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EFFECT OF DAPTATION TIME ON RETENTON OF MAXILLARY 3D PRINTED DENTURE VERSUS CONVENTIONAL HEAT-CURED ACRYLIC DENTURE: A RANDOMIZED CONTROLLED TRIAL

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Objectives: The study aimed to investigate the effect of adaptation time on the retention of 3d printed versus conventional heat-cured acrylic maxillary complete dentures.

Methods: 20 patients were distributed into: Group A received ten conventional complete heat-cured acrylic dentures and Group B received ten printed complete dentures. Denture retention was measured at 0, 1 , and 3 months.

Results: For acrylic denture and printed denture groups, Mean values in denture retention increased with time but this increase was statistically non-significant. The change in denture retention over time (difference in retention between the third month and at the time of insertion) in the printed denture group was more than that for the conventional denture group with statistically significant differences.

Conclusions: 3D-printed and conventional dentures showed a non-significant retention increase over the 3-month follow-up period but the change in denture retention (increase in retention) was more for the printed denture group.

Keywords: 3D printing, complete denture, denture retention, digital denture, denture adaptation.

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Conflicts of interest:
The authors declare no conflicts of interest.

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EFFET DU TEMPS D'ADAPTATION SUR LA RETENTION D'UNE PROTHÈSE MAXILLAIRE IMPRIMÉE EN 3D PAR RAPPORT A UNE PROTHÈSE ACRYLIQUE THERMODURCISSABLE CONVENTIONNELLE: UN ESSAI CONTRÔLÉ ET RANDOMISÉ

Objectifs: L'étude visait à examiner l'effet du temps d'adaptation sur la rétention des prothèses complètes maxillaires imprimées en 3D par rapport à celles fabriquées en acrylique polymérisé à chaud de manière conventionnelle.

Méthodes: 20 patients ont été répartis en deux groupes: Groupe A 10 prothèses complètes en acrylique polymérisé à chaud de manière conventionnelle. Groupe B 10 prothèses complètes imprimées en 3D. La rétention des prothèses a été mesurée à 0, 1 et 3 mois.

Résultats: Pour les groupes utilisant des prothèses en acrylique et des prothèses imprimées, les valeurs moyennes de la rétention des prothèses ont augmenté avec le temps, mais cette augmentation n'était pas statistiquement significative. Cependant, le changement dans la rétention des prothèses au fil du temps (différence de rétention entre le troisième mois et le moment de l'insertion) dans le groupe utilisant des prothèses imprimées était supérieur à celui du groupe utilisant des prothèses conventionnelles, avec des différences statistiquement significatives.

Conclusions: Les prothèses imprimées en 3D et conventionnelles ont montré une augmentation non significative de la rétention sur la période de suivi de 3 mois, mais le changement de rétention (augmentation de la rétention) était plus important pour le groupe utilisant des prothèses imprimées.

Mots clés: impression 3D, prothèse complète, rétention de prothèse, prothèse numérique, adaptation de prothèse.

Introduction

Edentulism is not a natural healthy occurrence in the adult population, but it is most typically the outcome of recurrent tooth extractions caused by a combination of pathologic processes such as dental caries, periodontal disease, or lack of dental treatment for a long time. A complete denture is a removable acrylic prosthesis for missing teeth and bone in the entire dental arch. Complete dentures are reasonably affordable, simple to make, and repair, and aesthetically and functionally acceptable to many individuals [1].

Since 1946, nearly all dentures have been made from polymethyl methacrylate (PMMA) and copolymers. In comparison to other materials, PMMA is simple to use and affordable, and it may be processed using basic equipment. Because of these characteristics, it remains widely used. However, in the pack and press technique, which is still a more common technique for denture construction, residual stresses that occur during the packing process are released during deflasking, causing the resin to shrink, and this shrinkage leads to poor fit of the denture base and displacement of the artificial teeth from the denture base [2].

Rapid prototyping is a method of producing physical models from virtual three-dimensional (3D) data. In the field of prosthetic dentistry, additive manufacturing's ability to mold several materials simultaneously using Computer-Aided Design (CAD) data influences overall quality, mechanical properties of printed components, total cost, and production time. The milling process loses a significant portion of denture foundation material, while more recent 3D printing provides a new additive approach that utilizes less denture resin [3].

Denture retention denotes the force required to completely remove a denture from its basal seat. The influence of adhesive and cohesive forces, surface tension, atmospheric pressure, viscosity and volume of saliva, and gravity on denture retention has been demonstrated. Adaptation is one of the factors that affect retention. Keeping denture base deformation during processing as minimal as possible is essential for achieving appropriate adaptation to the mucosa. The degree of this deformation is influenced by the material and thickness of the base in addition to the processing method [4].

According to the authors' knowledge, few studies were found talking about printed denture retention, but no studies talked about the effect of adaptation time on printed denture retention.

The study aimed to evaluate the effect of adaptation time on the retention of maxillary 3d printed dentures compared to the conventional heat cure dentures in completely edentulous patients.

Materilas and Methods

The study was approved by the Research Ethics Committee (REC) at Suez Canal University Faculty of Dentistry no (318/2021) and clinical trial gov registration (NCT05585008). All patients provided written informed consent before enrollment in the study, while all methods were performed in accordance with the Declaration of Helsinki as well as relevant guidelines and regulations.

Participants selection

Twenty healthy completely edentulous patients with ages ranging between 50-65 years old who were seeking the construction of maxillary and mandibular dentures were selected from the outpatient clinic of the Prosthodontics Department Faculty of Dentistry, Suez Canal University. The patients were selected according to the following inclusion criteria: The selected patients, had maxillary and mandibular edentulous ridges covered with healthy firm and dense mucosa with no remaining roots, no severe bony undercut, or local pathological lesions. The patients had no previous dentures. Patients were free of any systemic condition that might alter the rate of bone resorption, such as diabetes mellitus, and had no history of poor behaviors, such as excessive clenching. Cases were chosen with no T.M.J problems and skeletal Angle Class I skeletal relation.

The following patients were excluded: patients with xerostomia, high or shallow palatal vault, and short or hyperactive lips.

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.

Study design

This was a prospective randomized, controlled trial. All treatments were performed by an experienced prosthodontist, and he was blinded until the try-in and denture delivery phase. Patients were divided randomly and equally with the aid of a randomization website (randomizer.com) and according to the method of denture fabrication into two groups: Group A patients received ten conventional packs and press heat cure acrylic complete maxillary and mandibular dentures. Group B patients received ten three-dimensional (3D) printed maxillary and mandibular complete dentures.

Clinical procedures

Group A (conventional heat cure acrylic denture)

Irreversible hydrocolloid alginate impression material was mixed following the manufacturer's instructions and was loaded onto the modified stock trays. Secondary impressions were made by using a modeling compound (Impression compound, Kerr, Italy) as border tracing material and zinc oxide impression material (Cavex outline, Cavex, Netherlands) as the final impression using the open mouth impression technique. The master cast was obtained by pouring the final impression using type IV stone (Elite Rock, Zhermack, Italy). Post-damming was achieved. After the trial denture base was fabricated, the conventional method for post-damming was achieved by inserting the trial denture base in the patient's mouth then the patient was instructed to say "ah" and the posterior vibrating line was marked with an indelible pen, and was transferred to the cast, then the anterior vibrating line was determined. A 1 to 1.5-mm-deep cutting line was formed along the vibration line using a sculpt knife and this area was gradually shallowed, forming a bow shape.

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.

The position of the maxilla to the hinge axis was recorded using an earpiece arbitrary facebow (bio-art elite face bow, bio art, Brazil), then the maxillary cast was mounted on a semi-adjustable articulator (bio-art A7plus, bio art, Brazil).

The resting vertical dimension (RVD) was measured, and the mandibular rim was adjusted to contact the maxillary occlusal rim evenly at a vertical dimension 3 mm less than the RVD. The maxillomandibular horizontal relation was recorded using a static method by manually guiding the mandible in a retruded contact position. Protrusive records were made. The lower cast with occlusion blocks was mounted on the articulator.

Artificial acrylic teeth with suitable size, shape, shade, and 33º cuspal angle were set according to the patient's gender, age, and arch shape. Following the bilateral balanced occlusion concept, the selected artificial teeth were arranged. Trial dentures were evaluated in the patient's mouth for phonetics, aesthetics, occlusal vertical dimension, and centric relation.

Processing of acrylic dentures was done from heat-cured acrylic (Heat cure acrylic, Acrostone, Egypt) using the conventional hot water path long cycle method (70^{o} for 9 hours). After deflasking, the denture and the corresponding master cast were separated from the flask with caution. Laboratory remounting and occlusal refinement were done Dentures were finished, polished, and then delivered to the patients. Clinical remounting was done by taking new interocclusal records in the patient's mouth and mounting the dentures on an articulator to correct errors made during the initial records. Selective grinding was then used to refine the occlusion based on the remount records.

Group B (three-dimensional printed denture)

The same impression technique, bite registration, and articulator mounting for group A were done. The same post-damming record was achieved as group A

Mounted maxillary and mandibular casts were scanned using a tabletop (DOV swing scanner) (fig 1 A-C) and since CAD software (Exocad Dental CAD 3.0, Exocad GmbH, Germany) does not support the trimming of the post-dam area in the 3D digital edentulous models, The post-dam area was trimmed on the physical master cast. On the master cast, a line was drawn between the pterygomaxillary notches on both sides. A carver was used to create a 1-1.5 mm deep cutting line along the vibration line. A layer of cast was removed from the area surrounding this cutting line to 5mm before it. Less was removed if the location was farther away from the cutting line. This region was eventually shallowed to produce a bow shape that was parallel to the palate's mucosal surface.

The master cast affixed to the articulator plate was scanned and saved in standard tessellation language (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 CAD software. The software automatically determined the orientation of the maxillary cast by comparing the associated plate to the virtual articulator plate. The mandibular master cast was digitally orientated using superimposition on a scanned occlusion block.

The path of insertion was determined. The CAD software supports the determination of the occlusal plane for the scanned maxillary cast. Feature points were selected at the Incisive papilla. The maxillary tuberosity, median palatine raphe, and canine region of the maxillary arch, the retromolar pad, midline, and canine area of the mandibular arch (figure 1 D-F). The border of the baseplates was created to satisfy the criteria for full dentures and to serve as the base for them. The labial and buccal borders ended at the mucobuccal fold between the alveolar mucosa and the labial and buccal mucosa, avoiding the labial/buccal frenulum; the mandibular denture lingual border ended at the lingual frenulum, avoiding the lingual frenulum; and the maxilla's rear margin ended at the line of pterygomaxillary notches on both sides and the points at 2 mm beyond the foveae palatinae.

The prosthetic teeth were positioned using CAD software and had a 33º cuspal angle, changing them in the sagittal, horizontal, and coronal planes during the modeling process. The length, width, height, and shape of the teeth may alter. Modifications/adjustments may be made to the entire tooth or particular portions of the tooth. The artificial teeth were arranged in the 3D virtual models such that they matched the exact shapes of the patient's arches (figure 1G).

The denture design was freely formed for finer adjustability (figure 1H). The CAD software can simulate the mandibular movement in laterotrusion, pro/retrusion, and side shift. During this virtual movement, different high spots were virtually marked with different colors. Those interfering spots were removed. Following this occlusal correction process, the creation of virtual 3D full dentures was completed.

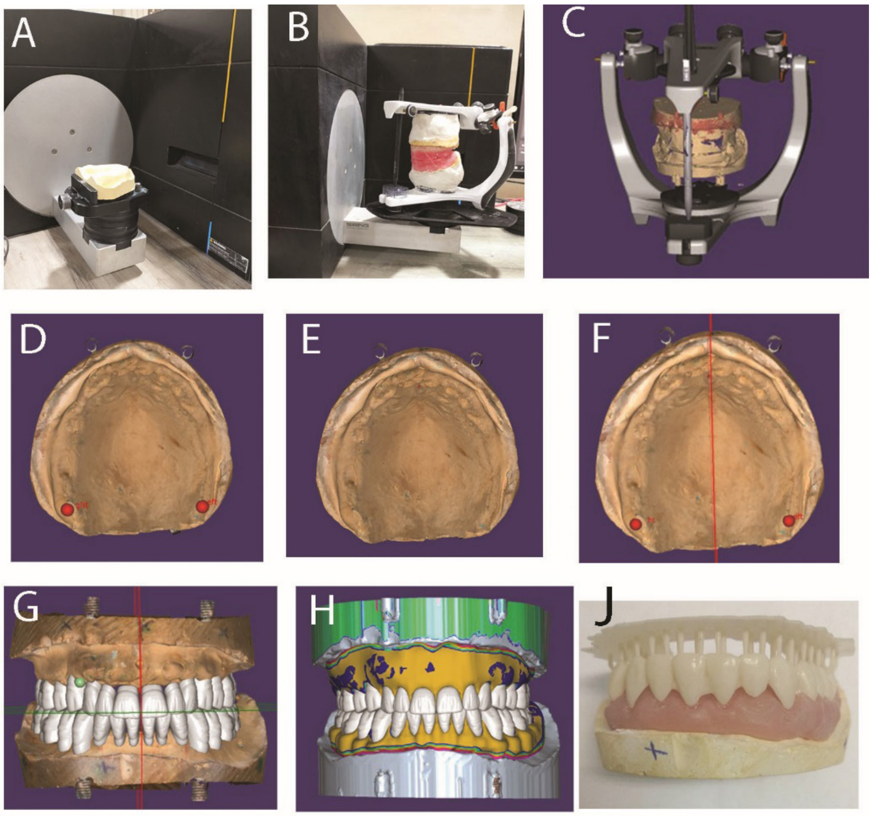

Figure 1. Different steps in printed denture fabrication. A- tabletop scanner scanning the master cast. B- Scanning of the occlusion bite record mounted on the articulator. C- Upper and lower casts mounted on a virtual articulator. D- Maxillary tuberosity determination. E- Incisal papilla determination. F-determination of the median raphe. G- Virtual setting of the teeth. H-Denture design free-forming. J- Support removal from the base and teeth fitting check.

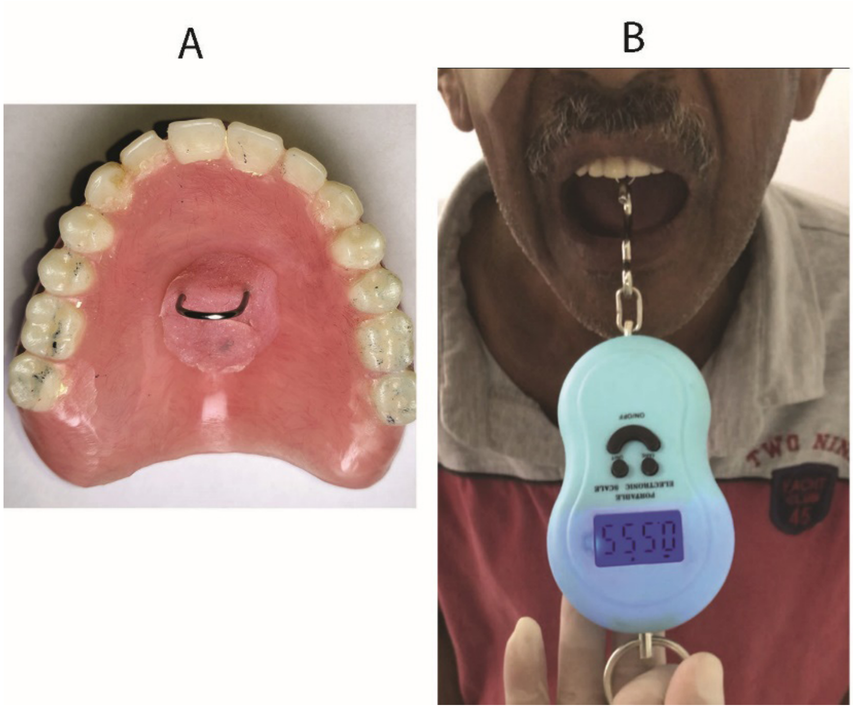

Figure 2 A- Hook attached to the geometric center of the denture. B- retention measurement.

The teeth and denture foundation were then sent as 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. The printing layer thickness was set to be 0.1 mm. After printing the teeth and denture bases using a Liquid Crystal Display (LCD) printer (any cubic, photon, China), the printing supports were removed with a specific cutter and a low-speed rotary tool.

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. The denture teeth were placed in their corresponding spaces in the denture base and secured with unfilled resin (figure 1J). The printed pieces were post-cured using a machine with a wide wavelength range (370-500nm) and 130 watts of lamp power for 30 minutes at 50°c (bre.Lux Power Unit 2, bredent, Germany).

Measuring denture retention

The Digital force meter (Digital force gauge, China) contained a spring connected to a metal hook. The spring stretched when a force was applied to the hook. The greater the vertical dislodging force applied at the geometric center of the maxillary denture, the longer the spring stretches and the greater the readings. By the intersection of two imaginary lines from the canine tip on one side to the maxillary tuberosity on the other side. One mm stainless steel wire loop was attached to the geometric center of the polished surface of the denture with the help of a self-cure acrylic denture (Self-cure acrylic, Acrostone, Egypt) (figure 2A). The hook of the digital force meter was attached to the wire loop of the denture base for measuring retention. All patients were asked to wear the denture for two hours before the measurement. Before retention measurement, the patients were asked to sit comfortably on the dental chair with their heads on the headrest and the occlusal plane of the maxillary teeth parallel to the floor. The metallic hook of the force meter was used to apply force on the single c wire positioned at the geometric center of the maxillary denture and try to remove it from the patient mouth by increasing the force gradually. The vertical dislodging force required to dislodge the denture from the patient's mouth was referred to as the value of retention of the denture (figure 2B). Three readings were recorded the same way in each session to get the mean value, and a 10-minute rest period between readings was taken. The device was automatically calibrated after each use. Records were measured in kilograms. For each patient, results were calculated, tabulated, and statistically analysed at intervals of (immediately, 1, and 3) months from the date of the first insertion time of the denture.

Statistical analysis

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

Results

Retention measurement

Shapiro-Wilk test data showed normal distribution for the two groups. Retention values for the two groups at three different time intervals (0,1 and 3 months) were described using mean, and standard deviation. The printed group shows higher means of retention values at all the observed time intervals than that of the acrylic denture.

As the data were normally distributed, an independent sample t-test was used to compare the two groups at different time intervals as shown in (Table 1). t-test shows a statistically significant difference between the two groups (p-value ≤ 0.05) at different time intervals.

Table 1. shows the mean, standard deviation, and independent sample t-test to compare acrylic
and printed groups' retention (in kilograms) (the significance level was set to 0.05)

	0 month	1 month	3 months
Group A	5.99±0.72	6.05±0.71	6.11±0.71
Group B	9.91±0.12	9.98±0.08	10.25±0.09
P value	0.00*	0.00*	0.00*

* Significant if p<0.05

<u>Effect of time within each group</u>

A one-way ANOVA test for each group was used to detect the effect of time on denture retention.

<u>For group A (acrylic denture):</u>

Mean values for denture retention increase with time as shown in Table 2. One-way ANOVA showed a non-significant difference in retention values at different time intervals.

Table 2. shows a one-way ANOVA test to compare acrylic denture retention means at different time intervals (the significance level was set to 0.05)

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	0.140	2	0.070	0.139	0.870 ns
Within Groups	13.576	27	0.503		
Total	13.716	29			

ns = no statistical significance difference

<u>For group B (printed denture):</u>

One-way ANOVA showed a non-significant difference in retention values at different time intervals (p-value> 0.05) as shown in Table 3.

Table 3. shows a one-way ANOVA test to compare printed denture retention means at different time intervals (the significance level was set to 0.05)

	Sum of Squares	Df	Mean Square	F	P value
Between Groups	.028	2	.014	1.468	.248 ns
Within Groups	.258	27	.010		
Total	.286	29			

ns = no statistical significance difference

The change in denture retention over time (difference in retention between the third month and at the time of insertion) in the printed denture group was more as shown in Table 4 where the difference in retention was 0.27 for printed group B and 0.12 for acrylic group A.

Table 4. shows the mean, standard deviation, and independent sample t-test to compare acrylic and printed groups' retention (in kilograms) (the significance level was set to 0.05)

	Group A	Group B	P value
Difference in retention over time (Mean ±SD)	0.12 ±0.01	0.27 ±0.03	0.02*

* Significant if p<0.05

Discussion

Denture bases undergo dimensional changes during processing which may adversely affect their support, stability, retention, and subsequent decreased patient comfort [5]. CAD CAM 3d printed denture fabrication technique is proposed to decrease such dimensional changes and get the balance between biocompatibility, aesthetics, minimal distortion, and adaptation [6].

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 [7].

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 [8].

Patients with flappy tissues were excluded as an excessive amount of movable soft tissue may permit the denture to move. This movement prevents denture base stability and decreases the retentive quality of the denture bases [9].

The patients selected for the research had no bony or soft tissue undercuts to eliminate the effect of mechanical factors on the retention of the denture bases [10].

Furthermore, patients with considerably resorbed maxillary ridge, V-shaped palatal vault, and torus palatinus were excluded to avoid their influence on denture base adaptation and retention [11].

Patients with xerostomia were excluded from the research because salivary flow rate and viscosity are critical determinants for denture retention [12].

Patients with TMJ issues were eliminated to enable the intraoral procedures and assessment of denture base retention [13].

The full denture imprint process aims to precisely capture all possible denture-bearing surfaces, allowing for the construction of a stable retentive prosthesis. Upper and lower impression and jaw relation records were made to give the data necessary to design and construct the denture foundation and fabricate a full denture to support each patient's oral rehabilitation [14].

The open-mouth tray mucocompressive impression technique was used in both acrylic and 3d printed denture groups to get better denture retention [15].

The mucocompressive technique was used instead of the intraoral scan for the 3D printed denture group because the intraoral scanner has many disadvantages in the complete denture workflow, such as making the impression in mucostatic conditions rather than mucocompressive conditions, as well as difficulty scanning with tissue retraction to obtain proper border seal. All these drawbacks may affect denture retention [16].

A tabletop scanner (DOV swing scanner) was utilized to scan the casts and jaw relationship information. The scanner utilized for all research groups employs structured white-light technology and has 7-micron precision, which is regarded as adequate to achieve decent findings [17].

Heat-cured acrylic resin is one of the most common methods of curing for many years in the field of dentistry [18]. Processing with a long cycle at 70°c for 9 hours 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 [19].

3D printing for denture building is a novel digital additive manufacturing technology that is now being compared to heat cured fabrication approach, which was previously assumed to be the primary technique for denture base creation. This approach was adopted because it allows for material conservation and can print complicated shapes with good dimensional accuracy [5].

For the virtual design of the printed denture, the incisive papilla and hamular notches were used to identify the midline since they are permanent landmarks whose placements do not alter with bone erosion [20].

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 [21, 22].

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 [23].

Another study investigated dimensional stability for printed dentures at different washing times and showed that increasing time does not increase cytocompatibility and may result in warpage, fissuring, and a loss in flexural strength [24].

Post-curing for printed parts was done with a post-curing machine for 30 minutes to increase long-term dimensional stability [25].

Bonded teeth printed denture was used instead of monolithic dentures because they are more aesthetically accepted and monolithic dentures require further cut back in denture base to add tissue color resin [26].

The location of the geometrical centre of the arch was chosen to measure the retention of the denture bases based on several previous studies which reported that it is the most reliable and fixed point to apply vertical and perpendicular dislodging force to test the retention of maxillary complete dentures [6].

The digital force gauge was chosen in this investigation because it is regarded as the simplest, most dependable, and most accurate technology for evaluating denture retention, having been utilized in several prior studies. The amount of effort required to dislodge the denture from its basal location inside the oral cavity using a force gauge was thought to be a measure of retention [7].

The patients were asked to sit on the dental chair so that the occlusal plane of the maxillary dentures was parallel to the floor. Patients were asked to fix their heads during the steps of the examination. Because any change in head position may alter the direction and length of traction.

To account for overall testing duration and participant convenience, patients were asked to take 10-minute intervals instead of longer periods during denture retention assessment. Soft tissues may not have fully conformed to their previous shape during this time frame. There were no significant differences between 10-minute intervals and longer periods [27].

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 [28].

Polymerization shrinkage during 3D printing is possible as the parts printed are not fully polymerized and still need post curing machine. Deformation may also occur during the removal of the denture base from the printing bed [29].

The result of this study showed superiority in terms of retention of the 3D printed dentures over the conventional dentures. Denture base retention depends on multiple factors including adaptation, dimensional changes, and accuracy of construction technique [6].

The result of the current study showed an increase in retention within each group over time and this might be attributed to the adaptive ability of the oral mucosa and the muscle of lips, tongue, and cheek to the new dentures as well as patient's tolerance.

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, and occlusal correction .... etc.

Conclusion

Within the limitation of this study, it was concluded that 3d printed dentures showed better retention compared to conventional heat-cured acrylic dentures. In addition, 3D-printed and conventional dentures showed a non-significant retention increase over the 3-month follow-up period but the change in denture retention (increase in retention) was more for the printed denture group.

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Data availability: The datasets generated and/or analysed during the current study are not publicly available due to ethical reasons but are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate: The study was approved by the Research Ethics Committee (REC) at Suez Canal University Faculty of Dentistry no (318/2021) and clinical trial gov registration (NCT05585008). All patients provided written informed consent before enrollment in the study, while all methods were performed in accordance with the Declaration of Helsinki as well as relevant guidelines and regulations.

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