EFFECT OF THREE-DIMENSIONAL (3D)-PRINTED COMPLETE DENTURES VERSUS CONVENTIONAL COMPLETE DENTURES ON CHEWING EFFICIENCY

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Abstract

Background: Chewing efficiency is one of a problem related to complete dentures wearers. Despite that digital technology simplified the complete dentures workflow steps; however masticatory efficiency is underreported.
Methodology: This crossover study was performed on 10 completely edentulous patients divided randomly in to two equal halves, each patient 5 patients received a complete denture constructed following conventional technique (Group I) for 3 months, and after 2week wash-out period each patient received a 3D printed complete denture for 3 months. While other 5 patients received 3D printed complete denture for 3 months, and after 2-week wash-out period received a complete denture constructed following conventional technique(Group II) for 3 months. Chewing efficiency was evaluated immediately at denture insertion, after 1 month, and after 3 months by using the standardized chewing test units.
Results: The present results revealed significant improvement in chewing efficiency by time in both groups as P<0.05 regarding soft, medium, and hard consistency. Comparison between both groups revealed a significant difference at T0 and T1 in hard consistency only, while in T2 group I was significantly higher than Group II in all consistencies as P<0.0001.
Conclusion: 3D printed dentures revealed lower-chewing efficiency if compared with conventional complete dentures, especially after 3 months.

Keywords:3D printed, Chewing efficiency, conventional denture.

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1. INTRODUCTION

Despite the last generation's edentulism incidence declining, the total number of edentulous patients is rising as a result of the longer life expectancy [1]. Complete tooth loss (edentulism) affects the orofacial region's appearance, phonetics, and function, which lowers quality of life [2].
For centuries, edentulous patients were rehabilitated with complete dentures (CD) [5] which replaces the entire dentition and related structures of the maxilla and mandible with an acrylic-based, removable prosthesis. However, due to their poor fit, limited retention, and instability, removable complete dentures present a significant issue, especially in cases of extensive alveolar ridge rebsorption, which causes discomfort and chewing difficulty [2,3].
Moreover, the fabrication of conventional complete dentures involves a complex workflow and needs considerable time. Acrylic teeth debonding from the denture foundation, especially to the anterior teeth, is a significant issue with complete dentures, accounting for between 22 and 30 percent of all denture repairs [4,5].
Digital technologies for making denture bases are now, including three-dimensional (3D) printing and computer-aided manufacture (CAM) [6]. Denture bases can be produced using digital techniques in a single block. The advantages of digital methods are saving time and simplicity of workflow which can reduce the probability of errors and accordingly provides denture with better fit, retention, and stability. Moreover, the phase of adhering the denture teeth is eliminated using digital manufacturing techniques like CAD/CAM and 3D printing [7].
The effectiveness of chewing can have an impact on an elderly patient's nutritional status. Complete denture wearers frequently struggle with chewing and fail to respond to food hardness by increasing muscle activity per masticatory cycle. As a result, they often compensate by chewing for longer periods of time, performing more chewing cycles at a slower masticatory rate, and swallowing larger food particles [8,9]. It is expected that chewing

capacity will improve denture delivery with an improved fit, retention, and stability following rehabilitation with complete dentures, within the bounds permitted by the anatomical and tissue circumstances [10,11].

Therefore, the purpose of this study was to investigate the impact of various denture manufacturing methods on patients who had received complete dentures for rehabilitation.

2. MATERIALS AND METHODS

- **Study design:**

Across-over study in which ten completely edentulous patients were selected, each patient received 2 dentures (Total number of dentures 20). The participants were randomly divided into two groups. Randomization was performed using a computer-generated list. Group I 5 Patients received conventional complete dentures, then chewing efficiency were tested using the three STU consistency at intervals of 1- immediately at insertion 2-one month 3 – three months. Then, after two-weeks washout period patients received 3D printed complete dentures for 3 months then chewing efficiency were recorded for group II at the same intervals, while of (Group II) 5 Patients received 3D printed complete dentures then chewing efficiency were tested using the three STU consistency at intervals of 1- immediately at insertion 2-one month 3 – three months. Then, after two-weeks washout period patients then received conventional complete dentures, chewing efficiency were recorded at the same intervals. All participants were notified of the change of complete denture during the study.

- **Sample size calculation**

According to the prior study (Ahmed N. Elsherbini1 2020), when the standard deviation is 0.65, the sample size was determined using the PS program. The minimum number of dentures accepted was 8 per group, which was then expanded to 10 dentures per group after adding 15% for dropout. The estimated mean difference between a conventional denture and a 3-D printed denture is 0.75, with 80 percent power and 0.05 type I error probability. In this trial, a total of 20 dentures were required [12].

- **Ethical Approval:**

All participants were informed the purpose and scope of the study and signed an informed consent before the study beginning. The Minia University Ethical Committee issued a certificate of ethical approval bearing the approval number **473/2021**.

- **Patients Selection Criteria:**

All patients were completely edentulous patients ages ranging from 45-55 years with previous denture experience. A proper clinical examination was performed on the evaluated condition of residual alveolar ridges and denture-bearing area. Patients have healthy firm mucoperiosteum, oral salivary secretion should be within the average amount and consistency, Angle's Class I maxillomandibular relationship. On the other hand, in patients with inadequate neuromuscular coordination and with temporomandibular disorders disorder, abnormal or para-functional habits such as clenching, and bruxism were excluded.

- **Denture construction:**

Conventional denture construction

Preliminary impressions were made using irreversible hydrocolloid impression material (*Cavex, Holland*). Secondary impression was performed by using zinc oxide and eugenol with border molded special tray and used as final impressions. Impressions were disinfected, boxed, and poured into dental stone.

Occlusion blocks were fabricated, Elite maxillary face bow record was taken and transferred to a semi-adjustable Bioart, then centric relation was recorded using bite wax wafer technique and mounting articulator was done. Setting up of anatomic teeth (*Acrostone Egypt*), the master cast was scanned for another 3-D printed denture construction, a try-in was performed, waxing up and A rubber index was taken of the waxed up tri-in to reproduce the thickness of the polished surface of the printed denture. Master cast and waxed up tri-in were scanned, then processing was done. Finally, denture delivery was made after checking proper extension, retention, and stability. The patient was informed about the proper oral hygiene measures.

- **3D printed denture:**

The files from the scanned (Mediate 500 scanner) master casts with wax up tri –in (**Figure 1**) were translated into stereolithography (STL) files, superimposition of the master cast with the waxed-up try-in and final design of the prosthesis were finalized using Blender software (Blender Australian)(**Figure 2**),printing of 3D virtual complete denture was printed with photosynthesized resin (*PHROZEN, Taiwan*) using 3D printer (*phrozen printer , Taiwan*).

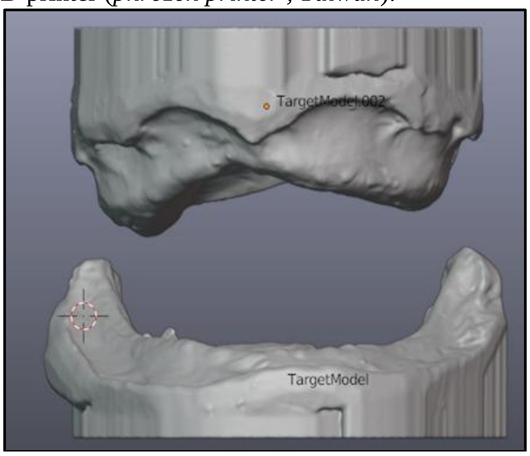

Figure (1): Scanned master casts.

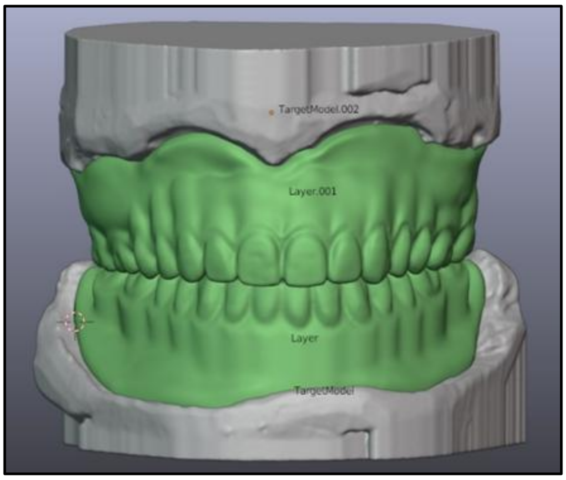

Figure (2): Virtual complete denture

Evaluation of chewing efficiency:

Patients received standardized chewing test units (SCT) from BREDENT to measure chewing effectiveness. The SCT is a prefabricated unite for testing made from jelly material that is spherical and uniform in size. It is offered in three colors mild, medium, and hard consistencies. Red is hard, yellow is medium, and green is soft, imitating the textures of natural foods. The patient's ability to cut the rounded unit into pieces is used to gauge their level of chewing efficiency (**Figure 3** and **Figure 4**); the more pieces they can cut, the better the efficiency. The soft unit was supplied to the patients initially, and chewing began for 10 full cycles. The same process was followed for the units at all intervals in both dentures.

Figure (3): Pattern of chewing in conventional complete denture

Figure (4): Pattern of chewing in 3D printed denture.

STATISTICAL ANALYSIS:

All data were tabulated in Microsoft Excell2010, then data were exported to SPSS 20® (Statistical Package for Social Science) to conduct the statistical analysis. Using the Kolmogorov-Smirnov and Shapiro-Wilk tests, which revealed non-parametric data, all the data were checked for normality. Standard deviation (SD)and means (M) were used to represent the data.

The Friedman test was used to compare data from various time points within each group in order to assess how time affected chewing effectiveness. Additionally, Man Whitney's analysis was done to determine the significance between the two groups during each subsequent visit. At $P<0.05$, the significant level was established.

3. RESULTS

Effect of time (Comparison between different intervals):

The present results revealed significant improvement in chewing efficiency by time in the conventional denture as a T0 was (1.2 ± 0.42), (1.5 ± 0.71), and (1.4 ± 0.7) then significantly increased at T1 to (3.0 ± 0.67), (3.2 ± 0.63), and (4.2 ± 1.23), finally at T2 non significantly increased to (3.1 ± 0.57), (3.4 ± 7), and (5.4 ± 1.58) regarding soft, medium, and hard consistency respectively. as presented in **Table (1)** and **Figure (4).**

In 3D printed denture as a T0 was (1.3 ± 0.48), (1.6 ± 0.7), and (1.1 ± 0.32) then significantly increased at T1 to (3.2 ± 0.63), (3.3 ± 4.8), and (4.3 ± 1.25), finally at T2 there was a significantly decreased to (1.2 ± 0.42) and (1.8 ± 79) regarding soft and medium respectively while there was insignificant decrease in chewing efficiency to (2.7 ± 0.95) in hard consistency. as presented in **Table (1)** and**Figure (4).**

Effect of chewing material consistency:

Comparison between different consistencies revealed insignificant differences at T0 and T1 in both dentures, while at T2 hard consistency revealed significantly higher results than medium and soft consistencies in both dentures as P<0.05, as presented in **Table (1).**

Effect of manufacturing technique (Comparison between different dentures):

Comparison between both dentures revealed insignificant differences at T0 and T1 in soft, medium and hard consistencies While in T2 conventional denture was significantly higher than 3D printed denture and revealed better chewing efficiency as P<0.0001, as presented in **Table (2)** and**Figure (5).**

Table (1): Mean and standard deviation of chewing efficiency at T0, T1 & T2 and comparison between them regarding soft medium and hard consistency in both dentures

Group	Consistency	T0		T1		T2		P value Friedman`s test
		M	SD	M	SD	M	SD	
Conventional CD	Soft	1.20 aA	0.42	3.00 bA	0.67	3.10 bA	0.57	<0.0001*
	Medium	1.50 aA	0.71	3.20 bA	0.63	3.40 bA	0.70	<0.0001*
	Hard	1.40 aA	0.70	4.20 bA	1.23	5.40 bB	1.58	<0.0001*
	P value	0.66		0.07		0.001*		
3 d printed CD	Soft	1.30 aA	0.48	3.20 bA	0.63	1.20 aA	0.42	<0.0001*
	Medium	1.60 aA	0.70	3.30 bA	0.48	1.80 aA	0.79	<0.0001*
	Hard	1.10 aA	0.32	4.30 bA	1.25	2.70 abB	0.95	<0.0001*
	P value	0.12		0.11		0.005*		

T0: Baseline T1: after 1-month T2: after 3 months

M: mean SD: standard deviation *Significant difference as P<0.05.

Lower case indicting significance in each group at different time intervals

Upper case indicating significance within each group with different standardized chewing testing units' consistencies.

Means with different superscript letters were significantly different (lowercase per raw / upper case per column) as P<0.05.

Means with the same superscript letters were insignificantly different (lowercase per raw / upper case per column) as P>0.05.

Table (2): Mean and standard deviation of chewing efficiency in both groups and comparison between them at T0, T1 & T2 regarding soft medium and hard consistency

Consistency	Group	T0		T1		T2	
		M	SD	M	SD	M	SD
Soft	Conventional denture	1.20	0.42	3.00	0.67	3.10	0.57
	3D printed denture	1.30	0.48	3.20	0.63	1.20	0.42
	P value (Mann Whitney's test)	0.99 ns		0.67 ns		<0.001*	
Medium	Conventional denture	1.50	0.71	3.20	0.63	3.40	0.70
	3D printed denture	1.60	0.7	3.30	0.48	1.80	0.79
	P value (Mann Whitney's test)	0.89 ns		0.98 ns		<0.0001*	
Hard	Conventional denture	1.40	0.7	4.20	1.23	5.40	1.58
	3D printed denture	1.10	0.32	4.30	1.25	2.70	0.97
	P value (Mann Whitney's test)	0.45 ns		0.97 ns		0.0002*	

T0: Baseline T1: after 1-month T2: after 3 months

M: mean SD: standard deviation

*Significant difference as P<0.05. ns: non-significant difference as P>0.05.

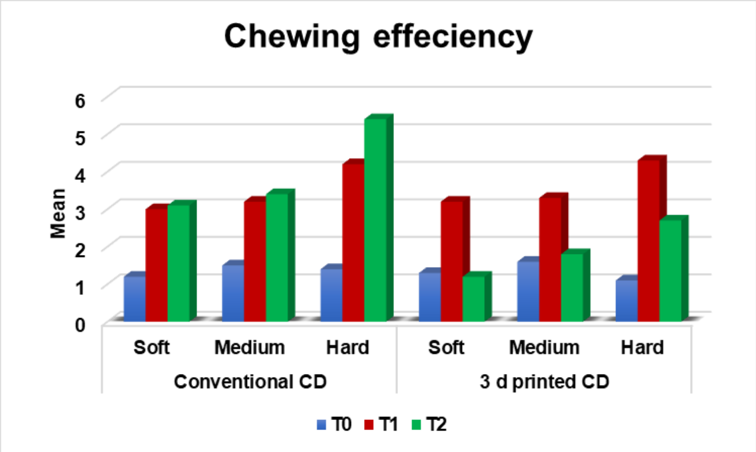

Figure (5): Bar chart representing chewing efficiency in both dentures at different intervals at all chewing consistencies.

4. DISCUSSION

All selected patient`s ages ranged from 45-55 as they can follow instructions easily, without para functional habits, with normal neuromuscular coordination which may affect the muscular activity and chewing efficiency [12,14]. Each patient received 2 dentures (Cross over study) to reduce inter-subject response variability and the impact of confounding factors and to promote statistical efficiency, each participant in this study received two sets of dentures [13]. In this study all selected patients had previous denture experience as previous patient experience has been acknowledged as a critical dimension of health-care quality alongside patient safety and clinical effectiveness [15].

The quantity of chewed particles in this study serves as a measure of chewing efficiency. On the other hand, other research compared the effectiveness of chewing by the size of the particle, finding that the smaller the size, the better the effectiveness [16,17]. But both approaches produced the same results because there is a relationship between particle size and number; this relationship is inversely proportionate; as the number of particles increased, the size of the particles shrank [18,19].

There was a statistically significant difference between the three consistencies at T2 in conventional denture and 3D printed for chewing efficiency. It was chopped into more pieces in the hard consistency than in the soft or medium consistency. This can be attributed to the teeth's better ability to manage hard structures, which can be moved about more easily and are therefore better suited for chewing. Because the medium and soft are gummier and difficult to maneuver, there is less tooth control and cutting [20,23].

Comparison between both dentures revealed significant difference at T2 as conventional denture revealed better chewing efficiency than 3D printed denture which may be attributed to lower hardness of 3D printed resins if compared with conventional materials, another studies were in accordance with this study as it was revealed that heat cured PMMA showed better flexural, bond, impact strength and hardness, while 3D printed resins revealed high surface roughness and porosity [24-25].

5. CONCLUSION

Within the limitations of this study, it was concluded that both techniques of denture fabrication improved chewing efficiency after 1 month, while after 3 months conventional complete denture showed better chewing efficiency if compared with 3 D printed complete denture. Although the procedure of fabrication of conventional complete denture is more complicated but provided better masticatory performance.

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