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Comparative Assessment of Polymerization Techniques on the Fit Accuracy of Acrylic Resins Fabricated by CAD-CAM Milling, 3D Printing, and Microwave Processing

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Abstract

Aims: Poly-methyl-methacrylate resin has been used commonly for denture bases. Polymerization shrinkage and release of thermal stresses are the major disadvantages exhibited of these materials Till date, no research is there in literature comparing the adaptation accuracy microwave acrylic resin cured by microwave energy and resin cured by CAD-CAM milling and 3D Printed technique The present study was conducted to check the effect of curing mode on the adaptation accuracy of CAD-CAM Milled, 3D Printed and microwave processed acrylic resin.

Materials and Method: A master cast was duplicated to obtain 36 gypsum casts. In the computer-aided design and computer-aided manufacturing (CAD/CAM) groups (milling and 3-D printing), the 24 gypsum casts from two groups were scanned. An STL file was obtained and a master complete denture base was designed and then fabricated according to each technique . In the conventional group, a polyvinyl siloxane putty Mold was obtained from the milled complete denture base, and this Mold was used to fabricate 12 microwave processed acrylic resin by microwave energy The base/cast sets were sectioned transversally in the posterior palatal seal zone. The measurements were made at the right marginal limit, left marginal limit, right ridge crest, left ridge crest and the palatal midline. The existence of gaps between the casts and acrylic was assessed using a stereomicroscope.

Results: The mean marginal discrepancy at Right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline was significantly more in microwave resin samples cured by microwave energy (500 W for 3 min) in comparison to resin samples cured by CAD- CAM 3D Printed Technique. The mean marginal discrepancy at, right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline was significantly more in microwave resin samples cured by microwave energy (500 W for 3 min) in comparison to resin samples cured by CAD–CAM milling Technique.

There was no significant difference at, right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline of dimensional discrepancy between resin samples cured by either CAD-CAM milling or 3D Printed technique.

Conclusion: It is evident that resin denture base produced by CAD-CAM milling or 3D Printed technique produced the minimal adaptation discrepancy.

Clinical Significance: CAD-CAM milling or 3D Printing technique can be adopted for fabrication of the complete denture bases.

Introduction

Denture bases for conventional or implant supported prosthesis usually are made of methacrylate-based polymers activated by thermal energy delivered by different methods e.g. immersion in hot water bath, microwave irradiation and injection molding techniques. [1]**Takahata Sestos JC reported** Poly-methyl-methacrylate have optimal physical properties and excellent esthetics with relatively low toxicity compared to other plastic denture base materials. [2] Despite its popularity its far from ideal ,polymerization shrinkage and release of thermal stresses are major disadvantage of this material[3].The combination of polymerization shrinkage and distortion due to the thermal stresses affects the adaptation accuracy of denture bases to underlying tissue and creating a micro gap[4,5]. The problems associated with the compression molding technique increase the gap between the denture base and the underlying mucosa ,compromising the fit of dentures. [6]Therefore acrylic resin and processing methods have been modified to improve physical and chemical properties of denture bases. The microwave disinfection at 690 W for 6 min promoted significant increase of baseplate distortion in a denture resin polymerized by microwave energy but not when same resin was polymerized by conventional water bath[7]. With advances in digital technologies, the CAD/CAM has emerged as a popular option for the design and fabrication of complete dentures. [8]The surface adaptation of CAD-CAM dentures were investigated, the digital light processing (DLP)-printed denture base has been reported to achieve clinically acceptable accuracy of tissue surface adaptation within 100 μm when compared to the milled denture base. [9,10] Jin et al[11]. evaluated the effect of build angle on the tissue surface adaptation of DLP-printed complete denture bases (CDBs) and found no statistical difference of the overall tissue surface adaptation among the different groups The results of various studies have been mixed and conflicting. Till date, no research is there in literature comparing the adaptation accuracy of microwave acrylic resin cured by microwave energy and resin cured by CAD-CAM milling and 3D Printed technique .

Therefore present study was conducted to check the effect of curing mode on the adaptation accuracy of microwave

processed acrylic resin and and denture base resin cured by CAD-CAM milling and 3D Printed technique. The null hypothesis was that no differences in adaptation accuracy would be found among the three different techniques with regard to accuracy and reproducibility.

Aims and Objectives

1. To check adaptation accuracy in microwave acrylic resin cured by microwave energy.
2. To check adaptation accuracy in acrylic resin cured by CAD–CAM 3D Printed technique.
3. To check adaptation accuracy in acrylic resin cured by CAD–CAM milling technique.
4. To comparatively evaluate adaptation accuracy of microwave acrylic resin cured by microwave energy, acrylic resin cured by CAD-CAM milling and 3D Printing technique.

Material and Method :

Fabrication of the Master Cast

An edentulous maxillary master cast was obtained by duplicating a typodont ideal maxillary arch following ideal residual ridge morphology classified as type I by the American College of Prosthodontists. The residual ridge had a class I morphology with absence of undercuts. The master cast was duplicated with polyvinyl siloxane material. [8,12]Thirty Six stone casts were obtained in our study Twelve casts (n = 12) were subjected to each group. In the milling and 3-D printing groups **(Figure 1),** the stone casts were labeled and scanned after 24 hours using a 3-shape laboratory scanner (Ivoclar) generating an STL file. [8]A master denture base was designed (Exocad) and fabricated according to each of the two techniques. For the conventional group, the denture bases were fabricated directly over the master cast using the microwave curing technique without the need for any cast scanning.

36 maxillary acrylic bases (2mm thick) were made on cast model. Acron MC microwaveable resin, pre-polymerized blocks of polymethyl methacrylate (PMMA) Ivoclar and 3D Printed polymer resin (ARMA RESIN) (**FIGURE 2)** was used for present study**.** The specimens were divided into 3 groups**.** In Each group sample size was 12 .

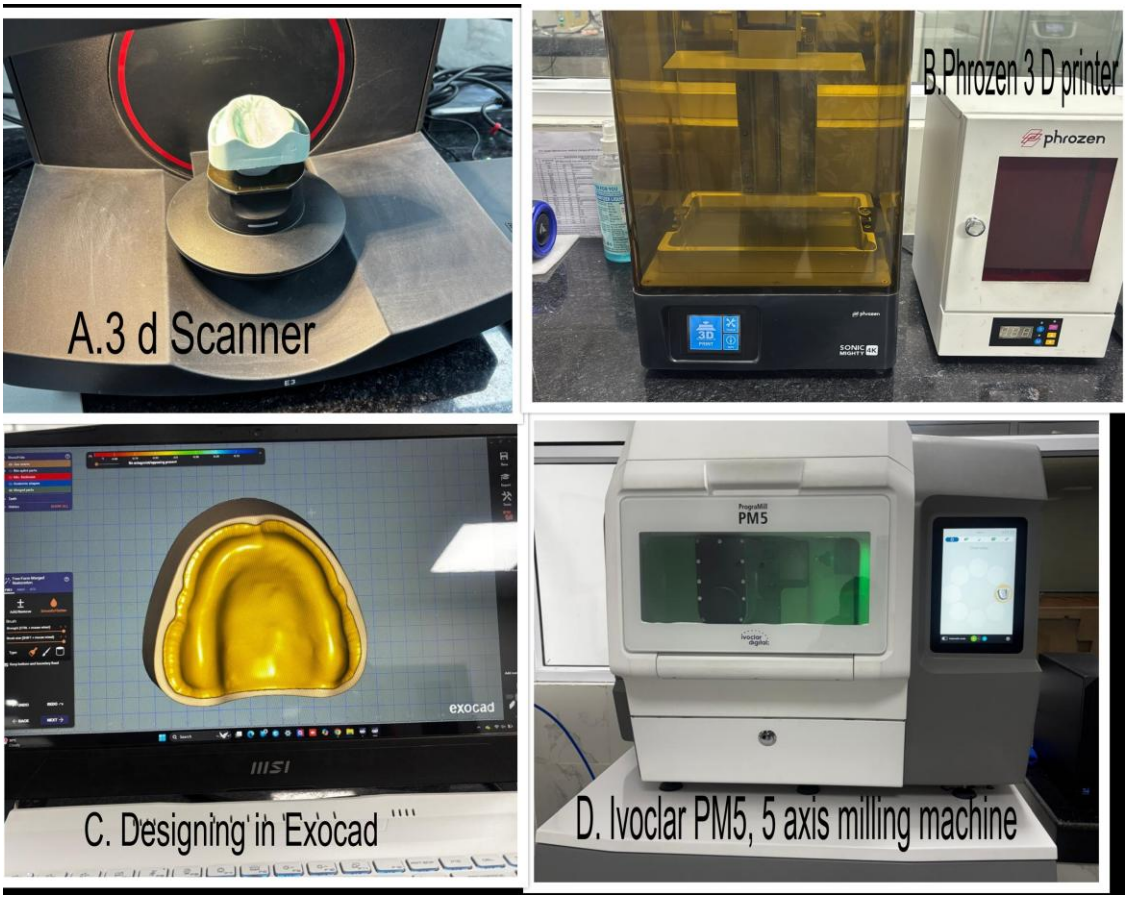

Figure 1: A. 3D Scanner, B. Phrozen 3D Printer, C. Designing in Exocad,

D. Ivoclae PM5, 5 axis milling machine

Figure 2: A. PMMA, B. ArmaResin

Group 1: Microwave resin samples cured by microwave energy(500W for 3 min).

Group 2: Acrylic resin samples cured by CAD -CAM Milling technique.

Group 3: Acrylic resin samples cured by CAD -CAM 3D Printing technique.

Curing procedure for Group 1: Microwave acrylic resin Acron MC samples cured by microwave energy (Figure 3)

The resin was mixed, and investing done in special flask. Curing was done in domestic microwave with time power of 500 W for 3 min[13]

A total of 12 test specimens were prepared using this curing technique.

Curing procedure for Group2: pre-polymerized blocks of polymethyl methacrylate (PMMA) Ivoclar cured by CAD- CAM milling technique (Figure 3)

Each specimen was fabricated from the scan file of each of the 12 casts in the group. The denture base was fabricated with a five-axis milling machine (Ivoclar PM 5) and PMMA blocks (Ivoclar). The milled denture bases were ultrasonically cleaned in alcohol for 10 minutes. [8]

A total of 12 test specimens were prepared using this curing technique.

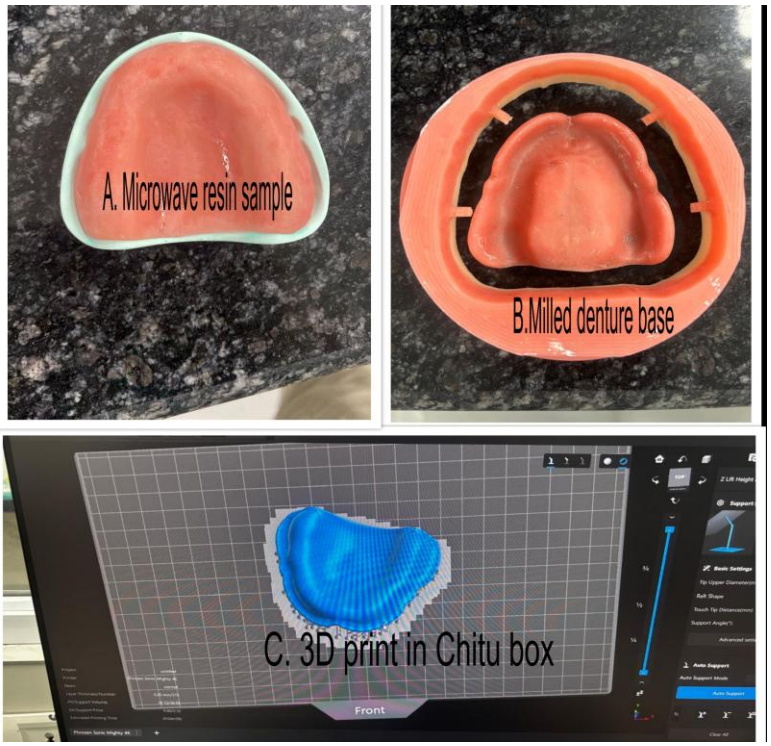

Figure 3: A. Microwave Resin Sample, B. Milled Denture Base, C. 3D print in Chitu box

Curing procedure for Group 3: Resin samples cured by 3 D Printing technique (Figure 3)

Each specimen was fabricated from the scan file of each of the 12 casts in the group. The same design of the master CDB was used to fabricate 12 specimens using Phrozen 3D - printer with 3 d printing polymer resin (Arma resin) 17 After printing, the denture bases were ultrasonically cleaned in alcohol for 10 minutes.

A total of 12 test specimens were prepared using this curing technique.

Thus, each group consists of 12 test samples and total of 36 samples from 3 study groups.

Measurement of adaptation accuracy in Test specimens

The base/cast sets were sectioned transversally in the posterior palatal seal zone. The measurements were made at the right marginal limit(A), left marginal limit (B), right ridge crest (C), left ridge crest (D) and the palatal midline (E**). (Figure 4**) The existence of gaps between the casts and acrylic was assessed using a stereomicroscope. **(Figure 5)**

Figure 4: Right Marginal Limit(A), Left Marginal Limit (B), Right Ridge Crest (C), Left Ridge Crest (D) and The Palatal Midline (E)

Figure 5: Stereomicroscope

Statistical Analysis:

The statistical analysis was done using Kruskal-Wallis test and Mann-Whitney U test

Level of Significance (p-value)

- **P-value < 0.05 - Significant**

RESULTS

Table I: The comparison of the mean marginal discrepancy was compared between the groups 1,2 and 3 at Right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline using the Kruskal-Wallis test.

The post-hoc inter-group comparison was done between the groups 1, 2 and 3 at Right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline using the Mann-Whitney U test. At all the margins, the mean marginal discrepancy was significantly more among group 1 in comparison to groups 2 and 3. Whereas, there was no significant difference was found between groups 2 and 3.

TABLE I: Comparative mean marginal discrepancy between all groups at the right marginal limit, left marginal limit, right ridge crest, left ridge crest and the palatal midline

	Right marginal limit	Left marginal limit	Right Ridge crest	Left Ridge crest	Palatal midline
Group 1	2.600±1.598	2.700±1.625	0.800±0.329	1.010±0.899	2.012±1.892
Group 2	1.020±0.674	1.400±0.912	0.040±0.023	0.004±0.008	0.421±0.335
Group 3	0.900±0.489	1.100±0.608	0.030±0.019	0.002±0.012	0.320±0.299
p-value [a]	< 0.001*	0.009*	< 0.001*	0.001*	0.003*
Group 1 vs 2[b]	0.006*	0.041*	< 0.001*	0.002*	0.010*
Group 1vs 3[b]	0.003*	0.010*	< 0.001*	0.001*	0.006*

Group 2 vs 3[b]	0.964[#]	0.825[#]	0.995[#]	0.823[#]	0.978[#]

P value <0.05 is considered to be significant

*** Significant difference**

[#] Non-significant difference

[a] Kruskal-Wallis test

[b] Mann-Whitney

DISCUSSION

Poly-methyl-methacrylate has been most commonly material used since decades. It has excellent aesthetic properties, strength ,low water sorption ,low solubility ,lack of toxicity and is one of the material of choice [14,15] **Anthony, DH,FA Peyton**[16] reported that the accurate fit of denture base is a principal criterion in the physical mechanism of complete denture retention. The polymerization shrinkage and distortion due to the thermal stresses affects the adaptation accuracy of denture base to underlying tissue ,and thereby creating a micro gap. **Jafar Gharechahi, Nafiseh Asadzadeh, Foad Shahabian, Maryam Gharechan** [17] stated that the acrylic specimen produced by injection moulded technique exhibited less dimensional changes compared to those produced with conventional water bath technique. The curing shrinkage was compensated by water storage time decreasing dimensional changes. **Webb et al** [13] stated that microwaving dentures at 350 W during 6 min may be more effective method of sterilization than soaking denture in 0.02 % sodium hypochlorite .**Burns et al**[18] reported that specimens made from three different denture base material had excellent stability after 15 min at 650 W of microwave radiation . Emera RMK ,Shady M,Alnajih MA[19] did a clinical study to compare the retention and denture base adaptation of 3D-printed complete dentures fabricated using Di methacrylate-based resins with a photo initiator versus conventional complete dentures. They reported 3D-printed complete dentures fabricated using Di methacrylate-based resins could be a promising alternative to conventionally fabricated complete dentures with satisfactory denture base adaptation and retention. Goodacre et al[20] evaluated the precision and duplicability of milled dentures compared to the traditionally fabricated ones. The milled dentures

outperformed the traditionally constructed ones. Hwang et al[21] compared the trueness and adaptability of conventional, milled, and printed denture bases and found that the printed bases performed better. The studies checking the adaptation of 3-D printed, milled, and microwave are very less in the literature , therefore present study was conducted to check the effect of curing mode on the adaptation accuracy of microwave processed acrylic resin and and denture base resin cured by CAD-CAM milling and 3D Printed technique.

A new technique with computer-aided design and computer-aided manufacturing (CAD-CAM), using pre-polymerized blocks of polymethyl methacrylate (PMMA), 3D printing resin material, Exocad computer software, and 5-axis milling was utilized for fabrication of test specimens in our study.

The mean marginal discrepancy at , Right marginal limit, Left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline was significantly more in microwave resin samples cured by microwave energy(500 W for 3 min) in comparison to resin samples cured by CAD- CAM 3D Printed Technique. (Table 1)

The probable reason may be that the dimensional stability may be influenced by combined effect of type of resin/polymerized technique and microwave irradiation setting.

The mean marginal discrepancy at, right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline was significantly more in microwave resin samples cured by microwave energy (500W for 3 min) in comparison to resin samples cured by CAD–CAM milling Technique. (Table 1)

The probable reason may be that CAD/CAM denture bases are denture bases manufactured using computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies. This digital workflow allows for highly accurate and reproducible denture fabrication, often with faster turnaround times compared to Microwave curing method

There was no significant difference at, right marginal limit, left marginal limit, Right Ridge crest, Left Ridge crest and Palatal midline of dimensional discrepancy between resin samples cured by either CAD-CAM milling or 3D Printed techniques. (Table 1)

The results of this study indicate that the newest processing technique, CAD-CAM, offers a desirable balance of minimal fabrication distortion and consistently better adaptation. It is evident that resin produced

by CAD-CAM or microwave acrylic resin samples cured by microwave energy produced the minimal adaptation discrepancy so either of the method can be followed for fabrication of the denture base

CONCLUSION

1. The greatest discrepancy were seen microwave resin samples cured by microwave energy (500W for 3 min).
2. The lowest dimensional discrepancy was seen with resin samples cured by CAD-CAM milling technique.
3. There was no significant difference of dimensional discrepancy between resin samples cured by either CAD-CAM milling or 3D Printed technique.
4. It is evident that resin produced by CAD-CAM or microwave acrylic resin samples cured by microwave energy produced the minimal adaptation discrepancy so either of the methods can be followed for fabrication of the denture base

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