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## Evaluation of Retention for Maxillary Complete Denture Constructed by Conventional and 3D Printing Techniques

Norhan Behairy

*Demonstrator of Removable Prosthodontics Faculty of Dental Medicine Misr International University, Cairo, Egypt., norhanbehairy.p5821@azhar.edu.eg*

Shereen Kabeel

*Assistant Professor of Removable Prosthodontics Faculty of Dental Medicine for Girls Al-Azhar University, Cairo, Egypt., shreenmmk@yahoo.com*

Hager El-Sadany

*Lecturer of Removable Prosthodontics, Faculty of Dental Medicine for Girls, Al-Azhar University, gogo\_elsadany@yahoo.com*

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## Evaluation of Retention for Maxillary Complete Denture Constructed by Conventional and 3D Printing Techniques

Norhan A. Behairy<sup>1\*</sup>, Shereen M. Kabeel<sup>2</sup>, Hager F. El-Sadany<sup>3</sup>

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azhardentj@azhar.edu.eg

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### ABSTRACT

**Purpose:** Evaluating retention of maxillary complete dentures fabricated by three-dimensional (3D) printing technique compared to conventional technique. **Subjects and Methods:** Ten completely edentulous patients were selected from the outpatient clinic of Removable Prosthodontics Department, Faculty of Dental Medicine for Girls, Al-Azhar University. Each patient received maxillary and mandibular dentures fabricated by conventional technique besides maxillary denture fabricated by 3D printing technique. All patients were divided equally into two groups; First group patients received conventional dentures first, then 3D printed ones. Second group patients received 3D printed dentures initially and conventional dentures later. **Results:** Regarding denture type, it was found that 3D printed dentures showed statistically significant higher retention at ( $P \leq 0.05$ ) compared to conventional dentures. Further, pair-wise comparisons between follow up times revealed that there was a statistically significant increase in mean retention values after one month as well as from one to three months. **Conclusion:** Utilizing 3D printing technique in complete denture fabrication yielded better retention compared to conventional technique. Nevertheless, regardless of denture type, retention improves over time.

### INTRODUCTION

Despite the vast abundance of treatment methods for edentulous patients, conventional complete denture treatment still prevails<sup>(1)</sup>. Nevertheless, problems may arise after insertion of complete dentures. Such problems are often complaints of insufficient retention, inadequate stability, tissue irritation, ulceration, and occasionally faulty esthetics<sup>(2)</sup>.

### KEYWORDS

Complete denture,  
3D printed Dentures,  
Retention

- Paper extracted from Master thesis titled "Evaluation of Retention, Accuracy and Patient Satisfaction for Maxillary Complete Denture Constructed by 3D Printing and Conventional Techniques."
- 1. Demonstrator of Removable Prosthodontics Faculty of Dental Medicine Misr International University, Cairo, Egypt.
- 2. Assistant Professor of Removable Prosthodontics Faculty of Dental Medicine for Girls Al-Azhar University, Cairo, Egypt.
- 3. Lecturer of Removable Prosthodontics Faculty of Dental Medicine for Girls Al-Azhar University, Cairo, Egypt.

\* Corresponding author email: norhanbehairy.p5821@azhar.edu.eg

One of the most used materials in complete dentures is Poly methyl methacrylate (PMMA)<sup>(3)</sup>. 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 affects denture retention, mastication and speaking ability. Thus, needs were raised for novel techniques to overcome complete dentures downsides<sup>(4,5)</sup>.

Incorporating Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) technology into complete dentures design and fabrication enhances dentures' quality and reduce lengthy laboratory work and procedures. CAD/CAM fabrication of complete dentures is attained by either subtractive Computerized Numerical Control (CNC) milling manufacturing, or by additive manufacturing via three-dimensional (3D) printing known as rapid prototyping (RP)<sup>(6,7)</sup>.

The subtractive manufacturing utilizes end-milling of solid block materials in order to produce physical model utilizing CNC machinery. Despite the subtractive method is effective in complete denture fabrication, it exhibits some drawbacks. Such downsides materialize in large amount of wasted material while milling, additionally, the milling tools are exposed to high abrasion and wear, moreover, it cannot be used in deep undercut<sup>(8)</sup>.

On the other hand, additive manufacturing is a process which entails layer by layer joining to produce models relying on computerized 3D data. This technology was introduced in late 1980s and has been used in the medical field for production of anatomical 3D models for surgeries since 1990s<sup>(9,10)</sup>.

Additive manufacturing using 3D printers has drawn attention in the field of prosthetic dentistry. Such technique materialized the ability to mold material based on CAD data influencing; the overall quality, the mechanical properties of printed parts, and the manufacturing time<sup>(11)</sup>. This study aimed to assess the retention of 3D printed maxillary dentures.

## SUBJECTS AND METHODS

Study scope was based on ten completely edentulous patients. The patients were selected from the outpatient clinic of Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University. Participants in this study were informed about the treatment steps, methodology, and written consent was granted accordingly (REC-PR-21-07). The targeted age range was from 55 to 60 years besides being free from any systemic and oral diseases. Each patient received two maxillary dentures; conventional and 3D printed, besides one mandibular conventional denture. The ten completely edentulous selected patients were divided into two equal groups, five patients each.

**1<sup>st</sup> Group:** Patients in this group had received their conventionally fabricated denture first then had been asked to take it off for 2 weeks as wash out period. Following to that they wore their rapid prototyped denture.

**2<sup>nd</sup> Group:** Patients in this group had worn their 3D printed denture first then had been asked to take it off for 2 weeks as wash out period. Following to that they wore their conventional denture.

### Denture Construction:

Conventional denture: Irreversible hydrocolloid impression material (Cavex alginate, Dust free, High consistency. Holland B. V.) was used to make primary impressions. Proper border molding with green stick compound (Tracing stick, Pyrax polymers, U.K.) was done followed by secondary impression using silicone impression material (poly-C-silicone impression material, thixoflex M, medium, Zhermack, Italy). Face bow was utilized to mount the maxillary cast on articulator device. Jaw relation was recorded at previously measured vertical dimension of occlusion using wax wafer technique. Accordingly, mandibular cast was mounted relying on centric jaw relation. Artificial teeth were set followed by try-in and delivery.

To get 3D printed denture, the below sequence was undergone per patient.

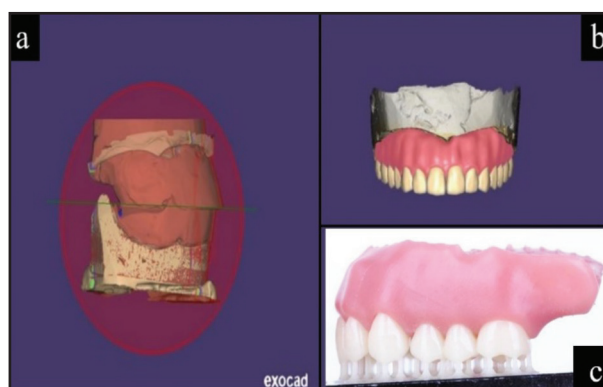
- i. Data acquisition: data obtained by scanning upper and lower master casts by extra-oral scanner (Sirona INEOS X5 scanner, Germany). The occlusion blocks were sprayed by scanner spray (Bilkim 3D scanning spray Menemen,Izmir,Turkey) then were fitted on their master cast. Following to that step the same device was used to scan the blocks.
- ii. Designing procedures: files in standard tessellation language (STL) format of master casts and jaw relation records were imported to Exocad™ software (ExoCAD DentalCAD;Exocad GmbH) platform (Fig.1.a). The software enabled virtually simultaneous mounting and aligning. This in turn allowed further analysis and designing to be completed (Fig.1.b). Each denture had two STL files that were printed separately; one for denture base, and one for the teeth using 3D printer (photon S, Anycubic, china).
- iii. Manufacturing procedures: the designed dentures STL files were sent to the 3D printer software. The dentures were printed with Stereolithography Apparatus (SLA) technology using desktop 3D printer. Pink denture base resin (NextDent Denture 3+, Netherlands) was used to print denture bases, whereas white teeth resin utilized for teeth printing. (NextDent Teeth, Netherlands). Afterwards, teeth were attached to recessed pockets in denture base via resin (Fig.1.c) followed by finishing. Eventually, denture was placed in post curing unit (Mogassam, Egypt).

### Retention measurements:

Retention was measured by universal testing machine (INSTRON, United states) by getting denture resistance corresponding to vertical displacement force (Fig.2). Each denture was modified to install two small metal tubes (3 mm in diameter). The tubes were mounted few millimeters above the laterals in maxillary dentures by self-cure acrylic resin. Both distances between the right tube to the geometric center and left tube to the same center were of similar values. The exact distance

for each tube was verified by the aid of orthodontic wire. Each patient was seated in an upright position, while properly fixing his chin on a support. The device's bar was firmly connected to the denture and in accordance the attachment part of the universal machine was adjusted. The device gradually exerted steps of increasing vertical load (10mm/min) until the denture came totally out of place. The load at dislodgment point is indicated by an audible tuck sound. Also, it is characterized by an abrupt drop in force plot in the recorded computer software data. (Nexyge- MT-4.6; Lloyd Instruments). The same test was repeated five times to obtain five records per patient at baseline, after one, and three months.

Based on data gathered for both groups at different post insertion recalls, further statistical analysis was carried out for retention evaluation.



Figure(1) a. STL file of master casts and jaw relation imported to Exocad software. b. Designing of the denture. c. Teeth attached to denture based.

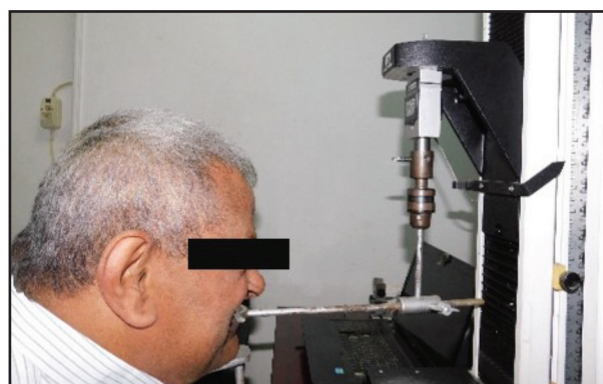


Figure (2) Retention measurement using universal testing machine

## RESULTS

### Retention:

Two-way repeated measures ANOVA results reflected that the two variables (denture type regardless of time, and time regardless of denture type) are independent. Regarding effect of different interactions on retention, it was found that at base line, after one as well as three months; 3D printed dentures showed statistically significantly higher

mean retention than conventional denture (P-value = 0.028, Effect size = 0.432), (P-value = 0.026, Effect size = 0.442) and (P-value = 0.017, Effect size = 0.489). With both denture types, there was a statistically significant change in mean retention values by time (P-value <0.001, Effect size = 0.947) and (P-value <0.001, Effect size = 0.89). Pair-wise comparisons between follow up times revealed that there was a statistically significant increase in mean retention values after one month as well as from one to three months. Table 1, fig.3

**Table (1)** The mean, standard deviation (SD) values and results of two-way repeated measures ANOVA test for comparison between retention values with different interactions of variables

Time	Conventional		3D Printed		P-value (Between dentures)	Effect size (Partial eta squared)
	Mean	SD	Mean	SD		
Base line	15.5 <sup>C</sup>	4.3	20 <sup>C</sup>	3.2	0.028*	0.432
1 month	18 <sup>B</sup>	3.9	22.5 <sup>B</sup>	3.2	0.026*	0.442
3 months	20 <sup>A</sup>	3.8	24.3 <sup>A</sup>	3.8	0.017*	0.489
P-value (Between times)	<0.001*		<0.001*			
Effect size (Partial eta squared)	0.89		0.947			

Significant at  $P \leq 0.05$ , Different superscripts in the same column indicate statistically significant change by time

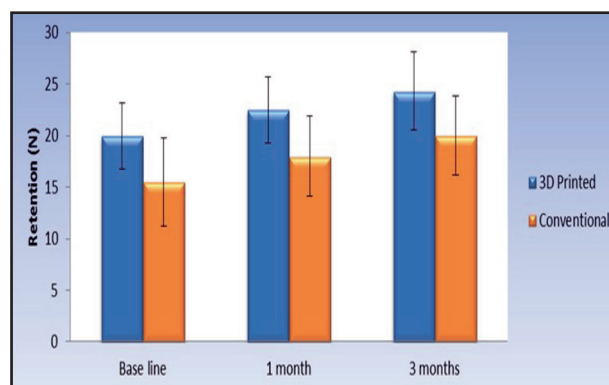


Figure (3) Bar chart representing mean and standard deviation values for retention with different interactions of variables

## DISCUSSION

In this study retention for two different manufacturing techniques of complete dentures, 3D printed and conventional, were compared. Retention is an inherent factor that greatly influences patient satisfaction, which is considered as an important outcome that enables better evaluation of success of any prosthesis<sup>(12)</sup>.

Several studies have proven that the dentures fabricated from conventional processing techniques suffer from dimensional changes due to polymerization shrinkage and release of internal stresses. That resulting distortion compromises retention besides support and stability of the denture, which lead to adverse consequences on



the patient's satisfaction. This in turn substantiated the need for advanced techniques in fabrication of complete dentures<sup>(5,13,14)</sup>.

The result of this study showed superiority in retention of the 3D printed dentures over the conventional dentures. This could be attributed to the utilized denture construction technique; this technique was attained by additive manufacturing methods that created the object by successive layering of photosensitive resin, then UV light polymerizing it. This technique was used because it allows material conservation and exhibits the ability to print complex geometries with reasonable dimensional accuracy. The dimensional changes of each layer are compensated by addition of the successive resin layer<sup>(15)</sup>.

In accordance with the findings of this study, other recent studies indicated that 3D printed dentures exhibited better retention compared to conventional dentures; the main reason was that 3D printed dentures revealed less shrinkage and distortion, along with consistent better adaptation compared to conventional dentures<sup>(15-17)</sup>.

The prolonged success of prosthesis is pivoted on the optimum fit attained between denture base and mucosal tissue, which in turn yields good retention. Recent studies evaluated denture bases manufactured by CAD/CAM and conventional techniques, these studies used surface matching software focused on accuracy of the denture base. The findings revealed that higher deformation was in the conventionally made dentures, whilst less deformation was associated with rapid prototyped dentures<sup>(11,18-20)</sup>.

On the contrary to the results of this study another invitro study evaluated denture base adaptation of digitally and conventionally fabricated dentures, exhibited superiority of denture adaptation of conventional dentures over digitally fabricated dentures<sup>(21)</sup>. This could be explained as 3D printing technique relied on utilization of unpolymerized resins for manufacturing complete dentures. Upon den-

ture processing, final light-polymerization step was mandated to fulfill the process, thus, polymerization shrinkage became theoretically possible throughout the workflow.<sup>(22)</sup>

## CONCLUSION

In the context of the subject study and the associated constraints, it was concluded that 3D printed dentures exhibit better retention. Additionally, independent of denture type, retention improved over time. However, further studies need to be conducted.

## RECOMMENDATION

Further studies need to be conducted to better evaluate effect of 3D printed technique on denture retention.

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## CONFLICT OF INTEREST:

The research team avails no conflict of interest

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