EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 69, 2869:2879, OCTOBER, 2023
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
FIXED PROSTHODONTICS AND DENTAL MATERIALS
Submit Date : 24-05-2023 • Accept Date : 01-08-2023 • Available online: 15-10-2023 • DOI : 10.21608/EDJ.2023.212382.2563

EVALUATION OF MASTICATORY EFFICIENCY BASED ON DENTURE DESIGN, PERIOD OF EDENTULISM AND GENDER

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ABSTRACT

Purpose: To compare masticatory efficiency (ME) as an indicator for difference between bar-assisted overdenture versus fixed detachable denture wearers and an indicator for the effect of gender and period of edentulism.

Materials and Methods: Twenty patients, 11 males and 9 females, were divided into two groups. Group I received fixed detachable overdenture assisted by four implants mounted by the all-on-four concept. Group II received mandibular implant overdenture assisted by extended ball-bar overdenture. ME was measured after 3 months of denture insertion (T1), six months (T2), and one year (T3).

Result: there was a significant increase of ME between both prosthetic design groups at T1 ($p=0.004$). In group I, there was a significant increase in ME through all time intervals ($p<0.01$ and $p=0.027$ for T1-T2, T1-T3, and T2-T3 respectively. For group II, there was a significant increase in ME between T1-T2 ($p=0.031$). At T3, there was a significant increase in ME for patients kept edentulous for less than a year before restoration and two-year edentulous patients before restoration ($p< 0.01$ and $p = 0.02$, respectively). Also, there was a significant increase in ME for two-year edentulous patients compared to patients who stayed more than two years edentulous before restoration ($p=0.02$). Males revealed an increase of ME at T3 compared to female groups ($p< 0.001$).

Conclusion: Within the limitation of the study, ME revealed a better prognosis with fixed detachable denture wearers. Male has better ME prognosis. ME revealed better prognosis with patients have shorter period of edentulism before denture insertion.

KEYWORDS: Overdenture, all-on-four, fixed detachable, masticatory efficiency, edentulism. Main subjects Prosthodontics, dental implantology

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INTRODUCTION

The advances in medical and dental technologies have led to an increase in the average human life expectancy, therefore leading to an increase the efficiency for rehabilitated edentulous patients. For these patients, merely providing stability and support for the dentures is not enough. The longer the dentures are worn, the more challenges arise due to the gradual atrophy of the dental ridges. In addition to issues related to neuromuscular coordination and the inability of the denture to form a tight seal with the surrounding soft tissues, patients have a lot of dissatisfaction and inability to masticate with the conventional complete denture.[1] The introduction of dental implants, have revolutionized the field of prosthodontics. It has provided various treatment options for edentulous individuals such as removable prosthesis, fixed prosthesis with implant-supported overdenture, and hybrid prostheses. This has resulted in improved overall oral function and addressed the issue of denture instability.[2]

A common issue with mandibular implant-supported prosthesis is an insufficient bone volume for the placement of implants. To overcome the obstacle, bone augmentation treatments are used to provide an optimal number of implants with an ideal location. However, these treatments can have surgical risks, costly and time consuming.[3] As an alternative, using four implants to support hybrid prosthesis has been found to provide positive clinical results, suggesting that additional implants may not be necessary.[4] Another treatment modality to restore the edentulous mandible is by using mandibular implant overdenture (MIOD) assisted with cantilever bar.[5] For this line of treatment, mandibular overdenture supported by implants placed between the mental foramina should have limited distal cantilever length in order to reduce torque-related stress on the implants.

All treatment methods have different clinical uses and varied outcomes, which depend on the patient's satisfaction with their chewing, and the overall improvement in their quality of life. Several ways of measuring the effectiveness of the masticatory system have been established, such as the assessment of maximum bite force as a common method to evaluate the denture performance and adaptability within time.[6] The most important perspective is to evaluate the masticatory efficiency (ME). The efficiency of mastication is a technique used to follow adaptation of both complete denture and MIOD.[7] Additionally, masticatory efficiency is an indicator for serviceability of restoration. Many methods and test food have been utilized to investigate ME as peanuts, carrot, almonds and bread. Also there are many methods for verification ME like sieving and mixing ability method.[8] Glucose-extract method is simple and reliable method to measure ME. This method based on measuring the released glucose from artificial food after certain chewing strokes.[9]

The ability of patient to use the denture properly in mastication and other daily work depends mainly on the prosthetic design but also on other factors. Age factor is important to define the controllability of the denture and the neuromuscular condition. Gender is monitored as a differentiation factor for the masticatory ability due to some variation in anatomical structure.[10], [11] Even more, the loss of propeoceptive receptors after teeth extraction and the length of duration stayed without restoration may affects the neuromuscular coordination and the memory of stomatognathic system.[12] So, ME is multi-factorial and does not depend only on the number of implants or the design of suprastructure.

The aim of this research work is to compare ME as an indicator of serviceability of fixed detachable all-on-four overdenture versus cantilever bar assisted overdenture. The null hypothesis is there is no statistical significance difference between the proposed prosthetic designs, gender and/or period of edentulism before rehabilitation regarding the ME.

MATERIALS AND METHODS

Patients selection and ethical approval

Twenty edentulous patients, 11 males and 9 females with age ranged from 57-65 years, were chosen from the Prosthodontics Department, Delta University, Faculty of Dental Medicine. The patients did not have any diseases that would increase bone resorption, compromise tissue health, or impair the ability to follow up. Patients with a history of clenching, bruxism, or TMJ disorders were excluded. All participants had a restorative space available for the planned overdenture suprastructure, and had an Angel's Class I maxillomandibular relationship verified by tentative jaw relation record. Additionally, all patients had sufficient bone quality and quantity in the mandibular intra-foramenal area, which was verified by cone beam CT (CBCT) for placement of the required implants. The final results and procedures were approved by the ethical committee under license number (FODMRC-2022-00106). The pre-surgical, surgical, pick-up, follow-up, and evaluation procedures were achieved.

Pre-surgical procedures

II.1. Conventional complete denture construction

Primary and master maxilla-mandibular impressions were made; and jaw relation was recorded and transferred to articulator by face-bow. Artificial teeth (Acrostone, Egypt) were set according to lingualized occlusion scheme. After clinical try in and denture flasking, the denture was finished and polished. Patient received denture and followed up for a month to assure adaptation and proper occlusion.

Grouping of patients

Patients were divided randomly in to two equal groups. Group I included ten patients received fixed detachable overdenture (FDO) over four implants placed by the all-on-four concept. Group II included ten patients received MIOD assisted with anterior cantilevered bar augmented with terminal balls. Both groups received conventional maxillary denture opposite to mandibular prostheses.

Fabrication of implant-placement guide template

The mandibular denture was duplicated and used for double scanning by CBCT with modified fitting and polished surfaces by adding gutta-percha inserts opposing to canine and premolar area. Images were loaded into 3D image planning software (In2guide software by Cybermed) to virtually determine the proper position of implants. A mucosal supported stereolithographic surgical guide with metal sleeves and anchor pins was printed according implant planned sites. For group I, the stereolithographic surgical guide was fabricated with four holes for anterior and posterior angled implants placement. For patients in group II, the stereolithographic surgical guide was fabricated with two holes for implants.

Surgical procedures

A dose of prophylactic broad-spectrum antibiotic (Flumox, EPICO. Egypt) was delivered one hour preoperatively. Under local anesthesia (Lignocaine 4% Alexandria Co. Egypt), universal surgical kit (In2Guide Universal Kit, Cybermed Inc.) was used to perform full drilling sequence through the anchored stereolithographic stent. For group I, each patient received four implants (3.7x11.5 mm; Dentaurum, Germany) placed according to the all-on-four concept (Fig 1). For group II, each patient received two fixtures. The intaglio of the mandibular denture was relieved opposite to implants and loaded with soft liner (Promedica, Germany). Patient was instructed for self-home care and soft diet with frequent recall and follow up. After three months, healing abutments were mounted for two weeks with required modification of mandibular denture.

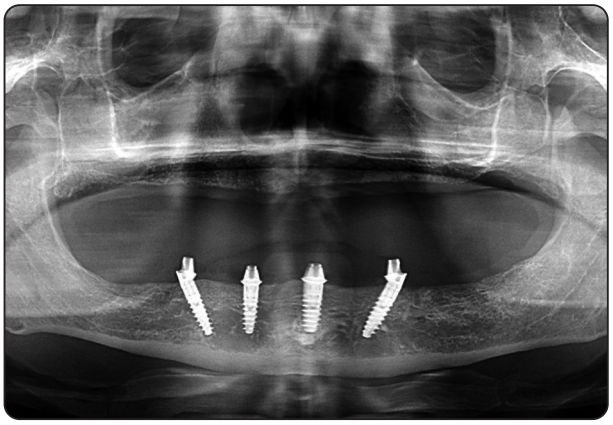

Fig (1) Panoramic x-ray film shows four implants placed according to the all-on-four concept

Construction of prosthetic suprastructure

Construction of cantilever ball-bar (CBB)

The analogue transfer was made for both implants with open tray technique. The implant analogues were attached to impression posts and the impression was poured with extra-hard dental stone. Two copings were screwed to the analogues. After cast scanning, bar was designed on the virtually. The virtual bar was milled to a resin-made prototype by CAM machine (Cerec inLab, Sirona, Germany). The resin bar was checked in-situ before casting. The bar was splitted and reassembled intraorally in case of passive fit was violated. Then, the passive fit resin bar was casted to metallic cobalt chromium bar (Fig 2).

Fig. (2) Cobalt chromium cantilevered ball-bar intraorally

Construction of fixed detachable denture

A mask index from silicon (Silaxil, Lascod, Italy) was made around the polished surface of mandibular interim prostheses on master casts to act as a guide for the final restoration. A screw-retained framework with retentive mesh was waxed up over the four implant abutments and cast to metal bar. The framework was returned to the master cast and the index was reseated. Acrylic teeth (Acrostone, Egypt) with the same size of interim denture were placed in their positions in the silicon index. Any interference from the base of the teeth with the framework was adjusted. Rather than attached teeth, the rest of the denture base is waxed up and flasked. The final denture within the framework was finished and polished.

Denture delivery procedures

For CBB assisted overdenture, after checking the passivity, of casted bar intraorally, all undercuts under the bar were blocked with putty rubber base. Two plastics clips were mounted on the anterior segment of bar. Mandibular denture was modified to include bar without rocking. The pick-up procedure was achieved by adding auto-polymerized acrylic resin (Acrostone, Egypt) to the intaglio of the denture and the clips were picked up under patient's intimate bite. Opposite to terminal bars, auto-polymerized soft liner were added as a female housing.

For fixed detachable prostheses, the denture was inserted and the occlusion was refined before final screwing of the denture. After occlusion and border adjustment, the denture was screwed to the abutments. A small cotton piece was adapted inside the screw hole and over the head of each screw. The hole is filled with light cure composite (Promedica, Germany). The occlusion was refined again at the end on delivery visit (Fig 3).

Assessment of ME

Glucose extraction method was used to evaluate the masticatory function. The patient was asked to chew readymade jelly specimen (10 mm width, 10 mm highest with 5% glucose concentration)

Fig (3) Intraoral occlusion check for mandibular fixed detachable denture opposite to conventional maxillary denture

Fig. (4) Gluco sensor GS-II set. Artificial food (left), glucose strips (middle), glucose measuring apparatus (right)

(Glucosensor Gummy, GC, Japan) for 10 seconds and expectorate into a plastic mesh filter over a plastic cup. Then, patient rinsed mouth with 10ml of water and spitted off into the same cup. Glucose concentration (mg/dl) in the filtrated cup was measured by glucose sensor apparatus (Gluco sensor GS-II, GC, Japan) (fig 4), Measurements were repeated three times for each measurement and mean was calculated.

RESULTS

The results of this study revealed no statistical significant difference between both group regarding age, gender and the period of edentulism before restoration (p= 0.47, 0.99 and 0.65 respectively). (Table I)

The comparison of ME between the two groups at different time intervals (Table II) revealed a statistically significant difference between groups at different time intervals. There was a statistical significant difference between groups only at T1 (p=0.004) with increasing of group I mean (45.8 mg/dl comparing to 33.8 mg/dl to CBB group). Regarding group I, at comparing the ME through the time interval, there was a statistical significant difference between time intervals (p<0.01 and 0.02 for difference between T1-T2, T1-T3 and T2-T3 respectively). While, the results of group II revealed that there is a statistical significant difference between T1 and T2 only (P=0.03)

TABLE (1) Demographic analysis of participants

	Group I	Group II	*p*
Age*	61.25	60.2	0.648***
Gender**			
Male	5	6	
Female	5	4	0.99****
Last time of extraction			
Less than one year	3	4	
Within 2 years	5	3	
More than 2 years	2	3	0.654****

Mean per year **count ***Independent t test ****Chi-square test

TABLE (2) Within and between groups comparison of ME

	Group I Mean*(SD)	Group II Mean* (SD)	*P***
T1	45.8(6.6)^{A}	33.8(9.7)^{A}	0.004
T2	54.5(5.2)^{B}	49.7(4.1)^{B}	0.35
T3	76.1(5.5)^{C}	75.6(4.6)	0.83
p***	AB<0.001 AC=0.027 BC=0.025	AB=0.031	

** Unit of measurement mg/dl** Independent t test*

**** Paired t test*

Different letters means significant difference within groups

TABLE (3) Comparing ME of participants based on the duration of edentulism before restoration.

Dependent Variable	(I) period of edentulism	(J) period of edentulism	Mean Difference (I-J)*	P**
T1	Less than 1 year	Within 2 years	5.73929	.577
		more than 2 years	5.22571	.634
	Within 2 years	Less than 1 year	-5.73929	.577
		more than 2 years	10.96500	.055
T2	Less than 1 year	Within 2 years	1.68571	.825
		more than 2 years	2.65429	.632
	Within 2 years	Less than 1 year	-1.68571	.825
		more than 2 years	4.34000	.248
T3	Less than 1 year	Within 2 years	5.23036*	.000
		more than 2 years	11.40286*	.002
	Within 2 years	Less than 1 year	-5.23036*	.000
		more than 2 years	6.17250*	.020

** Unit of measurement mg/dl*

*** Games-Howell test due to significance of Welch test of equality of variance with mean difference significance at the 0.05 level.*

At comparing ME based on the last time of extraction for each patient (Table 3), there was a statistical significant difference at T3. According to post-hoc test, there was a statistical significant difference between patients stayed edentulous for less than a year and within two years; and between patients stayed edentulous within two years and more than two years ($p<0.001$ and $p=0.002$ respectively). Also, there was a statistical significant difference between patient with stayed edentulous for more than two years and between one and two years ($p<0.02$). At comparing ME based on the gender through the different time intervals of the study (Table 4), there was a statistical significant difference between two gender at T3 with enhanced ME for male group ($p<0.001$).

TABLE (4) Comparison of ME based on the gender of participants

	Male Mean(SD)*	Female Mean(SD)	P**
T1	40.9(11.5)	38.5(8.7)	0.61
T2	53.1(5.6)	50.8(4.5)	0.34
T3	79.4(2.5)	71.5(3.3)	<0.001

** unit of measurement mg/dl*

*** Independent t teat significance level <0.05*

DISCUSSION

The ability of denture wearer to effectively chew food depends on the proper biomechanics of the MIOD. The number and placement position of implants and the use of cantilevers can improve the biomechanics of overdenture which, in turns, improve masticatory performance and quality of life.[13] To limit the risk of looseness of the screws and any other prosthetic complications, four implants were suggested as the optimum number to provide support for the distal cantilever bar up to 10 mm in each side.[14] While, Mericske-Stern et al.[15] reduce the number of implants and the length of cantilever to be 7 mm cantilever bar on two intra-foraminal implants. The total length of cantilever portion should be shorter than the anterior portion of the bar connecting the main implants.[13] Locator was used to augment the retention over the bar.[16] Kim et al.[17] used solitary attachment with double sided bar mandibular overdenture. Through our study, cantilever bar ball design was used to assist the retention and stability of overdenture in group II. To avoid complexity at denture manipulation at insertion and removal, soft liner is used as matrix for ball attachment.[18,19]

Hybrid prostheses requires frameworks to splint the implants for support as an assemble consideration of the keys to long-term clinical success. To investigate the optimum line to restore mandibular edentulism, all-on-four implant assisted overdenture was compared to other treatment modalities. Soni et al.[2] compared ME between conventional complete denture, all-on-four treatment concept and implant-supported overdenture. While other study compared ME after rehabilitation with MIOs assisted by two implants versus all-on-four assisted hybrid prostheses.[20] this study fill in the gap by comparing the cantilever bar ball assisted overdenture with all-on-four assisted prostheses.

Different methodologies are used to assist ME in edentulous and dentate persons. Glucose extraction method is a feasible method used for evaluation of ME in overdenture wearers. Glucose extraction method has recently gained significant interest due to its ease of manipulation and control of hygiene, as well as its consistent physical properties, which make it a suitable test food. Additionally, studies have shown a positive correlation between the masticatory performance of gummy jelly measured by this method and that measured by the sieving method.[21] In this study, the patient was asked to chew the artificial food for ten seconds to avoid swallowing of sampling with long time of test. While other researchers recommended 20 seconds as a mastication test period.[9,22]

By the demographic analysis of the participants, the results show no statistical difference in the gender and age of randomly allocated participants in both groups. This suggests that gender and age may not play a role at comparing ME for both groups. Additionally, there is no significant difference between both groups regarding the last time of extraction before prosthetic replacement.

The result revealed statistical significant difference between all times intervals in group I and between T1 and T2 in group II. The results go with previous studies have shown that mandibular overdenture provide an increase in masticatory efficiency within time as increase the number and stability of the denture. A study conducted by Limpuangthip et al.[23] found that when compare conventional dentures, mandibular overdenture improved patient satisfaction and oral health-related quality of life. Additionally, muscle activity was increased significantly by increasing the number of implants beneath overdenture.[24] This increase in retention and stability of the denture improves the nutrition of the overdenture wearers which reflects positively on the masticatory muscle performance.[25]

Within this line of enhancing ME based on number of implants, all-on-four overdenture revealed proper solution for patients seeking to replace the missing teeth. A previous clinical trial found that the all-on-four overdenture significantly improved chewing ability compared to conventional dentures.[2] Similarly, a collective study by Peñaloza et al.[26] reported that the all-on-four overdenture was associated with a significant improvement in the mastication of patients when compared to other dental prostheses. The same improvement was recorded for the CBB group. There was a statistical significance in the ME after the first three months. In previous article, authors compare between cantilevered and non-cantilevered bar within patient and the result revealed favorable ME at using cantilever bar design. According to Khalifa et al.,[19] there was a significant improvement of ME through follow up of the participants after wearing overdenture assisted with cantilevered ball bar comparing to anterior bar without cantilevering. Also, the cantilever bar improved the general clinical outcome for the participants to compare splinted and unsplinted suprastructure.[27] This improvement in ME may be explained by the more control of the patient for the prostheses. The more retentive and stable the denture assists the muscle acting for food comminution enhancing the ME. The stability and retention gained by the all-on-four assisted overdenture with different suprastructure revealed the improvement of bite force and chewing

efficiency within time.[28] This could be explained by the improving of the neuromuscular control of patient after wearing stable overdenture. The instability and looseness of restoration minimize the serviceability of the denture rather than the consistency and type of food.[29] Another reason why denture wearers chew less effectively is reduction of bite force due to loss retention and stability.[30] In reverse, the tight anchorage of the denture to the suprastructure reverses the situation to pleasant reflection on the ME.[31] Accordingly, the ME based on the comminution of the food to small chunks. This action requires proper occlusal table and stability of denture to comminute food under the optimum bite fore. The bite force for edentulous patient revealed good prognosis within the all-on-four and cantilever bar assessment of overdenture.[19,28]

The superior statistically significant difference revealed in ME for group I at the first time interval (T1) may be due to the simplicity of the design and more stability non-free posterior portion of the prostheses compared to the CBB group. Ares et al.[32] found that people who were satisfied with their chewing ability, mastication, and comfort while eating preferred implant fixed prostheses over removable prostheses. Similarly, Elsyad et al.[33] found that people who prioritized stability and chewing ability do not prefer removable prostheses comparing to other restorations. The non-significant difference between two groups throw the rest of the study may be explained by the progression of coadaptation of the patient to the new prostheses regardless the design. The adaptability of denture by time may be the reason of restoring normal function stabilizing feeding sequence regardless the condition of restoration.[34]

The result revealed statistical significant increase in the ME for male group compared to female groups. This may be due to difference in maximum bite force and other anatomical factors. After subdividing participants to five groups to control age factor, Palinkas et al.[10] found a factorial effect of the gender by increasing maximum bite force within 30% compared to female group. By another study, female revealed lower eating rate compared to male group[35] The higher ME, according to our findings, may be also explained by the thickset masticatory muscle in male. Previous studies supported the superiority of thickness in masticatory muscle in male compared to female.[10, 11] Also, muscle thickness showed that men have a greater muscular potential as compared to women.[10]

The result of the study elaborated significant difference in ME based on the duration of patient stayed edentulous without restoration. As the patient kept without dental restoration is reflected negatively of the ME measures based on our findings. Bite force was reported to be in correlation to muscular activity.[36] Such muscle activities revealed impairment due to long time loss of teeth has adverse effect on the masticatory performance even after restoration. Also, the loss of teeth can have a significant effect on the periodontal receptors which relay information from the oral cavity to the central nervous system and help regulate the activity of the masticatory muscles.[37] This can lead to a decrease in interocclusal perception, as the number of receptors in the masticatory mucosa is very small. Additionally, the loss of teeth can cause a loss of the occlusal surface, which is the only reference coordinate of the zero inter-maxillary separation and has a precise spatial representation in the somatosensory cortex. Without this contact, the memory pattern of the occlusal surface is lost, and fully edentulous mouths are characterized by a disintegration of the free interocclusal space.[12] The decreased mastication due to the morphological changes as attrition or loss of teeth and decreased masticatory muscle activity resulted in an impaired spatial memory related to mastication. Studies have demonstrated a functional relationship between mastication revealed a brain-driven behaviors which was validated by a reduction in neurons and neurogenesis, neuronal activity due to any cause.[38] As an additional evidence, activation of the representative areas in the sensorial and

motor cortex might elaborate the improvement of masticatory function after restoration which restore the reflex lost by teeth extraction.[39] Additionally, Yan et al., concluded change in somatosensory and motor inputs to the brain that are markedly different based on the dentition state.[40] Research over the past years suggests that the sensory cortex can be substantially changed even after the critical development period of the brain is over, through either training or losing inputs;[41] which can explain the efficiency of ME for patient with short time loss of teeth comparing to who kept without restoration for longer periods.

One of the limitations of the study is the limited number of participants. Another limitation is the short time of follow up, one year is a shortage of the study. Also, comparison of other different denture design should be in further research. So, further studies should be done to avoid limitation of the study.

CONCLUSION

Within the limitation of the study, ME revealed better prognosis and improvement with fixed detachable denture wearers compared to cantilevered ball-bar overdenture wearers. Male has better ME prognosis compared to female. ME revealed better prognosis with patients have shorter period of edentulism before denture insertion.

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