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IN-VITRO RETENTION OF HIGH -ARCHED MAXILLARY DENTURES CONSTRUCTED FROM CONVENTIONAL, THERMOFORMED, AND MILLED CAD/CAM RESINS

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ABSTRACT

Purpose: this study was to evaluate the retention of high-arched maxillary dentures constructed from conventional, thermoformed, and milled CAD/CAM resins.

Materials and Methods: An edentulous patient with a high-arched palate was selected from the outpatient clinic, Department of Prosthetic Dentistry, Faculty of Dentistry, Minia University. The patient was seeking complete denture treatment. Using the master cast in this case, thirty stone casts were duplicated, numbered, and randomly allocated to one of three study groups of 10 casts each. Thirty denture bases were constructed from the following materials to be as identical as possible: 10 of each of the following materials: conventional heat-cured resin, thermoformed resin, and milling resin by CAD/CAM. The retention of the produced denture bases was tested using a universal testing machine.

Results: The thermoformed group displayed the highest numeric retention mean (5.576 N), followed by CAD/CAM (4.888 N) and the conventional method (3.232 N). There were statistically significant differences between all groups.

Conclusions: Within the limitations of this in vitro study, it may be concluded that the thermoformed resin may be the most suitable material for high-arched palates, followed by CAD-CAM materials. The conventional technique in this case is less recommended.

KEY WORDS: Retention, Denture Base, Conventional, Thermoformed, Milled CAD/CAM Resins.

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INTRODUCTION

Conventional full denture therapy continues to be the most common option for edentulous individuals, despite the wide range of treatment options available. Nevertheless, problems may arise after the insertion of complete dentures. Such problems are often complaints of insufficient retention, inadequate stability, tissue irritation, ulceration, and faulty esthetics. [1]

Retention is regarded as one of the major factors that govern the success of a complete denture, which is also enhanced by denture base accuracy and tissue adaptation. [2]

Retention issues with maxillary full dentures are partly caused by a high (or v-shaped) palate. A v-shaped or high palate is more resistant to lateral changes. However, the seal is frequently broken all at once by vertical motion. So. Comparing several processing methods to get the best retention was the aim of this study. [1]

One of the most commonly used materials in complete dentures is polymethyl methacrylate (PMMA) [3]. Besides the great benefits such material offers, there are some downsides that restrict its use, such as high polymerization shrinkage, dimensional instability, and complicated processing procedures. Such downsides in turn affect denture retention, mastication, and speaking ability [4, 5]. Thus, needs were raised for novel techniques to overcome complete denture downsides.

The thermoformed complete denture has a predominant feel, no metallic taste, and is non-unfavorably susceptible. Free movement is allowed by the overall flexibility and can, therefore, be referred to as "a built-in stress breaker." On the other hand, flexible denture materials are more expensive than traditional ones. (4)

Faty et al (2022) , and Helal et al. (2023) suggested that CAD-CAM milling of complete dentures may be a preferred method of manufacturing complete dentures. They added that the retention provided by milled pre-polymerized computer-engineered complete denture (CECD) bases with polymethyl methacrylate can be greater than that of traditional heat-polymerized denture bases. [3]

The maximal adherence of flexible acrylic resin to the underlying mucosa may be the reason for the thermoformed full denture's greater retention [4] as compared to the standard heat-cured acrylic resin. The current study compared the retention force of thermoformed, milled complete denture bases versus a conventionally manufactured control, which was tested using a universal testing machine. The null hypothesis was that the retention force of denture bases would not be affected by the fabrication method.

MATERIALS AND METHODS

An edentulous patient with a V-shaped high-arched palate and a class III soft palate was selected from the outpatient clinic, Department of Prosthetic Dentistry, Faculty of Dentistry, Minia University. The patient was seeking complete denture treatment. The study design was approved by the ethical committee at the Faculty of Dentistry, Minia University.

Using the master cast of this patient, an acrylic replica of the master cast was constructed. This was carried out by obtaining a silicone mold (Elite Double 8, Zhermack Group, Polesine (RO), Italy) that was filled with molten modeling wax (Cavex, Haarlem, Netherlands). The wax model was retrieved after cooling the wax and invested by dental stone in a flask that was subjected to wax elimination, packing with acrylic resin dough, and heat polymerization using the long curing cycle. The obtained cast was finished and polished to be used for duplication of the samples and for measuring retention later on. Using this acrylic resin model, thirty stone casts were duplicated, numbered, and randomly allocated to one of three study groups—10 casts each. A

total of 30 specimens were randomly divided into conventional heat polymerized poly methyl metha acrylate (PMMA) group I (10), computer-aided designing/computer-aided manufacturing (CAD/CAM) milled group II (10), and thermoformed group III (10).

Sample size and fabrication of the master cast

For sample size determination, it was determined that nine samples (increased to ten samples to compensate for damaged samples) in each group would be adequate to detect a large effect size (d = 1.624), achieving an actual power (1-β error) of 0.95 (95%) and a significance level (α error) of 0.05 (5%) for a two-sided hypothesis test. (5)

Primary impressions were made using alginate impression material in suitable and adjusted maxillary and mandibular stock trays. Over the obtained primary cast, special trays were constructed from chemically activated acrylic resin. The borders of the trays were trimmed 2-3 mm shorter than the full depth of the vestibule. Special trays were examined extra orally, disinfected with 2.5% glutaraldehyde for fifteen minutes, and rinsed under running tap water.

Making border molding with putty. Border tracing was done using putty consistency addition silicone impression material and the final wash impression was made using medium consistency. (Elite Hd+, Zhermack Group, Polesine (RO), Italy) .The maxillary impression was boxed and then poured in type IV dental stone to obtain a master cast (Zhermack elite rock type 4 x-hard stone, Zhermack Group, Polesine (RO), and Italy).

Duplication of the master cast:

After obtaining the master cast, the acrylic model was obtained as previously mentioned to be Replicated into 30 stone models. Three molds of the acrylic model were created by using Duplicating silicone material (Fig. 1) (Elite Double 8, Zhermack Group, Polesine (RO), Italy).

This was done according to a previous study to avoid the deformity of any of the molds (6).

The three molds of the master cast were poured into type IV dental stone 10 times each to produce 30 stone casts, which will be used to construct the denture bases.

The casts were poured in a stone mix according to manufacturer instructions, including water ratio and temperature, to reduce dimensional changes between successive sets. The 30 duplicated masters Casts were numbered and randomly allocated to one of the three study groups. (7)

Fig. (1) Mold of master

Grouping:

Three groups were divided and defined according to the material of the denture base fabricated and fabrication techniques into:

Group I conventional technique of denture construction (PMMA) = 10 denture bases.

Group II thermoformed technique = 10 denture bases.

Group III milling CAD/CAM technique = 10 denture bases.

The geometrical center of the maxillary arch:

This step was done before the beginning of the scanning and designing processes. The midline of

the maxillary cast was drawn from the center of the incisive papilla and extended posteriorly till it met the midpoint on a line connecting the two hamular notches. A midpoint was marked on this midline to represent the center of the arch.[8, 2].

Simulation of the mucosa covering the residual ridges

For standardization, a series of holes, 2mm in depth, were created in the residual ridge of the model by a 5-round bur in one side of the model. The acrylic resin between the holes was removed using a cylindrical carbide cutter bur. After modification of the ridge at one side, it was replaced by a self-cured soft liner mixed according to the manufacturer's instructions (Acrostone Relining Material, Acrostone, 10th of Ramadan City, Egypt).

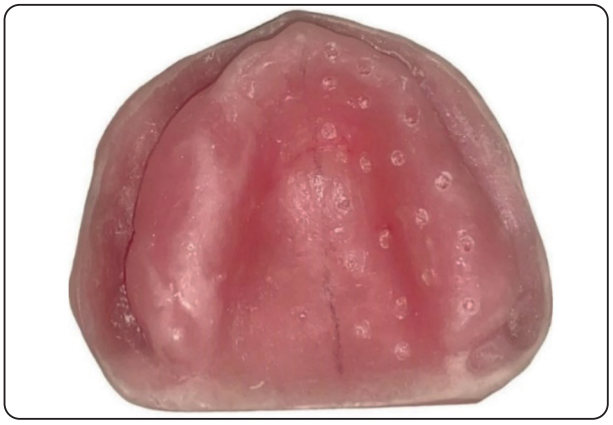

Fig.. (2) Removed Acrylic between Holes

Fig. (3) Cast after modification by soft liner

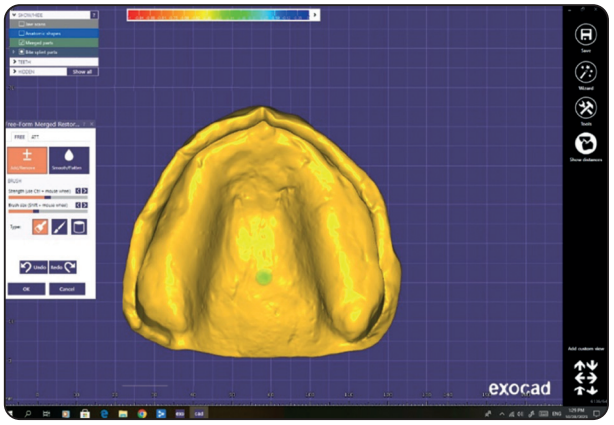

Fig. (4) Scanning of master cast

The model was then repositioned in the rubber mold, and pressure was applied to obtain the proper thickness in comparison to the other side. The other side was simulated similarly to the previous steps.[6]

Construction of denture base milling technique (cad/cam):

Scanning Step:

The master casts of the CAD-CAM group (10 stone casts) were ready for scanning. Each cast was secured to the scan holder using a special tightening key and placed inside the scanner (Ceramill MAP 200+, company, city, Germany), and the cast was scanned to obtain a digital model (Fig. 6) that was exported to the Exocad software.

Designing procedures:

Exocad Software:

Using the Exocad software, a STL file of the denture base with its supporting arms was loaded and adapted over the digital model and then sent to the milling machine. A hole was creed at the geometric center of the denture base, guided by that of the cast. This STL file was milled in pink disc resin to fabricate the milled denture bases.

Denture base manufacturing:

The denture bases were produced by the command software of the milling machine for the denture bases manufactured on PMMA discs (Ivoclar Vivadent Pink Zoomjy-047, Ivoclar, Germany), leading to a highly adapted denture base.

Construction of the heat-cured acrylic dentures

An extra CAD CAM denture base was manufactured to be used as a template for the heat-cured and thermoformed resin groups to ensure similar dimensions between groups. The CAD-CAM base was sealed with one of the stone casts of the heat cure group and flasked with dental stone. After setting the stone, the flask was opened, the denture base was retrieved, and a tin foil substitute was used to paint all stone surfaces inside the flasks to prevent resin from adhering to thestone.

Before packing the acrylic resin, the stone surface of the upper member of the flask was examined to make sure that there was an indentation opposite the geometric center hole. The production of the heat-cured denture bases was carried out in a standardized process following the manufacturer's instructions and the long curing processing technique described in the literature [9]. The procedure was repeated for each cast of the 10 samples. [8]

Construction of thermoformed dentures:

The same steps carried out for the heat cure group were followed for this group except for the flask type, dental stone, denture base material, and thermoforming injection device. A special flask was used (special flasks were used for flasking, dewaxing, and injecting moulted Valplast or Flexite denture material) as per the directions of the manufacturer (10), with extra hard dental stone (Zhermack Elite Rock type 4 x-hard stone, Zhermack Group, Polesine (RO), Italy) for investing to withstand the double injection procedure of the thermoformed resin. Complete investing of the waxed-up denture was carried out as usual, then left for complete setup of the stone material. The microinjection machine (Thermopress 400 version 2.4/2.56, Bredent, Germany) was programmed and adjusted at 230°C heating temperature, 13 minutes heating time, 90 seconds injection time, and 7 bar injection pressure.[11] A 30 gm piece of thermoformed denture base material. (TCS IFlex, company. City, USA) was mounted on the micro-injection machine and injected into the flask according to the manufacturer's instructions. The denture was finished on its cast with finishing burs and stones.

Ready-made metal palatal rings were fixed to the geographic centers of the obtained denture bases by self-cure acrylic resin. After making a hole 1mm in depth, they were created in the geographic centers by a number 5 round bur in the denture base.

Measurement of retention:

Retention was measured by a Materials Testing Machine (MODEL 3345; Instron Industrial Products, Norwood, USA) with a load cell of 5 KN. Data were recorded using computer software (Bluehill Lite; Instron Instruments).

The upper plate of the machine included a specially designed retention measuring metal hook, from which the denture was engaged to the hook with the palatal ring that was fixed to the base. While the lower compartment was attached to the acrylic base via cyanoacrylate glue. Each sample was painted with artificial saliva before being seated over the acrylic cast. The sample was subjected to a slowly increasing vertical pull-out load (1 mm/min) until total dislodgment of the denture base. The load was also accompanied by a decline in the load-displacement curve recorded by specific software.

All these measurements were carried out within 2 weeks of simulated model [12]. The obtained data for all the testing conditions regarding the force at which retention was lost; were collected, arrayed, and tested statistically by Tukey`s post hoc test.

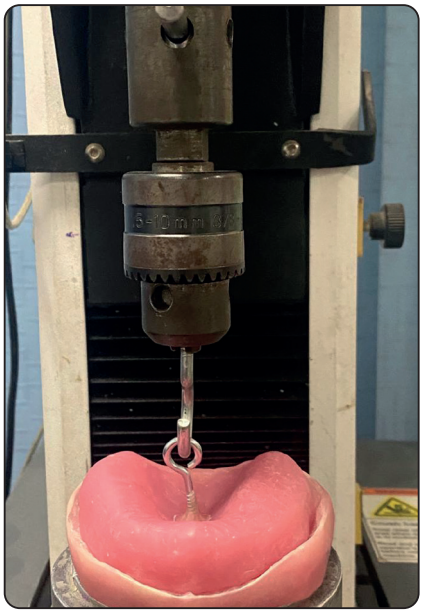

Fig (5) Metal hock engaged on denture base

RESULTS

Data were coded and entered by Microsoft Excel® 2016 [1], Statistical Package for Social Science (SPSS)® Ver. 24 [2], and Minitab® statistical software Ver. 16. The data was analyzed and summarized by using the mean and standard deviation. For comparison of serial measurements within each patient, repeated measures are used (ANOVA. Post-hoc test: Tukey's test was used for multiple comparisons between different variables. The significance level was set at $p \leq 0.05$ within all tests.

The values of retention for each group and the comparison between the three groups (as shown in Table 1): It was found that the mean value of retention of conventional heat-cured dentures in group 1 was 3.232 N, followed by the mean value of retention of thermoformed dentures in group 2 (5.576 N), and the mean value of retention of CAD/CAM milled dentures in group 3 was 4.888 N. A significant difference between the three groups was noticed ($P \leq 0.05$). When comparing the three tested groups, it was found that the mean value of retention in group 2 is higher than that of groups 1 and 3. On the other hand, the mean value of retention in Group 1 is the lowest compared to the other groups. A significant difference was found between groups 1 and 2 with a p value of 0.0003, while a significant difference was found between groups 1 and 3 with a p value of 0.0120.

This table represents the results of ANOVA comparisons between three maxillary denture fabrication techniques - conventional heat-cured, Thermoformed, and CAD/CAM milling.

TABLE (1) Retention force values in Newton and Comparative Statistics of different maxillary denture bases using One Way ANOVA:

	Group I (Conventional heat-cured)	Group II (Thermoformed)	Group III (CAD/CAM Milled)	P-value
Min	1.074	3.839	3.224	
Max	6.211	10.73	8.042	
M	3.232	5.576	4.888	0.0053*
SD	1.407	1.717	1.370	

Min; Minimum, Max; Maximum, M; Mean, SD; Standard Deviation, P; Probability Level *; Significant Different

DISCUSSION

The current study was conducted to assess denture retention for three types of complete dentures: milled CAD/CAM, conventional, and thermoformed types. Thermoformed denture base material showed the greatest retention, followed by CAD-CAM-milled denture base material and conventional denture base. The null hypothesis is rejected.

We focused on the measurement of retention in this study, as retention significantly impacts prosthesis success evaluation; it also affects masticatory performance, speaking ability, and patient quality of life. [13]

Patients with firm, healthy mucoperiosteum and well-developed ridges were chosen, with no sign of inflammation or flabby tissues covering the edentulous ridge, to avoid denture base movement over the rebound tissues, which could affect denture base stability and thus give false records while measuring the retentive quality of the denture. [14]

High arched contribute to the problem of retention of the maxillary complete denture. A high (or v-shaped) palate resists lateral shifts well. But vertical displacement tends to break the seal in all areas at once. Gagging is more common, and processing shrinkage is greater. [1]

The conventionally fabricated complete denture was selected as the comparator for this study because, according to Altaie et al. (2023), it has been the gold standard for treating edentulous patients for many years in terms of restoring speech, masticatory function, and aesthetics. [15]

In this study, the long curing cycle for processing heat-activated acrylic denture bases was used, and it was recommended by AlHelal et al. (2016) to use a lower processing temperature to avoid the sharp rise in temperature inside the acrylic resin. [8]

Recently, CAD/CAM denture fabrication has been introduced. This method can reduce human variables and processing errors and, therefore, facilitate the production of more reliable prostheses with an improvement in their retention [16].

Exocade software is one of the most popular CAD software used in digital dentistry, with an open source license that allows the operator to import any STL file and export it to any manufacturing machine, whether a 3D printer or milling machine, unlike closed systems that only allow their exported files to be manufactured through their machine. The existence of the full denture module in the software, digital complete denture conducted a study where maxillary denture bases were designed using CAD. It was found that the total average deviation from the reference scanned cast was less than 0.1 mm.(17)

Retention was measured using the universal testing system, a tool for precise measurement that is standardized. The best way to measure total denture retention is to remove the denture from its geometric center. This center was thought to represent the junction of two lines, one of which extended perpendicularly from the master cast's premolar region on one side to the other side. [18]

The standard deviations indicate there was a substantial spread of retention within each group as well. Significantly increased retention was observed for the milled denture bases compared with that of the conventional heat-polymerized denture bases. [2, 3, 8, 19]

It was obvious from Hssan et al. (2016) that the retention of the thermoformed complete denture was higher than that of the conventional heat-cured acrylic resin; this may be attributed to the maximum adhesion of flexible acrylic resin to the underlying mucosa. Aloush et al. (2019) reached the same conclusion in their study and reported a significant superiority in retention for the thermoformed acrylic resin (Versacryl) mandibular complete denture when compared to conventional heat-cured acrylic resin dentures. [4, 20]

Unlike the current study, Alloush et al. (2019), El Afandy et al. (2019), Shawky et al. (2014), Elmorsy et al. (2015), and Abd AlAziz et al. (2018) concluded that the use of thermoformed and conventional

heat-polymerized denture bases has no significant difference regarding denture retention. The time intervals for denture retention showed an increase in denture retention regarding the time factors. [21-24]

Studies that agree with the current study Hssan et al. (2016), Shukry et al. (2020), and AbdEl Rahim et al. (2021) concluded that retention was improved after the delivery of a flexible acrylic resin denture rather than a conventional heat-cured acrylic resin denture. [4, 25, 26]

Unlike the current study by Heikal et al. (2022), Maniewicz et al. (2022) concluded that the complete denture bases manufactured by CAD-CAM techniques provided retention and fit similar to that of conventionally manufactured bases. [27, 28] furthermore, a recent study compared conventionally heat-polymerized PMMA to both milled and some printed denture base materials and found that milled denture base materials show higher flexural strengths than compression-molded denture base materials. The reasoning for this finding is due to the processing technique in which the milled PMMA pucks are fabricated under significantly higher pressure and temperature, producing a more dense material with fewer voids. This process allows a milled denture to be fabricated with thinner dimensions while still achieving adequate strength.[29]

The limitation of the current study is the inability of the simulated saliva to wet the simulated mucosa and fit the surface of the denture. Artificial saliva was used for this purpose. However, it was diluted with water to reduce the emulsion and facilitate its application to the simulated mucosa and fitting surface

CONCLUSIONS

Based on the findings of this in vitro study and its limitations, it may be concluded that thermoformed resin may be the most suitable material for a high-arched palate, followed by CAD CAM materials. The conventional technique in this case is less recommended.

RECOMMENDATION

Clinical trials with a controlled, standardized study design are recommended to illustrate the long-term clinical performance of the tested techniques.

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