd Valsad) was used to mill ten samples using CAD/CAM milling machine. (ARUM 5X-200, Doowon, USA). Rapid prototyping 3-D printing resin (NEXTDENT C&B crown and bridge, USA, shade N2) was used to print ten samples in a rapid prototyping 3-D printed unit (NEXTDENT 5100 USA). The samples were subjected to post cure for 60 mins in (NEXTDENT Post curing unit).

The samples were subjected to finishing and polishing using acrylic trimmers and aluminium oxide abrasive papers (120,200,300,420 grits).The dimensions of all the twenty samples (n=20) were verified using vernier caliper.The samples were grouped into two groups Group I comprising of CAD/CAM milled test samples (n=10) and Group II consisting of Rapid prototyping 3-D printing resin test samples (n=10).

All the twenty samples were tested using 3-point bend test to evaluate the flexural strength in a universal testing machine (ASTM D 790 INSTRON 3369).The samples were mounted on the vertical support of the sample holding apparatus which had a support span of 20mm.After inserting each of the test samples,load was applied at the centre of each sample at a crosshead speed of 1 mm/min until the samples get fractured.Load deflection curve and the ultimate load to failure was recorded and displayed by the computer software of the universal testing machine.The maximum load at fracture was recorded in Newtons (N) and the flexural strength (σ) was calculated in megapascals (MPa)with flexural strength (FS) formula $\sigma = 3Fd/2wh^2$ where F (N) is the maximum load at fracture, d (mm) is the distance between vertical support spans, w (mm) is the measured width at the centre of the sample and h (mm) is the height at the centre of the sample.The results obtained were tabulated and statistically analysed using statistical software package SPSS version 20.Mean and standard deviation were estimated from the values obtained from the test samples for each study group.The data was analysed using student t-test at the significance level of 5%.

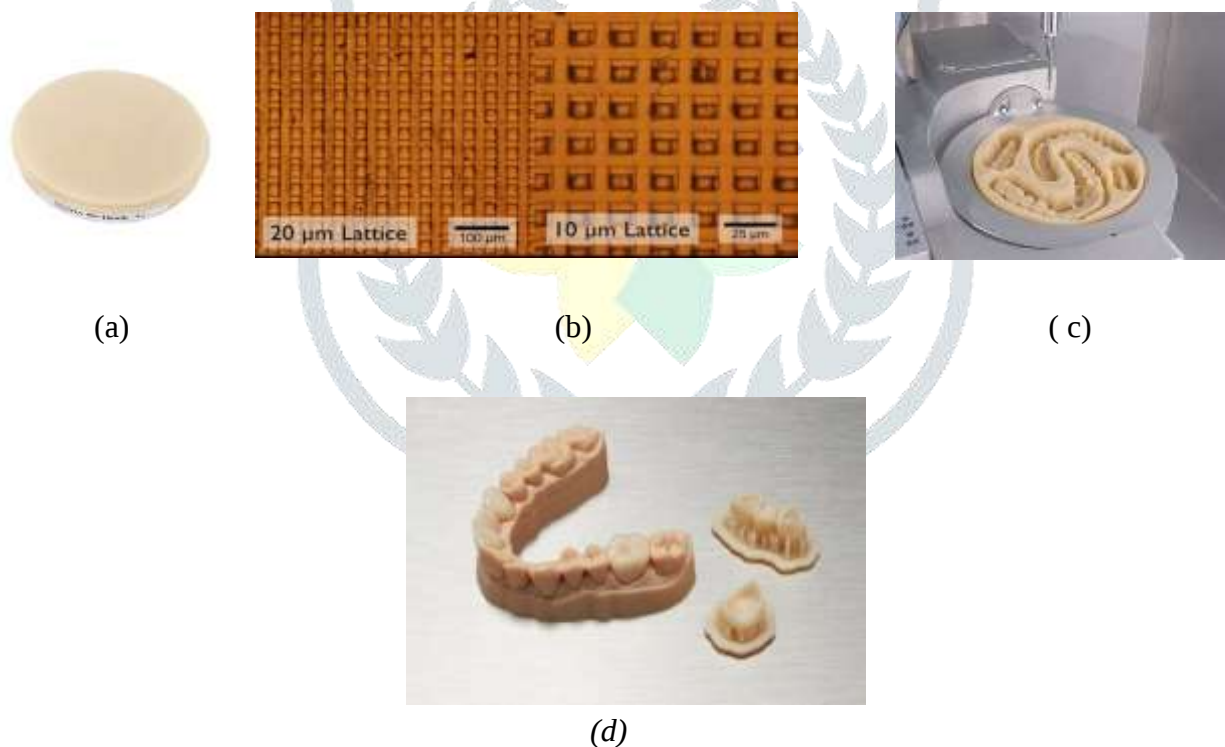


Fig.1. Steps of Stereolithography and Rapid Prototyping

3. Result

The flexural strength of the CAD/CAM milled PMMA resin samples and rapid prototype 3-D printed resin samples were measured using a universal testing machine at a crosshead speed of 1mm/min until fracture.The flexural strength values were obtained in Megapascals (MPa).The values obtained were tabulated and statistically analysed using student t-test.

Basic data for the evaluation of flexural strength of CAD/CAM milled PMMA resin samples are given in Table 1 and those of rapid prototype 3-D printed resin samples are presented in Table 2. The comparison of mean flexural strength of CAD/CAM milled PMMA resin samples and rapid prototype 3-D printed resin samples are given in Table 3.

The maximum flexural strength of CAD/CAM milled PMMA resin samples was found to be 112Mpa and the minimum flexural strength was found to be 75 Mpa. The maximum flexural strength of rapid prototype 3-D printed resin samples was found to be 75 Mpa and minimum flexural strength was found to be 37.5 Mpa. On comparative evaluation of mean flexural strength of CAD/CAM milled PMMA resin samples (group I) and rapid prototype 3-D printed resin samples (group II) using student t-test, the difference was found to be statistically highly significant ($p < 0.001^{**}$).



Fig.2. Universal Testing Machine

S.NO.	SAMPLE	FLEXURAL STRENGTH (Mpa)
1.	A	100
2.	B	95
3.	C	88
4.	D	75
5.	E	80
6.	F	82
7.	G	112
8.	H	90
9.	I	110
10.	J	80

Table . 1. Flexural Strength of Cad/Cam milled PMMA

S.NO.	SAMPLE	FLEXURAL STRENGTH (Mpa)
1.	A	60
2.	B	65

3.	C	70
4.	D	75
5.	E	65
6.	F	75
7.	G	50
8.	H	45
9.	I	40
10.	J	37.5

Table.2. Flexural Strength of Rapid Prototype 3-D Printing Resin

S.NO.	SAMPLE	GROUP 1	GROUP 2	MEAN FLEXURAL STRENGTH (Mpa)
1.	A	100	60	80
2.	B	95	65	80
3.	C	88	70	79
4.	D	75	75	75
5.	E	80	65	72.5
6.	F	82	75	78.5
7.	G	112	50	81
8.	H	90	45	67.5
9.	I	110	40	75
10.	J	80	37.5	58.75

Table.3. Mean Flexural Strength of Group 1 and Group 2

4. Discussion

The provisional restorations have become a routine and an essential component of fixed dental prosthesis involving rehabilitations of tooth supported and implant supported prosthesis until the definitive restorations are delivered. The duration between preparation of the abutment and cementation of the final restorations can vary from a few days to several weeks several months or complex cases when additionally therapy like orthodontic stabilization, extensive periodontal treatment and evaluation of change in vertical dimension is required. In such situation placement of provisional restoration becomes imperative to maintain occlusal stability, function and esthetics¹¹.

An optimum provisional restoration must be resistant to occlusal forces, stable during function, durable, chemically inert and esthetically pleasing. However the provisional restoration used for long-term use should be able to resist both functional and para functional forces permit the patient to allow proper oral hygiene maintenance¹². They are often prone to fracture which may lead to biological, functional and esthetic problems³, therefore selection of appropriate material for fabrication of long term fixed provisional restoration is considered to be critical in fixed dental prosthodontics. Materials used in the fabrication of provisional fixed dental prosthesis fall in two categories mainly based upon their chemical composition : a) Methyl methacrylate b) Composite resins. Flexural strength is an important criterion in determining the mechanical strength and rigidity of the material. Treatment scenarios involving long span edentulous cases, patients with parafunctional

habits such as bruxism and treatment plan requiring extended duration will all require provisional material with adequate flexural strength property.¹³

Conventional PMMA materials are mono-functional, low molecular weight, linear molecules that exhibit decreased strength and rigidity. Lang et al¹⁴ exhibited fracture resistance of interim fixed partial denture after storage for 14 days in distilled water and artificial aging and found low mechanical fracture behaviour and total failure of PMMA materials tested because of the deformation of the material during oral simulation. They also found that PMMA showed water absorption upto 32 $\mu\text{g}/\text{mm}$.

CAD/CAM milling PMMA blanks (subtractive method) has been used in the fabrication of fixed dental prosthesis for the past few years. CAD/CAM PMMA based polymers have chemical structure similar to that of conventional PMMA materials. However CAD/CAM PMMA based materials have improved mechanical properties as they are highly cross linked, more homogenous and have low water sorption and solubility.¹⁵ Additionally, CAD/CAM PMMA based polymers are stored in air until they are used which ensures the post polymerization process occurs accompanied with relaxation phenomenon. Rekow et al¹⁶ reviewed the CAD/CAM PMMA resin used in dentistry and proposed its use of provisionalisation. Manufacturing under industrial condition permits high density polymer based restoration which offers favourable mechanical behaviour and biocompatibility.

Rapid prototype 3-D printing (additive method) is the emerging technology for the same. It basically produces solid layers using a concentrated UV light beam that moves on a photosensitive liquid polymer resin placed on a platform. As the first layer polymerizes, the platform is lowered a few microns then the next layer is cured. This process is repeated until the whole solid object is completed. The object is then rinsed with a solvent and placed in a UV oven to thoroughly cure the resin. It has been used in the fabrication of maxillofacial prosthesis, complete dentures, crowns, bridges or coping resin patterns for the same and making dental cast models, surgical templates for guided surgery implants and fabrication of pattern for Cast Partial Dentures (CPD) and post and core. However, in spite of its versatile usage, there is a paucity of data on its role in the fabrication of long term provisional fixed dental prosthesis¹⁷.

In the view of the above discussion, the present in vitro study was focused to compare and evaluate the flexural strength of CAD/CAM milled PMMA resin Rapid prototype 3-D printed resin. Alph G et al¹⁵ compared the flexural strength of CAD/CAM based polymers and conventional interim materials using 3-point bend test and the results revealed that flexural strength of CAD/CAM based polymers was greater and the least flexural strength was exhibited by conventional PMMA resin. The material used for CAD/CAM milling in this study ruthenium disc is a cross linked polymer of PMMA resin. The cross linking consists of methacrylic acid ester based polymer. According to Edelhof et al¹⁸, these high density polymers based on highly cross linked resins are manufactured in an industrial process thus, exhibiting superior qualities. Alt et al¹⁹ who investigated the influence of fabrication methods, storage condition and use of different materials on the fracture strength of provisional 3-unit FDPs using CAD/CAM technologies and resin based blanks cured under optimal conditions. They concluded that CAD/CAM specimens exhibited increased mechanical strength and had less porosity within the restoration. Shruti digholkar et al⁴ compared flexural strength and microhardness of CAD/CAM PMMA specimens exhibited improved flexural strength than Rapid prototype 3-D printed resin group. The result obtained in the present study is comparable to the study done by Shruti digolkar et al⁴ where the mean flexural strength of CAD/CAM milled PMMA resin was (104.20 Mpa) and rapid prototype 3D printed resin was (79.54 Mpa). In the present study, the mean flexural strength was (86.25 Mpa) and Rapid prototype 3-D printed resin was (45 Mpa).

The mechanical property of Rapid prototype is influenced by the method of fabrication causing the shrinkage of the material during building and postcuring. In addition, data conversion and manipulation while formatting into an stereolithography (STL) format could also result in some changes²⁰. Therefore it can be postulated that rapid prototype resin group has lesser flexural strength than CAD/CAM resin group. The findings in the present study reveals that CAD/CAM milled PMMA resin group has lesser flexural strength than CAD/CAM resin group. Also it reveals that CAD/CAM milled PMMA resin exhibited the maximum flexural strength than Rapid prototype 3-D printed resin samples. Thus, the null hypothesis of this study is rejected because the present study reveals that there was statistically highly significant differences in the flexural strength of CAD/CAM milled PMMA polymers and rapid prototype 3-D printed resins.

5. Conclusion

The study revealed that flexural strength of CAD/CAM milled PMMA resins (group-I) were higher than that of rapid prototype 3-D printed resins (group – II) and hence CAD/CAM milled PMMA resin can be recommended in the fabrication of long term and long span provisional fixed dental prosthesis. Though, rapid prototype 3-D printed resin produced lesser flexural strength, it has the advantage of producing provisional prosthesis with good precision and fit, therefore rapid prototype 3-D printed resin maybe considered for short span fixed dental prosthesis.

6. References

1. Nejatidanesh, F., Momeni, G. and Savabi, O. (2009), Flexural Strength of Interim Resin. Materials for Fixed Prosthodontics. Journal of Prosthodontics, 18:507-511. <https://doi.org/10.1111/j.1532-849X.2009.00473.x>.
2. Haselton DR, Diaz-Arnold AM, Vargas MA. Flexural strength of provisional crown and fixed partial denture resins. The Journal of prosthetic dentistry. 2002 Feb 1;87(2):225-8.
3. Karaokutan I, Sayin G, Kara O. In vitro study of fracture strength of provisional crown materials. The journal of advanced prosthodontics. 2015 Feb 1;7(1):27-31.
4. Digholkar S, Madhav VN, Palaskar J. Evaluation of the flexural strength and microhardness of provisional crown and bridge materials fabricated by different methods. J Indian Prosthodont Soc. 2016 Oct-Dec;16(4):328-334. doi: 10.4103/0972-4052.191288. PMID: 27746595; PMCID: PMC5062140.
5. Yao J, Li J, Wang Y, Huang H. Comparison of the flexural strength and marginal accuracy of traditional and CAD/CAM interim materials before and after thermal cycling. The Journal of prosthetic dentistry. 2014 Sep 1;112(3):649-57.
6. Chitchumnong P, Brooks SC, Stafford GD. Comparison of three- and four- point flexural strength testing of denture-base polymers. Dent Mater 1989;5:25.
7. Koumjian JH, Nimmo A. Evaluation of fracture resistance of resins used for provisional restorations. The Journal of prosthetic dentistry. 1990 Dec 1;64(6):654-7.
8. Kaiser DA, Cavazos E. Temporisation techniques in fixed prosthodontics. Dent Clin North Am 1985;29:403-12.
9. Gegauff AG, Pryor HG. Fracture toughness of provisional resin for fixed prosthodontics. J Prosthet Dent 1987;58:23-9.
10. Dennis YB, Mullick SC, Johansen RE. Provisional fixed partial denture using the new visible light curing resin system. Clin Prev Dent 1988;10:10-3.
11. Gratton DG, Aquilino SA. Interim restorations. Dental Clinics of North America. 2004 Apr;48(2):vii-487.
12. Abduo J, Lyons K, Bennamoun M. Trends in computer- aided manufacturing in prosthodontics: A review of the available streams. Int J Dent 2014;2014:783948.

13. **Abdullah AO, Tsitrou EA, Pollington S.** Comparative in vitro evaluation of CAD/CAM vs conventional provisional crowns. *Journal of Applied Oral Science*. 2016 Jun;24(3):258-63.
14. **Lang R, Rosentritt M, Handel G.** Fracture resistance of PMMA and resin matrix composite based interim FPD materials. *Int J Prosthodont* 2003;16:381-4.
15. **Alp G, Murat S, Yilmaz B.** Comparison of Flexural Strength of Different CAD/CAM PMMA-Based Polymers. *Journal of Prosthodontics*. 2019 Feb;28(2):e491-5.
16. **Rekow ED.** Dental CAD/CAM systems: A 20- year success story. *J Am Dent Assoc* 2006;137:5S-6S.
17. **Haverman TM, Karagozoglu KH, Prins HJ, Schulten EA, Forouzanfar T.** Rapid prototyping: een veel belovende methode [Rapid prototyping: a very promising method]. *Ned Tijdschr Tandheelkd*. 2013 Mar;120(3):136-41. Dutch. doi: 10.5177/ntvt.2013.03.12213. PMID: 23600178.
18. **Güth JF, Almeida E Silva JS, Beuer FF, Edelhoff D.** Enhancing the predictability of complex rehabilitation with a removable CAD/CAM fabricated longterm provisional prosthesis: A clinical report. *J Prosthet Dent* 2012;107:1- 6.
19. **Alt V, Hannig M, Wöstmann B, Balkenhol M.** Fracture strength of temporary fixed partial dentures: CAD/CAM versus directly fabricated restorations. *Dental materials*. 2011 Apr 1;27(4):339-4.
20. **Jiao T, Zhu C, Dong X, Gu X.** Rehabilitation of maxillectomy defects with obturator prostheses fabricated using computer- aided design and rapid prototyping: A pilot study. *Int J Prosthodont* 2014;27:480- 6.



Licensed under [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/)