AL-AZHAR
Journal of Dentistry

The Official Publication
of The Faculty of Dental
Medicine For Girls,
Al-Azhar University
Cairo, Egypt.

Print ISSN 2974-4156 • Online ISSN 2974-4164

AZJD, Vol. 10, No. 2, April (2023) — PP. 301:307

Effect of Rapid Prototyped Complete Denture on Electromyographic Activity

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Codex : 1-03/23.04

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http://adjg.journals.ekb.eg

DOI: 10.21608/adjg.2023.103072.1427

Restorative Dentistry
(Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

ABSTRACT

Purpose: This study was directed to evaluate the electromyographic activity (EMG) of patients with rapid prototyped (RP) complete denture. **Subjects and methods:** A total of ten completely edentulous subjects aged between 45-50 years were selected following specific inclusion criteria from the outpatient clinic of Removable Prosthodontics Department, Faculty of Dental Medicine for Girls, AL-Azhar University. All Patients had received two complete dentures; one constructed by rapid prototyped technology and the other constructed by conventional heat compressed method. Patients were classified into two groups, five patients in each. First Group received the RP complete denture first then the conventional complete denture (CCD) while, second group received the (CCD) first then RP complete denture. All patients were instructed to wear their denture for equal periods and recalled after 1- week, 1- month and 3- months to measure the (EMG). After an interval of 2- weeks, as a wash out period, patients received their other dentures. **Results:** Conventional complete denture showed significant higher EMG than RP denture at different testing periods and with different tested foods. Also, the EMG of both masseter and anterior temporalis muscles improved with time for each tested denture. **Conclusion:** Conventional complete dentures still the best rehabilitation choice for completely edentulous patients. Rapid prototyped denture could be suitable alternative for completely edentulous patients.

KEYWORDS

Complete dentures,
Electromyographic activity,
Rapid prototyping

INTRODUCTION

For decades, denture construction for rehabilitation of completely edentulous patients did not changed substantially and its fabrication technique was based mainly on the traditional compression molded method which compelling frequent clinical appointments and multiple clinical and laboratory steps started from recording the preliminary

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impressions to denture delivery [1,2]. These frequent steps usually require massive human intervention and comprehensive material handling, which may cause some processing errors, inaccuracies, and lengthen the fabrication time [2].

Implementation of the newly developed digital technology such as rapid prototyping technique as alternative method for denture fabrication seemed to simplify the required procedures for denture fabrication as it markedly reduced the required number of clinical visits [3,4]. This fabrication method is totally digitalized and utilize digital scanner for recording the detailed scanned information of the desired restoration which digitally analyzed via special software and finally manufactured by digitally controlled 3-D printer through adding of successive layers of the material liquid which cured with ultraviolet (UV) light curing unit [5,6].

Electromyography usually measure the activity of muscle during function and subsequently its masticatory efficiency which is markedly affected by various factors such as patients age and gender, food texture (soft/hard), and mandibular movement [7,8]. Also, other psychological factors included fear of pain or fracture could have a great influence on muscular activity reduction. Moreover, denture instability, improper retention, and interference with process of mastication are also considered as determinable factors that could markedly influence the recorded muscular activity [7,9].

Thus, the present study was directed to evaluate clinically the electromyographic activity of patients wear dentures fabricated by rapid prototyped technology in comparison to the conventional complete denture.

SUBJECTS AND METHODS

A prospective cross-over clinical study, involved ten completely edentulous, medically free, male subjects aged between 45-50 years were selected from the Outpatients' Clinic of Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University. The selection of the enrolled subjects was based on presence of well-developed alveolar ridge with uniform reduction, temporomandibular joint (TMJ) with no functional or neuromuscular disorders, and angle class I maxillomandibular relation, as well as absence of bruxism, abnormal eccentric occlusion, or xerostomia [10,11]. Ethical approval was obtained from Research Ethics Committee (REC) Faculty of Dental Medicine for Girls, Al-Azhar University with approval code (REC-PR-21-06) before starting this study.

Denture Construction:

For all patients, primary impression was taken to record the upper and lower edentulous ridges and their related structure with irreversible hydrocolloid impression material in a stock tray with proper size. The impression was poured with plaster to fabricate diagnostic cast and construction of special acrylic tray. Then, the secondary zinc-oxide-eugenol (ZOE) impression was taken and poured with improved stone to construct the master cast. After that, the master cast was duplicated with the aid of rubber-base impression material. The original master cast was used to construct the CCD with conventional procedure according to the manufacture instructions [11,12].

While the printed denture was fabricated via Digital Light Projection (DLP) technology, the duplicated cast was used to fabricate RP denture which sent to lab to be digitally scanned with lab scanner, and printed with 3-dimentional printer (Anycubic Photon S made in china), by applying liquid monomer (Next-Dent Base liquid) layer by layer with the aid of digital software, and cured in UV unit during printing. Then, each printed denture was cleaned by rinsed for 5 min in 99 % solution of isopropylethyl (IPE) alcohol and finally dried. Finally, each printed denture was finished and polished according to manufacturer instruction [6, 13]. (fig.1)

The printed maxillary and mandibular dentures for each patient were used as record blocks with occlusal wax rims and finally the acrylic teeth of suitable dimensions were bonded to the denture base with autopolymerized acrylic resin and then clinically adjusted.

Figure (1) A photograph showing Anycubic Photon S 3D printer

Figure (2) A photograph showing EMG of masseter muscle

Subject Grouping:

The enrolled patients were grouped into two groups, then each patient in each group had received two upper and lower complete dentures; one constructed by RP technology and the other constructed by heat compressed traditional method. In the first group; patients were received RP complete denture first then conventional complete denture (CCD), while, in second group patients were received CCD first then RP complete denture.

Electromyography Recording:

In each group the enrolled subjects were informed to wear their first denture and recalled after 1- week, 1-month, and 3-months to measure the EMG for each patient in their related group. After that, each subject in each group was left without denture for 2-weeks (wash-out period), then the patients received their other denture. The EMG for each patient in their related group was measured after 1-week (base-line), 1-month, and 3-months. Electromyographic activity of masseter and anterior temporalis muscles for each tested denture was measured with 3 different testing food (silicon index, soft food/banana, and hard food/carrot) of standard size (13x13x13mm) [14]. (fig.2)

During EMG recording; subjects were settled in upright position with their head unsupported. The bipolar electrodes of the EMG were placed on the masseter muscle bellies on both right and left side in position parallel to the orientation of the muscle fiber. A third electrode was placed on the palm of the subject hand. The test food samples were chewed for 10 sec and the reading were recording. The same procedure was repeated with temporalize muscle with a 2 min period of recovery rest between the two records [14]. All results were collected and statistically analyzed with ANOVA test with level of significance of $P \leq 0.05$.

RESULTS

The EMG activity of anterior temporalis muscles during clenching, soft food and hard food at different time:

The results of the EMG of anterior temporalis muscles during clenching, eating soft and hard food at different time intervals (1- week, 1- month, and 3-months) showed a significant differ+ence between the CCD and RP denture at all tested periods. The CCD recorded the higher mean EMG values for anterior temporalis muscles at different tested periods, Table 1.

Table (1) *Comparison between rapid prototyped denture and CCD according to EMG signals of anterior temporalis muscles during clenching, eating soft and hard food.*

Temporalis	Variable	Follow-up periods (mean ±SD)			P-value
		1 week	1 month	3 months	
Clenching	RP	110.96±2.73^{Aa}	132.62±8.12^{Ba}	213.36±5.75^{Cb}	<0.0001*
	CCD	130.26±6.29^{Ab}	192.73±6.82^{Bb}	214.07±10.35^{Cb}	
	P-value		<0.0001*		
Soft food	RP	97.52± 6.17^{Aa}	127.87± 17.97^{Ba}	160.65± 23.79^{Ca}	<0.0001*
	CCD	136.32± 7.42^{Ab}	175.82± 15.82^{Bb}	195.13± 12.9^{6C}b	
	P-value		<0.0001*		
Hard food	RP	116.3±6.98^{Aa}	198.3±10.16^{Ba}	236.56±8.15^{Ca}	<0.0001*
	CCD	164.72±9.13^{Ab}	205.22±7.31^{Bb}	243.82±15.57^{Cb}	
	P-value		<0.0001*		

*Different superscript letter indicates a statistically significant difference within the same horizontal row. Different small-script letter indicates a statistically significant difference within the same vertical column. *; significant (P ≤ 0.05), ns; non-significant (P>0.05).*

The EMG activity of anterior masseter muscles during clenching, soft food and hard food at different time:

The results of the EMG of masseter muscles during clenching, eating soft and hard food at different time intervals (1- week, 1- month, and 3-months) showed a significant difference between the CCD and RP denture at all tested periods. The CCD recorded the higher mean EMG values for masseter muscles at different tested periods, Table 2.

Table (2) *Comparison between rapid prototyped denture and CCD according to EMG signals of masseter muscles during clenching, eating soft and hard food.*

Masseter	Variable	Follow-up periods (mean ±SD)			P-value
		1-week	1-month	3-months	
Clenching	RP	179.12±10.94^{Aa}	215.97±24.59^{Ba}	228.35±14.97^{Ca}	<0.0001*
	CCD	234.72±34.28^{Ab}	264.18±36.77^{Bb}	343.5±23.30^{Cb}	
	P-value		<0.0001*		
Soft food	RP	118.88±10.48^{Aa}	197.93±30.99^{Ba}	242.5±19.29^{Ca}	0.0006*
	CCD	172.35±19.35^{Ab}	210.05±12.12^{Bb}	260.20±30.11^{Cb}	
	P-value		<0.00001*		
Hard food	RP	171.9±14.43^{Aa}	264.75±23.89^{Ba}	312.15±14.13^{Ca}	<0.0001*
	CCD	217.15±23.38^{Ab}	290.45±16.78^{Bb}	347.43±24.73^{Cb}	
	P-value		<0.0001*		

*Different superscript letter indicates a statistically significant difference within the same horizontal row. Different small-script letter indicates a statistically significant difference within the same vertical column. *; significant (P ≤ 0.05), ns; non-significant (P>0.05)*

DISCUSSION

Denture instability, improper retention, and interference with process of mastication are also considered as determinable factors that could markedly influence the recorded muscular activity[7,9]. Hence, this study was directed to evaluate the electromyographic activity (EMG) of patients with rapid prototyped (RP) complete denture.

In this study, ten completely edentulous patients with age ranging from 40 to 50 were included to avoid muscle changes due to senility and muscle fatigue, as the performance of the masticatory muscle decrease with the increase of age [14]. Also, the patients selected for this study were only male to avoid the excepted discrepancy in muscle efficiency between both genders [14,15]. As it was reported that the female patients showed lower masticatory efficiency than the males in the same age group which may be due to psychological factor or hormonal disorders [16,17].

Additionally, patients with TMJ function or neuromuscular disorders were excluded from this study to avoid any possible disturbance in muscle tone or muscle behavior and hence the resultant masticatory efficiency [14,18]. Moreover, patient with well-developed alveolar ridge with uniform reduction and firm alveolar mucosa were included in this work as it was found that the existence of flabby mucosa and/or flat ridges could showed negative effect on the denture stability and hence its proper function [19].

Patient with bruxism, unwanted habitual eccentric motions, excessive salivation or xerostomia were excluded, as these factors could adversely affect the denture retention, stability, and hence the expected functional rating of the denture [14,20].

In this study, each enrolled patient received both types of dentures (conventional and rapid prototyped) alternatively to avoid bias that could resulted because of individual variations [21].

During fabrication of the 3D-printed denture in this study, the digital scanner was used for scanning the master cast because the intra-oral scanner cannot capture the extensions of soft tissue adequately which needed for the stability of the removable prosthesis without the existence of the conventional border molding [22]. Also, DLP technology were used in the fabrication of the printed denture as it uses digital "micro-mirror" device that produce printed objects with fast and accurate manner [23]. However, the printed denture bases were rinsed for 5 minutes in 96% IPE alcohol to remove the uncured resin material. Also, the clean printed dentures were placed for 15 minutes in a UV- light curing unit to insure the full conversion of polymer [24].

The EMG was selected as the test method in this study for recording the masticatory function. This was due to the fact that it provided a safe, simple, and noninvasive method for objectively quantifying muscle energy [25]. Also, in this study, the EMG activity of the masseter and anterior temporalis muscles was used to assess the masticatory function of CCD and RP dentures. Because these muscles are the strongest, largest, and the most superficial masticatory muscles, they are also accessible to surface EMG examination [14].

Preformed silicon index was used in this study to measure the muscle activity during clenching [14]. Moreover, carrot (hard food) and banana (soft food) were selected as test foods in this work, because of their natural testing and their suitability for easily grinding and mixing in patients with complete dentures [26]. While, a small symmetrical cubs of a standardized 13 mm dimensions of silicon index, carrot, and banana were used in this study to eliminate the influence of different food size on muscular efficiency [14].

During EMG recording, the patients were seated in an upright position to ensure proper muscle relaxation and to avoid the negative postural effect on the recorded muscle activities [27]. Also, the bipolar electrodes were placed parallel to the fiber

orientation on the muscles' bellies because higher electrical activity was recorded from electrode pairs parallel to the muscle fibers [28].

The results of this study showed a significant increase in muscular activity measured by EMG for the CCD when compared with RP dentures, with higher mean scores of EMG activity for the CCD for masseter and temporalis muscle during clenching on a preformed silicon index when chewing soft and hard food after three months. This result may be due to the better retention and stability of the CCD as well as the better flexural strength of these dentures when compared to RP dentures [4,29].

Moreover, the result showed that the EMG activity of the masseter and temporalis muscles during chewing hard food was higher than chewing soft food. This finding also agreed with previous study [30], which stated that harder food consistency requires higher muscle activity levels due to the higher muscle force needed to comminute hard food. Also, the results revealed that the masseter muscle showed higher muscle activity compared to anterior temporalis muscle. These results were in accordance with the results of a previous study [14]. This may be due to the multiple functions of anterior temporalis muscle [31].

Additionally, the results showed that the mean of EMG activity increased with time in both CCD and RP dentures in either the masseter or anterior temporalis muscles (i.e. the longer the period of denture wearing, the better the neuromuscular control gained). This may be due to the chewing efficiency showed a marked increase by time because of improving denture adaptation, which may be due to the improved neuromuscular control which is gradually and slowly generated by time [14].

CONCLUSIONS

Conventional complete dentures are still the best rehabilitation choice for completely edentulous patients. Although, Rapid prototyped denture could be a suitable alternative for those patients.

RECOMMENDATIONS

1. Further studies are required to evaluate the clinical outcomes of the dentures manufactured by the rapid prototyping digital method.
2. More sample size may be also required to evaluate the clinical outcomes of the dentures manufactured by the rapid prototyping digital method.

CONFLICT OF INTEREST

There is no conflict of interest in this work.

FUNDING

There is no funding from any institute.

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