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The Effect of Different Occlusal Schemes on Masticatory Performance for Conventional and Digital Complete Dentures

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KEYWORDS

PMMA resin, 3D printing, Balanced Occlusion, Lingualized Occlusion, Masticatory Performance.

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ABSTRACT

Aim: to evaluate effect of different schemes of occlusion; bilateral balanced occlusion (BBO) and lingualized occlusion (LO) of conventional and digital (3D printing) complete dentures on masticatory performance (efficiency). **Subjects and Methods**: Ten completely edentulous patients were selected randomly. Then received a complete conventional and digital (3D printing) denture with BBO. After three months, all patients were recalled for recording mean values of masticatory efficiency that was evaluated by assessing the chewing time and number of strokes until first swallow and until clearance of the mouth from food using different types of food (carrot, apple and banana). The occlusal schemes were interchanged to LO schemes on the patients' denture bases, reinserted in the mouth with resting period three weeks between occlusal schemes. Then, masticatory efficiency measurements were recorded as mentioned before. One way ANOVA was used for comparison of the different dentures followed by Tukey HSD post hoc test used to compare between every two dentures. The significance level was set at P-value ≤ 0.05. Statistical analysis was performed using IBM® SPSS® Statistics Version 20 for Windows. **Results:** The results showed no significant difference in masticatory performance between different occlusal schemes or between conventional and 3D printing dentures and the patients were satisfied by the masticatory function when eating different types of food. **Conclusion:** BBO as LO penetrated the food polus well and provide more stability and favorable stress distribution in parafunctional and excursive movements. However, 3D printing dentures with BBO were somewhat better than other dentures

INTRODUCTION

Different techniques have been described for fabricating complete dentures (CDs). The conventional protocol for fabrication involves a complex sequence of multiple clinical and laboratory steps averaging at least 5 clinical appointments, if the patient approves the overall esthetics at the wax trial insertion appointment before the dentures are processed. Even though the conventional protocol for denture fabrication has been clinically predictable for over 70 years, disadvantages include high treatment costs because of increased patient visits, varying laboratory expenses, and extended chair time.[1] These inconveniences may discourage clinicians from offering CDs as part of their services. Therefore, without overlooking the fundamental concepts and still providing favorable outcomes for patients, cost- and time-efficient CD fabrication protocols should be established.[2] Recently, Computer Aided Design - Computer Aided Manufacturing (CAD/CAM) technology has become commercially available for fabrication of complete dentures. Many systems have been introduced in dental market from different companies, an example of such systems are AvaDent and Dentca. By these systems, impressions, interocclusal records, and tooth selection can be completed in one appointment. The dentures are then fabricated using CAD/ CAM technology and placed in the second appointment.[3]

There is a subtractive method of manufacturing that uses images from a digital file for creation of an object by machining (cutting/ milling) to physically remove material to achieve the desired geometry. This is in contrast to the additive method of manufacturing (such as rapid prototyping), where images from a digital file are used for creation of an object by laying down successive layers of a chosen material.[4]

The process of 3D printing utilizing rapid prototyping (RP) technology in printing denture bases carried out by calibrating the printer using the photopolymerizable pink PMMA liquid resin manufactured for denture bases. The STL file is supported by support rods on the CAM software then the printing process proceeds creating the denture in an additive 3D object. The denture base support rods are then removed finishing, polishing and curing of denture base is done.[5]

The choice of an occlusal scheme will determine the pattern of occlusal contacts between opposing teeth during centric relation and functional movement of the mandible. With dentures, the quantity and the intensity of these contacts determine the amount and the direction of the forces that are transmitted through the bases of the denture to the residual ridges. That is why the occlusal scheme is an important factor in the design of complete dentures.[6]

The occlusal scheme described as fully bilateral balanced articulation, this occlusal scheme is designed for the bilateral, simultaneous anterior and posterior occlusal contact of the denture teeth in the centric and eccentric positions with a cross-arch balanced articulation. Lingualized occlusion is defined as denture occlusion that articulates the maxillary lingual cusps with the mandibular occlusal surfaces in centric working and nonworking mandibular positions, this means that the buccal cusps of the upper teeth and the cusps of the lowers take no part in the articulation.[7] Bilateral balanced occlusion is considered by many authors as fundamental for treatment success, as it would be able to provide greater retention and stability .Better masticatory function is attributed to the bilateral balanced occlusion, since it brings more grinding surfaces in contact at each movement.[8] **Kimoto et al. (2006)** studieded weather patients treated with complete dentures with LO exhibit more positive results than patients treated with complete dentures with BBO. They found that edentulous patients with LO experienced and expressed greater satisfaction with their denture retention.[9]

Chewing ability is defined as the ability to break down foods and can be evaluated by either the subjective or the objective method.[10] The subjective method uses a questionnaire to evaluate chewing ability.[11] Masticatory performance is evaluated objectively[12] and is defined as the median particle size calculated from the percentage ratio of test food size distribution caused by comminution at a certain number of chewing strokes. Masticatory performance was evaluated with the multiple sieve method with 20, 40, and 60 chewing strokes. Masticatory performance was evaluated 2 months after denture delivery; then, the other occlusal scheme was placed on the same denture base by modifying **Khamis** and **Hussein** method.[13] Participants underwent the same test procedures after denture delivery.

MATERIALS AND METHODS

Ten completely edentulous patients (6 males and 4 females) were selected randomly from outpatients' clinic of Removable Prosthodontics Department, Faculty of Dental Medicine, Al-Azhar University, Assiut Branch for this study. All patients followed the first steps of complete denture construction as; diagnosis and examination, preliminary impressions, final impressions **Fig (1-A)**, facebow and jaw relation records and try-in. The finished conv. dentures with BBO were delivered to patients and were followed up **Fig (1-B)**. Patients were instructed to wear the dentures for accommodation. Proper home care was described for the patients. The patients were left 3 months to be accustomed to the denture then recall for recording the masticatory efficiency. The following measures were recorded: a) Number of chewing strokes until the first swallow. b) Time (in seconds) elapsed until the first swallow. c) Number of chewing strokes until clearance of the mouth from food. d) Time (in seconds) until clearance of the mouth from food. The measures were repeated three times for each type of food (carrot, apple and banana) that cut in to standardized pieces (1cm x 1cm), and then the mean values of the records (number of strokes and time in seconds) were used for evaluating the masticatory efficiency.

Following the measurement of masticatory efficiency for conv dentures with bilateral balanced occlusion, occlusion was exchanged to lingualized occlusal scheme using maxillary anatomic and modified anatomic (semi-anatomic) mandibular teeth. Using the plaster index of the first denture and after removal of the upper and lower posterior teeth, the teeth prepared for LO were secured to the denture base using a mix of auto polymerizing resin. The finished dentures with LO were delivered to the patients, check occlusion and with resting period three weeks between occlusal schemes; masticatory efficiency was measured and evaluated as before. **Fig (1-C), Fig (1-D).**

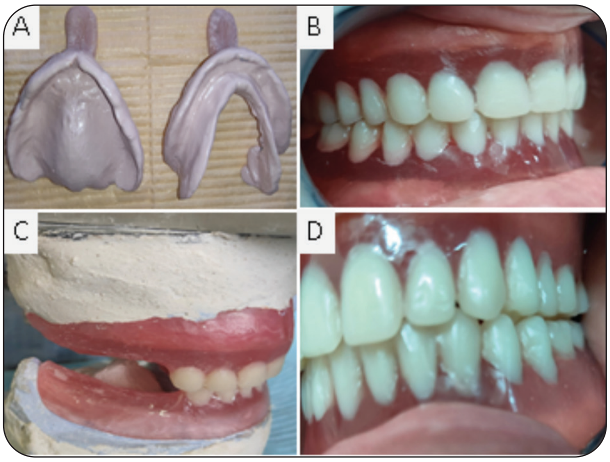

Fig. (1) A) Final zinc oxide eugenol impression. B) Insertion and delivery of the conventional denture with bilateral balanced occlusion (BBO). C) Removal of maxillary and mandibular posterior teeth. D) Insertion and delivery of the conventional denture with lingualized occlusion (LO)

After jaw relation recording step of the conventional dentures, bite record with its corresponding master casts were digitalized using an extra-oral desktop 3D scanner. First, the order was created on Exocad full denture module by the patient's personal information and the operator. The next station is the scanning station having the sequence of scanning upper cast, lower cast then bite registration, to be stored with an extension of standard tessellation language (STL) file. All STL files were imported to Exocad digital design software in full denture modules. Starting the designing step, intraoral landmarks were virtually marked on both arches as marking incisive papilla, maxillary tuberosities, retromolar pads for the lower arch, residual ridge, buccal contour and midline. Afterwards, artificial teeth were designed with their sizes and shapes followed the recorded inter-arch space and been set in BBO **Fig (2-A)**. The designed denture bases were exported as STL files and sent to the 3D printer software to be adjusted virtually with their support rods on X, Y and Z axes of the printer machine plate to be manufactured by rapid prototyping technology **Fig (2-B)**. STL files for the acrylic teeth were imported in Shera CNC milling software to be nested in the correct position of the PMMA blank and adding support rods for teeth to be ready for milling. The next step is bonding the already milled artificial PMMA teeth for denture base sockets. The full dentures were then finished and polished and inserted for each patient checking their retention, stability and occlusion **Fig (2-C)**. The patiens were instructed to wear the dentures for accommodation. Proper home care was described for the patients. The patients were left 3 months to be accustomed to the dentures then recall for recording masticatory efficiency.

Fig. (2) A) Adapting teeth to denture bases. B) 3D printed denture base. C) Delivery of 3D printing denture with BBO. D) Delivery of 3D printing denture with LO

Following the measurement of masticatory efficiency for 3D printing dentures with BBO, occlusion was exchanged to LO using maxillary anatomic and modified anatomic (semi-anatomic) mandibular teeth with the same method made for conv dentures. The finished denture with LO was delivered to the patient, check occlusion and with resting period three weeks between occlusal schemes; masticatory efficiency was measured and evaluated as before **Fig (2-D)**.

RESULTS

Table (1) shows the difference between the four dentures in the number of chewing strokes until the first swallow when eating carrot (P-value=0.21163), apple (P-value=0.30925) and banana (P-value=0.51477) as their P-values>0.05 as indicated by ANOVA test. The highest mean value when eating carrot, apple and banana was recorded for Conv D with LO followed by Conv D with BBO then 3D Printing D with LO and the lowest was 3D Printing D with BBO indicating that the better in masticatory performance (efficiency) is 3D Printing D with BBO followed by 3D Printing D with LO followed by Conv D with BBO then Conv D with LO.

Table (2) shows the difference between the four dentures in the time (in seconds) elapsed until the first swallow when eating carrot (P-value=0.09334), apple (P-value=0.13087) and banana (P-value=0.46709) as their P-values>0.05 as indicated by ANOVA test. The highest mean value when eating carrot, apple and banana was recorded for Conv D with LO followed by Conv D with BBO then 3D Printing D with LO and the lowest was 3D Printing D with BBO indicating that the better in masticatory performance is 3D Printing D with BBO followed by 3D Printing D with LO followed by Conv D with BBO then Conv D with LO.

Table (3) shows the difference between the four dentures in the number of chewing strokes until clearance of the mouth from food when eating carrot (P-value=0.07902), apple (P-value=0.06412) and banana (P-value=0.10556) as their P-values>0.05 as indicated by ANOVA test. The highest mean value when eating carrot, apple and banana was recorded for Conv D with LO followed by Conv D with BBO then 3D Printing D with LO and the lowest was 3D Printing D with BBO indicating that the better in masticatory performance is 3D Printing D with BBO followed by 3D Printing D with LO followed by Conv D with BBO then Conv D with LO.

Table (4) shows the difference between the four dentures in the time (in seconds) until clearance of the mouth from food when eating carrot (P-value=0.43385), apple (P-value=0.09436) and banana (P-value=0.08114) as their P-values>0.05 as indicated by ANOVA test. The highest mean value when eating carrot, apple and banana was recorded for Conv D with LO followed by Conv D with BBO then 3D Printing D with LO and the lowest was 3D Printing D with BBO indicating that the better in masticatory performance is 3D Printing D with BBO followed by 3D Printing D with LO followed by Conv D with BBO then Conv D with LO.

Table (1) *The number of chewing strokes until the first swallow*

Type of food	Number of chewing strokes until the first swallow				P value
	Conv D with BBO	Conv D with LO	3D Printing D with BBO	3D Printing D with LO	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Carrot	20.66 ± 2.08	21.77 ± 0.769	19.77±0.509	19.88± 0.384	0.21163
Apple	16.88 ± 2.58	18.00 ± 1.52	16.22±0.384	16.66 ± 0.666	0.30925
Banana	14.66 ± 2.08	15.66 ± 2.00	13.88± 0.509	14± 1.17	0.51477

Table (2) *The time (in seconds) elapsed until the first swallow*

Type of food	Number of chewing strokes until the first swallow				P value
	Conv D with BBO	Conv D with LO	3D Printing D with BBO	3D Printing D with LO	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Carrot	20.66 ± 2.08	21.77 ± 0.769	19.77±0.509	19.88± 0.384	0.21163
Apple	16.88 ± 2.58	18.00 ± 1.52	16.22±0.384	16.66 ± 0.666	0.30925
Banana	14.66 ± 2.08	15.66 ± 2.00	13.88± 0.509	14± 1.17	0.51477

Table (3) *The number of chewing strokes until clearance of the mouth from food*

Type of food	Number of chewing strokes until clearance of the mouth from food				P value
	Conv D with BBO	Conv D with LO	3D Printing D with BBO	3D Printing D with LO	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Carrot	25.00 ± 2.18	26.33 ± 0.666	24.66±0.192	24.77± 0.385	0.07902
Apple	21.66 ± 3.00	22.88 ± 1.67	20.44±0.384	20.88± 0.509	0.06412
Banana	18.0 ± 3.17	19.33 ± 2.18	17.22 ± 0.192	17.33± 0.577	0.10556

Table (4) *The time (in seconds) until clearance of the mouth from food*

Type of food	Time in seconds elapsed until clearance of the mouth from food				P value
	Conv D with BBO	Conv D with LO	3D Printing D with BBO	3D Printing D with LO	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Carrot	19.85 ± 2.45	19.90 ± 0.732	18.33± 0.189	19± 0.294	0.43385
Apple	17.43 ± 1.97	18.37 ± 1.14	16.7± 0.474	16.72± 0.750	0.09436
Banana	14.58 ± 2.40	15.78 ± 1.91	13.61± 0.142	13.96± 0.421	0.08114

DISCUSSION

According to type of food and type of denture, the results of the present study show no significant increase in the masticatory efficiency (decreased number of strokes and time until first swallow also until clearance of the mouth from food) when the 3D Printing dentures were used, these results are in agreement with the clinical trial of **Inokoshi et al. (2012)** in which 10 patients received one 3D printing and one conventionally fabricated CD, showed higher processing accuracy with 3D printing technique using stereolithography apparatus (SLA) compared to the conventional wax dentures technique and reported that there is no significant differences between conventional and digital methods utilizing 3D printing of CD fabrication in terms of overall satisfaction.[14] An in vitro study in 2017 concluded that the trueness of the fitting surface of digital 3D printing and conventional techniques seems to remain within a clinically acceptable range in terms of adaptation and fit that directly affects the retention of dentures, which seems to explain the reason of little increase in masticatory performance (efficiency) for 3D Printing dentures printed than conventional dentures.[15]

According to type of food and type of occlusal scheme, the results of the present study show no significant increase in the masticatory efficiency (decreased number of strokes and time until first swallow also until clearance of the mouth from food) when comparing BBO with LO in 3D Printing dentures or in Conv dentures but BBO recorded higher mean value than LO and this may be attributed to the better cutting efficiency of anatomic teeth in BBO since it brings sufficient grinding surfaces in contact at excursive movement and facilitates patient's adaptation to new complete dentures.[16, 17]

The results are in agreement with the study that concluded that BBO and LO reduce selective food avoidance and physical disability aspects of patient satisfaction and there is no difference in the masticatory efficiency was reported among these schemes. It also concluded that BBO is one of the preferred choices for occlusal schemes but not for all the ridges.[18] In contrary, a prospective study has been realized by **Kimoto et al. (2006)**. The study includes 28 edentulous patients divided equally into two groups. The first group was treated by complete dentures fabricated using LO scheme. The second one was treated by complete dentures with BBO.

Two months after the post-insertion follow-up, we found that there is an ultimate correlation between complete denures' retention and occlusal schemes. In addition, patients were more satisfied with LO in terms of masticatory performance and retention.[9]

CONCLUSIONS

Based on the results and within limitations of the current study it can be concluded that:

1. There was no statistical significant difference according to masticatory performance (efficiency) between 3D printing and conventional complete dentures with different occlusal schemes.
2. Different occlusal schemes have no effect on masticatory efficiency when eating different types of food.
3. BBO as LO, penetrate the food polus well and provide more stability and favorable stress distribution in parafunctional and excursive movements.

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تأثير أنظمة الإطباق المختلفة على كفاءة المضغ للأطقم التقليدية والرقمية الكاملة

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الملخص :

الهدف: تقييم تأثير أنظمة الإطباق المختلفة وهى الإطباق الثناءى المتوازن و الإطباق اللسانى للأطقم الكاملة التقليدية و الرقمية (طباعة ثلاثية الأبعاد) على كفاءة المضغ.

المواد والاساليب: تم اختيار عشرة مرضى عديمي الأسنان تمامًا بشكل عشوائي. حصل كل مريض على أطقم الأسنان الكاملة التقليدية والرقمية (الطباعة ثلاثية الأبعاد) مع اطباق ثنائي متوازن. بعد ثلاثة أشهر ، تم استدعاء جميع المرضى لتسجيل القيم المتوسطة لكفاءة المضغ التي تم تقييمها من خلال تقييم وقت المضغ وعدد ضربات المضغ حتى البلع الأول وحتى إزالة الطعام من الفم باستخدام أنواع مختلفة من الطعام (الجزر والتفاح والموز). تم تبديل أنظمة الإطباق إلى الإطباقات اللسانية على قواعد أطقم الأسنان الخاصة بالمرضى ، وأعيد إدخالها في الفم مع فترة راحة لمدة ثلاثة أسابيع بين أنظمة الإطباق. بعد ذلك ، تم تسجيل قياسات كفاءة المضغ كما ذكر من قبل. تم استخدام ANOVA بطريقة واحدة للمقارنة بين أطقم الأسنان المختلفة متبوعة باختبار TUKEY HSD المستخدم للمقارنة بين كل طقم أسنان. تم تعيين مستوى الأهمية عند P-VALUE 0.05 إجراء التحليل الإحصائي .IBM® SPSS® STATISTICS باستخدام الإصدار 20 لنظام التشغيل WINDOWS

النتائج: أظهرت النتائج عدم وجود فرق ذو دلالة إحصائية في أداء المضغ بين أنظمة الإطباق المختلفة أو بين أطقم الأسنان التقليدية والطباعة ثلاثية الأبعاد وكان المرضى راضين عن وظيفة المضغ عند تناول أنواع مختلفة من الطعام .

الخلاصة: الإطباق الثناءى المتوازن مثل الإطباق اللسانى اخترق كل منهم كمية الطعام جيدًا ويوفر مزيدًا من الاستقرار وتوزيعًا ملائمًا للضغط في الحركات شبه الوظيفية والانحراف. ومع ذلك ، كانت أطقم الأسنان ثلاثية الأبعاد أفضل إلى حد ما من أطقم الأسنان الأخرى.

الكلمات المفتاحية : راتينج ، طباعة ثلاثية الأبعاد ، اطباق متوازن ، اطباق لسانى ، كفاءة المضغ