Sapporo Medical Journal
Volume 58, Issue 09, September 2024

Denture base adaptation of three-dimensional printed versus conventional heat-cured acrylic maxillary complete denture

Ahmed Hebeshi [1], Moatz Elmahdy[1], Sayed Elmasry[1], Halaabdel hameed[1]

[1]faculty of dentistry, Suez Canal University, Ismailia, Egypt

Abstract— Introduction: Complete denture rehabilitation remains the most common solution for treating edentulism. 3D-printed dentures have evolved as a new treatment modality to decrease fabrication time, increase patient predictability, and be a cost-effective option compared to milled dentures. The study aimed to investigate the retention of 3D-printed dentures versus conventional heat-cured acrylic dentures. Methods: After calculating the sample size and obtaining ethical committee approval, twenty patients were recruited and randomly and equally divided into two groups: Group A received a conventional heat-cured acrylic denture, and Group B received printed complete dentures. Denture adaptation was measured. Results: The t-test shows a statistically significant difference between the two groups (p-value <0.05). Conclusions: This study's limitations allowed us to conclude that 3D-printed dentures showed better adaptation than conventional heat-cured acrylic dentures.

Keywords: 3D printing, complete denture, digital denture, edentulism.

1. Introduction

Edentulism is not a healthy occurrence in an adult population. However, it is most often the result of repeated tooth extractions from the combined pathologic processes of dental caries, and periodontal disease, or is a way to lower the expense of dental treatment. A complete denture is a removable acrylic substitute for missing teeth and bone in the entire dental arch. Complete dentures are inexpensive, simple to make and repair, and aesthetically and functionally acceptable to a wide range of individuals.

Since 1946, the majority of dentures have been fabricated using polymethyl methacrylate (PMMA) and copolymers. Compared to other materials, PMMA has the advantage of a simple method of fabrication and low cost. Because of these properties, it remains in wide use. However, in the pack and press technique which is still a more common PMMA denture fabrication technique, residual stresses that occur at the time of packing are released when the material is removed from the flask, causing the resin or the denture to shrink, and this shrinkage is considered as a cause of poor fit of the denture base and displacement of the artificial teeth to the denture base.[1]

Rapid prototyping generates automatic physical models from computerized virtual three-dimensional (3D) data. In the field of prosthetic dentistry, additive manufacturing's capacity to generate prosthetic components from CAD data has an impact on overall quality, mechanical qualities of printed parts, total cost, and manufacturing time. Furthermore, when compared to the milling technique, the milling process wastes a substantial amount of denture foundation material; on the other hand, 3D printing requires less denture resin. [2]

The accuracy of denture mucosal surface, as well as clinical reporting for denture retention, were compared between dentures made with additive manufacturing and those made with traditional heat-cured acrylic dentures.
The study aimed to evaluate the effect of the 3d printing technique versus the conventional heat cure pack and press technique on the adaptation, of the maxillary complete denture for completely edentulous patients.

2. Materials and methods

2.1. Sample size calculation

Sample size calculation was performed using **G*Power version 3.1.9.2(**University Kiel, Germany).
The effect size was 1.6 using an alpha (α) level of 0.05 and a Beta (β) level of 0.05, i.e., power = 95%; the estimated minimum sample size (n) was a total of 20 samples.
After approval of the Research Ethics Committee (REC) at Suez Canal University Faculty of Dentistry, Twenty healthy completely edentulous patientswere selected from the outpatient clinic of the Prosthodontics Department Faculty of Dentistry, Suez Canal University.

2.2. The patients were selected according to the following criteria:

*Patients had ages ranging between 50-65 years old and were seeking the construction of maxillary and mandibular dentures.
* the edentulous ridge was covered with healthy firm and dense mucosa i.e. free from signs of inflammation or hyperplastic tissue.
*They have upper and lower edentulous healthy alveolar ridges with no remaining roots, no severe bony undercut, or local pathological lesions.
* The cases selected with no T.M.J disorders and with Angle Class I skeletal relation.
*patients had no previous dentures.
Ethical considerations:regarding patient well-being and confidentiality were undertaken. Informed consent was signed by the patients before commencing the study explaining all clinical examinations, procedures, and follow-ups.

2.3.Patient grouping

Twenty patients were divided randomly and equally with the aid of a randomization website (www.random.org)and according to the method of denture fabrication into two groups:
Group A (10 patients) patients received the conventional pack and press heat cure acrylic dentures.
Group B patients(10 patients) received three-dimensional (3D-printed complete dentures).

2.3.1. GroupA(conventional heat cure acrylic denture)

Suitable sizesof perforated maxillary and mandibular metal stock trays were selected, adapted, and modified stock trays were tested in the patient's mouth; if necessary, more adjustments were made by applying wax to the borders or cutting the tray borders.
Irreversible hydrocolloid alginate impression material (Tropicalgin,zhermack,Italy) was mixed according to manufacturer instructions and was loaded onto the modified stock trays. Preliminary maxillary and mandibular impressions were made.

Individual cold cure acrylic resin (Cold cure, Acrostone, Egypt) trays (maxillary and mandibular) were constructed over the primary cast which was obtained after pouring the primary impression.Special trays were trimmed to 2-3 mm shorter than the depth of the vestibule and evaluated intraorally for accurate adaptation and extension.

Secondary impressions were created with green stick compound (Impression compound, Kerr, Italy) as the border tracing material and zinc oxide impression material (Cavex outline, Cavex, Netherlands) as the final imprint using the open mouth technique.

The master cast was created by pouring the final imprint of type IV stone (Elite Rock, Zhermack, Italy). The master cast was scanned using a tabletop scanner (DOF swing, DOF, Seoul. Korea).and saved as an stl file under the name of the conventional master cast.

The scanner used for all study groups has the following specifications: 1.3-megapixel camera-Dimensions: 330mm x 330mm x 330mm (W x H x D)-use structured white light technology 7-micron accuracy)

A bite occlusion block was fabricated on the master cast and was checked in the patient's mouth for retention, stability, and proper border extension.

A registration record of the maxilla's position relative to the hing axis was created using an earpiece arbitrary facebow (BIO-ART ELITE FACE BOW, BIO ART, Brazil), and the maxillary cast was put on a semi-adjustable articulator. The appropriate vertical dimension was acquired. Anatomic artificial acrylic teeth with appropriate size, shape, and shade were chosen based on the patient's gender, age, and arch form. The selected prosthetic teeth were placed according to the bilateral balanced occlusion principle. The trial dentures were examined in the patient's mouth for phonetics, aesthetics, occlusal vertical dimension, and centric relationship.

Acrylic dentures were processed using heat-cured acrylic (Heat cure acrylic, Acrostone, Egypt) using the traditional hot water route long cycle method (70 for 9 hours).After deflasking, the denture and accompanying master cast were carefully removed from the flask. (Figure 1).

Figure 1shows the processed acrylic denture on its corresponding cast after deflasking

The processed acrylic denture was scanned using a tabletop scanner and saved as an stl file with the name (processed acrylic denture). The processed acrylic dentures resting on their matching cast were scanned as a single item with the name (processed denture and master cast).

Occlusal refining and laboratory remounting were completed. The dentures were finalized, polished, and presented to the patients. All required changes were performed, and the patients were given instructions.

2.3.2. Group B (three-dimensional printed denture)

The same impression technique, bite registration, and articulator mounting for group A were done.

Because CAD software (Exocad Dental CAD 3.0, Exocad GmbH, Germany) does not allow for trimming of the post-dam region in 3D digital edentulous models, the post-dam area was cut on the physical master cast. In brief, on the master cast, a line was drawn along the pterygomaxillary notches on both sides, with the tips 2mm below the foveae palatinae. A sculpting knife was used to create a 1 to 1.5 mm deep cutting line along the vibration line. A layer of cast was removed from the area surrounding this cutting line, up to 5mm before it. Less was removed if the location was further from the cutting line. A bow shape was made by gradually shallowing this region, which was parallel to the

The master cast affixed to the articulator plate was scanned and saved in STL format as a mounted printed denture master cast. The occlusion block was scanned and stored in stl format as the scanned occlusion block. Scan the upper, lower, and occluded blocks. STL files were loaded into the CAD program. The program automatically determined the orientation of the maxillary cast by comparing the associated plate to the virtual articulator plate. The lower master castings were orientated digitally by superimposing them on a scanned occlusion block.

Model analysis:

The path of insertion was established using the software's digital surveyor tool. The CAD program helps to determine the occlusal plane for the 3D digital edentulous model. In the 3D digital edentulous model, three spots on the upper and occlusal rim's contacting plane were selected. Feature points were chosen from the Incisive papilla. The maxillary tuberosity, median palatine raphe, and canine portion of the maxillary arch; the retromolar pad, midline, and canine area of the mandibular arch. The baseplate borders were created to suit the requirements for full dentures and serve as the foundation for them. Specifically, the labial and buccal stopped at the mucobuccal fold between the alveolar mucosa and the labial and buccal mucosa.

Artificial tooth arrangement: The EXOCAD program allows you to move the teeth in the sagittal, horizontal, and coronal planes when modeling. The length, breadth, height, and form of the teeth might be changed. Modifications/adjustments might be performed to the entire tooth or specific areas of the tooth. To conduct this investigation, we selected a collection of standard dentitions with A2-colored artificial teeth from the Smile database. All of the previously described features were utilized to arrange the artificial teeth in the 3D virtual models to match the specific forms of the patient's arches. Free forming of denture design was done for finer adjustment.

The CAD program can simulate the movements of occlusion, laterotrusion, pro/retrusion, and side shift. During the virtual occlusal correction, the contacting locations were recorded in distinct colors for each movement. The conflicting spots were eliminated using the virtual grinding method. Following this occlusal correction process, the creation of virtual 3D full dentures was completed.
Then the teeth and denture base were exported as two separate stl files to the slicing software(Chitu box,china.). The printing angle was set at 45 degrees with the incisal edge toward the printing bed for teeth and the fitting surface away from the printing bed for denture bases.Supports were set using the auto support function.The teeth and denture foundation were then sent as two independent STL files to the slicing program (Chitu Box, China). The printing angle was adjusted at 45 degrees, with the teeth's incisal edge toward the printing bed and the denture bases' fitting surface facing away from the bed. Supports were configured using the auto support mechanism.

Table 1shows the printing parameters.

Layer thickness(mm)	Normal exposure time(s)	Off time(s)	Bottom exposure time(s)	Bottom layers
0.1	15	1	100	8

Sliced stl files were sent to an LCD-based SLA 3D Printer（Anycubic photon,china.) which has suitable specifications as shown in (Table2).

Table2 shows the LCD printer specification

Light-source	UV integrated light（wavelength 405nm）
XY DPI	47um (2560*1440)
Y-axis resolution	1.25um
Layer resolution	25 ~ 100um
Printing speed	20mm/h
Rated Power	40W
Printer size	220mm*200mm*400mm
Printing volume	115mm *65mm *155mm (4.52″*2.56″*6.1″)
Printing material	405nm photosensitive resin

Tooth-colored printing resin (Flexcera smile ultra, Desktop health, USA.) was used for printing denture teeth and then was changed with denture base printing resin (Denture 3d, NextDent, USA.) for printing denture base.
After printing, the printing supports were removed with a specialized cutter and low-speed rotary device. The printed pieces (teeth and denture base) were cleaned with 95% ethyl alcohol for two minutes to remove excess resin, then rinsed in a water bath at 50°C. The

denture teeth were rebuilt in their proper location in the denture base and fastened with unfilled resin.

Post-curing for printed components was done with post-curing equipment (bre.Lux Power Unit 2, Bredent, Germany) that has a wide range of wavelength (370-500nm) fit and 130 watts lamp power for 30 minutes at 50°C.

2.4. For accuracy measurement

For groups A and B, after scanning the denture base alone, the denture base was placed on each matching cast, and all of those files were superimposed using a point-to-point match and the best-fit method. This was done to align the denture with the appropriate cast. Metrology software was used to measure distances between the denture base and cast at various points, allowing fit issues to be evaluated. Color maps of surface matching differences were generated. Color-coded 3D surface deviation spectra were shown at each measurement point, with a maximum critical value of ±1 mm.

The distance between the denture fitting surface and the relevant data was measured in millimeters. Areas ranging from yellow to red suggest denture base impingement with the cast. Blue spots denote the gap between the denture base and the cast. The perfect denture had a fully green color map, resulting in a measurement value of 0, indicating no processing deformation and an excellent fit of the denture base to the cast. (figures 2&3)

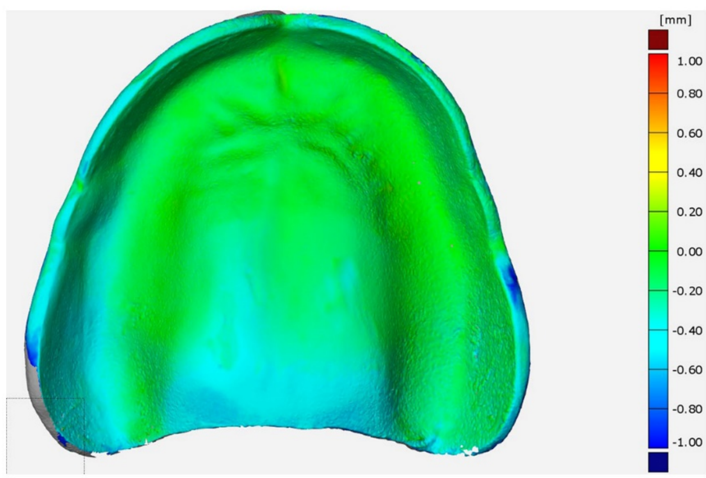

Figure 2shows a color map of the printed denture base deviation from its corresponding cast.

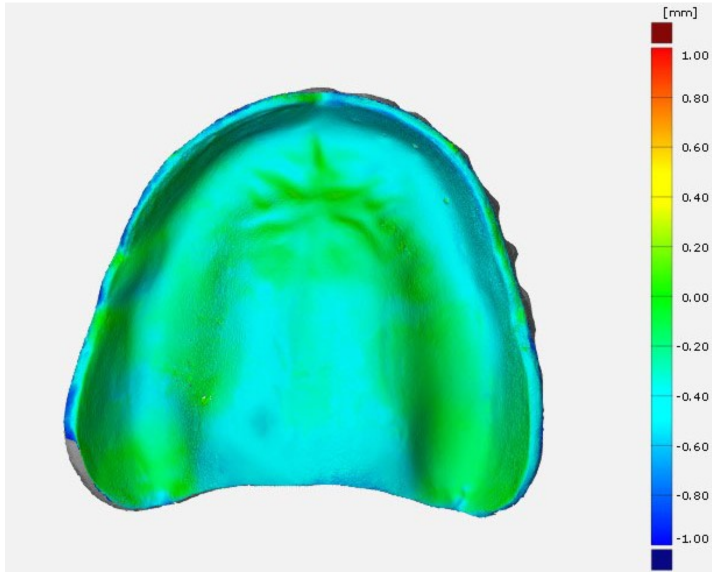

Figure 3shows a color map of heat-cured acrylic denture base deviation from its corresponding cast

2.5. Statistical analysis

The results were collected,tabulated, and statistically analyzed using SPSS Statistics Version 20 for Windows (SPSS, Inc., an IBM Company, USA).

Results

The accuracy of the maxillary denture of each group is represented by the adaptation of the denture base fitting surface to the cast (discrepancy between the fitting surface of the maxillary denture and its corresponding cast).

3. Results.

3.1. Normality test

After data was tabulated and imported to statistics software (SPSS version 26, IBM, USA), the Shapiro-Wilk test was used to test normality as shown in Table 3.

The table shows that there is no statistically significant difference (p-value > 0.05) and that indicates normal data distribution.

Table 3shows the normality test for adaptation measurement (the significance level was set to 0.05)

	Shapiro-Wilk test		
adaptation	**group**	**p-value**	**Normality interpretation**
	acrylic	0.795 ns	Normally distributed
	printed	0.703 ns	Normally distributed

ns=no statistical significance difference p-value>0.05

3.2.Descriptive statistics

Accuracy was described using mean, and standard deviation. The mean deviation of group1(0.35 mm) was more than group 2 (0.16 mm) as shown in Table 4.
As the data were normally distributed, an independent sample test-t was used to compare the two groups' mean as shown in Table 4 and Figure 4.
The t-test showed a highly statistically significant difference between the two groups (p-value ≤0.05).

Table 4shows the mean, standard deviation, and significant difference between acrylic and printed denture accuracy(the significance level was set to 0.05)

group	Mean (mm)	Standard deviation	P value
Acrylic denture (group 1)	0.350	0.018	0.000*
Printed denture (group 2)	0.160	0.012	

**Statistical significant difference p-value≤ 0.05*

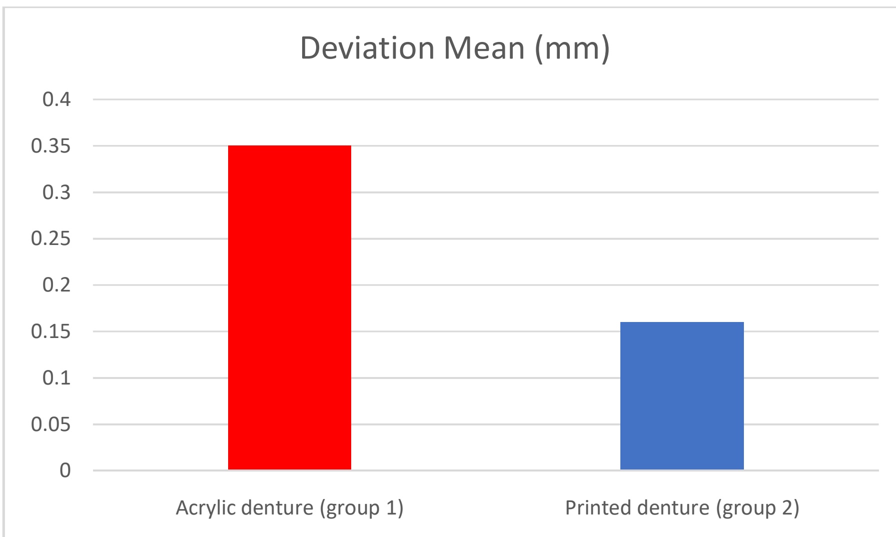

Figure 4shows the deviation means for acrylic and printed dentures.

4. Discussion

Denture bases undergo dimensional changes during processing which may adversely affect their support, stability,retention, and subsequent decreased patient comfort.[3]
The CAD-CAM 3D printed denture fabrication technique is presented to reduce such dimensional fluctuations and achieve the balance between biocompatibility, aesthetics, minimal distortion, and adaption.[4]
In this study, the selected patients had ages ranging from 50-65 years old as the prevalence of edentulism over the age of 50 years is high. Patients over 65 may have bone resorption and systemic diseases.[5]
The selected patients had healthy and firm mucoperiosteum without any signs of inflammation as inflammation causes edema of the soft tissue and changes their natural size,

especially at the time of impression making which may affect the retention of the denture when the inflammation subsides.[6]

Patients with flappy tissues were rejected because an excessive amount of moveable soft tissue may allow the denture to move about the bone, preventing denture base stability and decreasing the retentive quality of the denture bases.[7]

Patients had no bone or soft tissue undercuts to remove the influence of mechanical variables on denture base retention.[8]

Furthermore, patients with significantly resorbed maxillary ridge, torus palatinus, and V-shaped palatal vault were eliminated to avoid their negative impact on denture base adaption and retention.[9]

Patients with xerostomia were excluded from the trial because salivary flow rate and viscosity are critical determinants for denture retention.[10]

Patients with TMJ disorders were excluded to facilitate the intraoral procedures as well as the evaluationof denture baseretention.[11]

An objective of the complete denture impression procedure is to record all available denture-bearing surfaces accurately such that a stable retentive prosthesis can be constructed. Upper and lower impression and jaw relation records were made to provide the data required to design and constructthe denture base and fabricate acomplete denture to facilitate the oral rehabilitation for each patient at the end of the study.[12]

The open-mouth tray mucocompressive impression technique was used in both acrylic and 3d printed denture groups to get better denture retention.[13]

For the 3d printed denture group, the mucocompressive technique was used instead of the intraoral scan, as the intraoral scanner has a lot of disadvantages in complete denture workflow like making the impression in mucostatic, not in mucocompressive condition, difficulty in scanning with tissue retraction to obtain proper border seal.All those disadvantages may alter denture retention.[14]

A tabletop scanner (DOV swing scanner) was used to scan the casts and jaw relation records.The scanner used for all study groupsuses structured white-light technology and has 7-micron accuracy which is considered acceptable to get good results.[15]

Heat-cured acrylic resin has been one of the most common methods of curing for many years in the field of dentistry.[16]

Processing with a long cycle at 70^{o}c for 9hours without terminal boil to provide a slow rate of polymerization so that temperature rise does not vaporize monomer therefore porosity was avoided, which might affect the accuracy in palatal denture base adaptation.[17]

3d printing for denture construction is a new digital additive manufacturing technology and nowadays, it is considered the subject of interest to be compared regarding different items with heat-cured fabrication methodology that is thought the main technique for denture base fabrication. This technique was used because it allows material conservation and exhibits the ability to print complex geometries with reasonable dimensional accuracy.[4]

For the virtual design of the printed denture, the incisive papilla and the hamular notches were chosen to detect the midline as they are fixed landmarks and their positions do not change with bone resorption.[18]

The digital surveyor confirmed the absence of undercuts in the denture-bearing area thus there was no need for any blockout that would have adversely affected the results of both adaptation and retention of denture bases in the study.

The printing angle was set at 45 degrees with the incisal edge toward the printing bed for teeth and fitting surface away from the printing bed for denture bases as this printing angle has the least deviation.[19,20]

Printing parameters were set at 0.1 mm printing layer thickness, which was found by previous studies to have the best accuracy and tissue surface adaptation compared to 0.05 mm layer thickness.[21]

the printed parts(teeth and denture base) were washed with ethyl alcohol(99%) for 10 minutes which is the ideal time to remove excess resin to avoid cytotoxicity and affect accuracy due to warpage and fissuring.[22]

Another study compared dimensional stability for printed dentures at different washing times and found that increasing time will not improve the cytocompatibility and may result in warpage, fissuring, and a decrease in flexural strength.[23]

Post-curing for printed parts was done with a post-curing machine for 30 minutes to increase long-term dimensional stability.[24]

Bonded teeth printed denture was used instead of monolithic dentures because it is more aesthetically accepted and monolithic dentures require further cut back in denture base to add tissue color resin.[25]

This study uses surface matching and best-fit algorithms to evaluate the adaptation and accuracy of the denture base as atrial to provide a recent and accurate method for evaluation. This contrasts with earlier research that assessed denture base adaptability using physical parameters such as polysiloxane. One disadvantage of any study investigating denture adaptation in vitro is the ability to correlate the results in vivo. There is no experimental methodology that can correctly recreate soft tissue compression. In this investigation, the procedure that consistently delivers the closest adaptation of the denture base to the cast was determined to be superior. The cast represents the patient's anatomy depending on the clinician's impression-making abilities. The more precisely the denture fits the cast, the less deformation the denture experiences during manufacturing.[26]

In conventional heat-cured fabrication technique,the decreased palatal adaptation may be attributed to the combination of factors such as intrinsic features of the material, the monomer/polymer ratio, thermal expansion and contraction during cooling,stress elevated during removal of the flask from the hydraulic press and presence of porosity.All these reasons lead to a decrease in denture base adaptation.[27]

The primary disadvantages of 3D printing include the staircase effect, limited repeatability, and the need for supporting structures. These supporting structures require more materials and time. Discrepancies can be integrated into each phase of the process, including designing in the CAD program, slicing in the printing software, and throughout the printing process.[28]

Many elements impact the accuracy of each printed product, including light intensity, printing direction, angle, number of layers, software, and post-processing tools.[20]

Polymerization shrinkage during 3D printing is potentially feasible since the denture bases are not fully polymerized before the final light polymerization step. Deformation may also occur during demounting the partly polymerized denture base from the constructing platform.[29]

Also during accuracy measurement,the accuracy of the scanner used and scanning spray powder size are considered errors that affect measurement results.

The company claims the scanner is accurate to within 7-8 µm. Since the mismatch reported in earlier investigations was more than the scanner's accuracy, the experimental setup and measurement in this study looked to be adequate for evaluating differences.[30]

An error may be encountered by the powder that was sprayed on the denture base before scanning .it was addressed that marginal fit and internal adaptation in partial coverage restorations were adversely affected by the powder for scanning.[31]

In vitro investigations suggest that surface preparation with powder does not significantly impair scanning accuracy due to the tiny particle size of aerosol sprays (about 5µm).[7]

Although this error may be considered in the field of fixed prosthodontics,inaccuracies of the degree of the micrometer are considered clinically acceptable in the field of complete denture prosthodontics.[28]

It has been stated that additive manufacturing technology can produce complicated structures with high dimensional accuracy. This is true for the maxillary denture, which has a palatal vault and a large surface area. In contrast, a heat-cured one exhibits large gaps at the palatal vault and posterior palatal portions...[29]

In the current study, analysis of the overall deviation of the denture bases from their corresponding casts revealed that group (1) attained a higher value of deviation from the corresponding casts than group (2) The dimensional changes of each layer are compensated for by the addition of the successive resin layer and this result in less shrinkage and distortion, along with consistent better adaptation compared to conventional dentures.[32]

further clinical studies over a longer time were recommended to test retention and patient satisfaction of 3d printed dentures compared to conventional heat-cured acrylic dentures. Further comparative clinical investigation was recommended between 3d printed and heat-cured denture wearers regarding oral rehabilitation of the patient as chewing efficiency, biting force, EMG activity, remounting, occlusal correction ....etc.

5. Conclusion

Within the limitation of this study, it was concluded thatdenture bases fabricated from 3d printing showed better fitness accuracy compared to conventional heat-cured packs and press ones.

6. References

[1] Artopoulos A, Juszczyk AS, Rodriguez JM, Clark RK, Radford DR: Three-dimensional processing deformation of three denture base materials. The Journal of Prosthetic Dentistry. 2013, 110:481-487.

[2] Barazanchi A, Li KC, Al-Amleh B, Lyons K, Waddell JN: Additive technology: update on current materials and applications in dentistry. Journal of Prosthodontics. 2017, 26:156-163.

[3] Savabi G, Savabi O, Dastgheib B, Nejatidanesh F: Effect of the processing cycle on dimensional changes of heat-polymerized denture base resins. Dental Research Journal. 2015, 12:301.

[4] Faty MA, Sabet ME, Thabet YG: A comparison of denture base retention and adaptation between CAD-CAM and conventional fabrication techniques. Int J Prosthodont. 2021.

[5] Kailembo A, Preet R, Stewart Williams J: Common risk factors and edentulism in adults, aged 50 years and over, in China, Ghana, India and South Africa: results from the WHO Study on global AGEing and adult health (SAGE). BMC Oral Health. 2017, 17:1-16.

[6] Salinas TJ: Treatment of edentulism: optimizing outcomes with tissue management and impression techniques. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2009, 18:97-105.

[7] Naggar SME, Helal E, Khalil MF, El-Sisy AME, Gouda A: Comparative study of maxillary denture-base retention between CAD/CAM (3D printed) and conventional fabrication techniques: a randomized clinical study. Journal of The Arab Society for Medical Research. 2022, 17:46.

[8] Hashem MI: Advances in soft denture liners: An update. J Contemp Dent Pract. 2015, 16:314-318.

[9] Vaithilingam B, Mohan J, Kamaraj Loganathan M, Varghese T, Varghese A: Comparative Analysis of Retention and Bite Force in Completely Edentulous Patients with Torus Palatinus Restored with Two Different Denture Designs. World. 2022, 13:139.

[10] Tanaka A, Kellesarian SV, Arany S: Xerostomia and patients' satisfaction with removable denture performance: systematic review. Quintessence International. 2021, 52:46-55.

[11] Kabeel SM, Kholief DM: Evaluation of retention and microbial colonization of two different denture base material. Egyptian Dental Journal. 2017, 63:3879-3887.

[12] Carlsson GE, Örtorp A, Omar R: What is the evidence base for the efficacies of different complete denture impression procedures? A critical review. Journal of Dentistry. 2013, 41:17-23.

[13] Russo LL, Caradonna G, Troiano G, Salamini A, Guida L, Ciavarella D: Three-dimensional differences between intraoral scans and conventional impressions of edentulous jaws: A clinical study. The Journal of Prosthetic Dentistry. 2020, 123:264-268.

[14] Elkafrawy MMG, El-Sheikh AM: Digital versus conventional impression technique for flabby ridge in complete denture construction. Tanta Dental Journal. 2021, 18:109.

[15] Williams R, Bibb R, Eggbeer D, Collis J: Use of CAD/CAM technology to fabricate a removable partial denture framework. The Journal of prosthetic dentistry. 2006, 96:96-99.

[16] Hashem M, Alsaleem SO, Assery MK, Abdeslam EB, Vellappally S, Anil S: A comparative study of the mechanical properties of the light-cure and conventional denture base resins. Oral Health Dent Manag. 2014, 13:311-315.

[17] Babu MR, Rao CS, Ahmed ST, Bharat J, Rao NV, Vinod V: A comparative evaluation of the dimensional accuracy of heat polymerised PMMA denture base cured by different curing cycles and clamped by RS technique and conventional method-an in-vitro study. Journal of International Oral Health. 2014, 6:68.
[18] Norli Anida A: Statistical methods in analyzing the shape of maxillary dental arches for dental applications/Norli Anida Abdullah. University of Malaya; 2016
[19] Jin M-C, Yoon H-I, Yeo I-S, Kim S-H, Han J-S: The effect of build angle on the tissue surface adaptation of maxillary and mandibular complete denture bases manufactured by digital light processing. The Journal of Prosthetic Dentistry. 2020, 123:473-482.
[20] Hada T, Kanazawa M, Iwaki M, et al.: Effect of printing direction on the accuracy of 3D-printed dentures using stereolithography technology. Materials. 2020, 13:3405.
[21] AB VT, Dos Reis AC: Influence of parameters and characteristics of complete denture bases fabricated by 3D printing on evaluated properties: a scoping review. The International Journal of Prosthodontics. 2021.
[22] Katheng A, Kanazawa M, Komagamine Y, Iwaki M, Namano S, Minakuchi S: Effect of post-rinsing time and method on accuracy of denture base manufactured with stereolithography. The Journal of Advanced Prosthodontics. 2022, 14:45.
[23] Xu Y, Xepapadeas AB, Koos B, Geis-Gerstorfer J, Li P, Spintzyk S: Effect of post-rinsing time on the mechanical strength and cytotoxicity of a 3D printed orthodontic splint material. Dental Materials. 2021, 37:e314-e327.
[24] Tasaka A, Shimizu T, Kato Y, et al.: Accuracy of removable partial denture framework fabricated by casting with a 3D printed pattern and selective laser sintering. Journal of prosthodontic research. 2020, 64:224-230.
[25] Andreescu CF, Ghergic DL, Botoaca O, Hancu V, Banateanu AM, Patroi DN: Evaluation of different materials used for fabrication of complete digital denture. Mater Plast. 2018, 55:124-128.
[26] Goodacre BJ, Goodacre CJ, Baba NZ, Kattadiyil MT: Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. The Journal of prosthetic dentistry. 2016, 116:249-256.
[27] Shibayama R, Filho HG, Mazaro JVQ, Vedovatto E, Assunção WG: Effect of flasking and polymerization techniques on tooth movement in complete denture processing. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2009, 18:259-264.
[28] Lee S, Hong S-J, Paek J, Pae A, Kwon K-R, Noh K: Comparing accuracy of denture bases fabricated by injection molding, CAD/CAM milling, and rapid prototyping method. The journal of advanced prosthodontics. 2019, 11:55-64.
[29] Masri G, Mortada R, Ounsi H, Alharbi N, Boulos P, Salameh Z: Adaptation of complete denture base fabricated by conventional, milling, and 3-d printing techniques: An in vitro study. J Contemp Dent Pract. 2020, 21:367-371.
[30] Hsu C-Y, Yang T-C, Wang T-M, Lin L-D: Effects of fabrication techniques on denture base adaptation: An in vitro study. The Journal of Prosthetic Dentistry. 2020, 124:740-747.

[31] Prudente MS, Davi LR, Nabbout KO, et al.: Influence of scanner, powder application, and adjustments on CAD-CAM crown misfit. The Journal of prosthetic dentistry. 2018, 119:377-383.

[32] Abdullah M: Evaluation of retention and patient satsifaction for maxillary complete denture constructed by 3D printing technique and conventional technique. Biomaterials Journal. 2022, 1:28-34.