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Bar Versus Locator Implant Assisted Maxillary Overdentures Opposing Two Implants Retained Mandible Overdentures: A Study of Chewing Efficiency and Electromyographic Activity

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Abstract: ***Two implants retained mandibular overdenture opposing conventional maxillary complete denture may induce a combination syndrome, implant supported maxillary overdenture was indicated to avoid this phenomena. Selection of splint or solitary attachment for this issue is a matter of debate.This study aimed to compare and evaluate chewing efficiency and electromyographic activity of patients wearing implant assisted maxillary overdentures by bar versus locator attachments opposing two implants retained mandibular over dentures. Six completely edentulous healthy male patients were selected for this study .After three months of conventional complete denture construction, the electromyographic (EMG) activity of masseter muscle and chewing efficiency measured by unmixed fractions of (UF) of double colored chewing gum were evaluated(Group I): (control group). Two implants were installed bilaterally in the mandibular canines areas; and four implants were installed in the maxilla. After the osseointegeration period, bar assisted maxillary overdenture was constructed against mandibular locator retained overdenture and the (UF) and EMG were evaluated after three months (Group II) . After two weeks resting period, the bar attachments in was replaced by locator attachments (Group III) and the evaluation was done after three months of denture insertion. After two weeks resting period , the bar in group II was replaced by locator and the locator in group III was replaced be bar attachment to evaluate the (UF) and EMG after three months of replacement.Statistically significant difference in (UF) and (EMG) activity of masseter muscle between implant assisted overdenture and conventional complete denture groups. 2- A statistically insignificant difference in(UF) and (EMG) activity of masseter muscle between bar and locator assisted maxillary overdentures. Four implant assisted maxillary overdentures opposed by two implant retained mandibular overdentures significantly improve the chewing efficiency and EMG activity of masseter muscle compared with conventional complete dentures regardless the attachment design(splint bar or solitary locator) used for the maxillary overdenture.***

Keywords: Chewing Efficiency, Electromyographic, Attachments, Overdentures

1. Introduction

Poor retention and stability of conventional complete dentures impedes adequate oral function, lowers bite forces and changes in the masticatory functions have been reported widely[1].Owing to the reduced surface areas of supporting tissues and the inherent compromised retention and stability of conventional mandibular complete denture, two implants retained mandibular overdenture is considered the minimal standard of care to provide stable and retentive denture that can improve oral function and patient satisfaction.

Patients wearing mandibular two implant-retained prostheses opposed to maxillary conventional complete dentures may face degenerative tissue changes similarly seen in the classic combination syndrome [2-4]. These changes include: loosening of the maxillary denture, loss of posterior occlusion, increased anterior occlusal pressure and anterior maxillary bone loss with flabby tissue formation [5-7]. The mandibular implants encourage the patients to incise anteriorly with maximum bite force creating a similar biomechanical situation to the distal extension removable partial denture [2]. In such situations, it is recommended to assist the maxillary denture with four implants to resist these undesirable effects.

Two attachment systems are recommended for the four implants assisted maxillary overdenture including; the splint bar and solitary attachments. Splint bar provides greater retention and stability, resists lateral and rotational movement, enabling better force balance by its splinting effect and can correct implant disparalellisms [6]. Locator solitary attachments are widely used due to low profile height [7], self-alignment, dual retention mechanism (inner and outer) [8] and correction of problems related to implant angulation [7, 8]. In addition, repair and replacement are easy and fast [7].

When attachments used for implant overdentures, the activity of masseter muscle significantly were increased [9].It was agreed that improvement of oral function depends on the degree of retention and stability of the denture which are directly related to the design of the attachment system [10, 11]. Abdelhamid et al [11], observed statistically

insignificant differences in maximum bite force and masticatory performance between different attachments used to retain mandibular implant overdentures. This study was aimed to evaluate and compare chewing efficiency and electromyographic activity of masseter muscles of patients wearing four implants maxillary overdentures assisted by bar versus locator attachments opposing to two implants retained mandibular overdentures.

2. Materials and methods

2.1 Patient's selection:

Six healthy completely edentulous patients of age ranged between 50 and 65 years were selected from Prosthodontics Department, Faculty of Dentistry, Mansoura University-Egypt. All patients were free fromfacial and oral neurological, myoskeletal or TMJ disorders.

2.2 Pre-surgical procedures

Maxillary and mandibular conventional complete dentures were constructed. Artificial acrylic resin teeth were arranged for balanced lingualized occlusion. The patients were instructed to use the dentures for three months and asked for regular periodic follow up to adjust any complain. The electromyographic(EMG) activity of masseter muscle and chewing efficiency were evaluate after the three months and used as a **control group(G1)** as follows:

2.2.1 Chewing efficiency measured byUnmixed Fraction (UF):

According to Schimmel et al. [12], two-color chewing gum test was used to evaluate the masticatory efficiency. Samples of a two-color chewing gum were prepared. Strips of 30 mm length were cut from both colors and manually stuck together so that the test strip presented were 30×l8×3 mm. Patients were instructed to chew five samples of chewing gum for 5,10,20,30 and 50 chewing cycles. After chewing, the samples were then spat into transparent plastic bags, which were labeled with corresponding numbers of strokes. All samples were assessed after flattening to 1 mm thick 'wafers'. The unmixed pixels counted using Adobe Photoshop Elements to calculate the ratio of unmixed color to the total surface. An interval of at least 1 min was imposed between the different tests to reduce the effect of fatigue. The total duration of the experiments was approximately 8 minutes. A PC (Intel Pentium_ 3, 2 GHz, 256 MB) with MS Windows XP and a Digital camera were used for electronic assessment. The wafers were scanned from both sides with a resolution 100 dots per inch. The scanned image was copied into an image of fixed size (1175 x 925) pixels and stored in Adobe Photoshop_ format (.psd). Then, the color range tool was used (fuzziness 20, 25, 30) to select the unmixed white parts of the image. The numbers of selected pixels were recorded from the histogram for each side and each tolerance and mean of those figures calculated. Subsequently a ratio was computed for the Unmixed Fraction (UF) using the following formula: Pixels white side a + Pixels white side b) - 2 X Pixels of scale.

2.2.2 Electromyographic activity (EMG) of the masseter muscle

The masseter muscle activity of preferred chewing side was recorded by bipolar Ag/AgCl-surface electrodes positioned on the bellies of the muscles (active electrode on mid of longitudinal fibers and reference electrode on tendon of muscle). The recording and reference surface electrodes were placed on the body of the muscle midway between the origin and insertion. While, the ground surface electrode was placed around the neck of the patient. Celluloid sheet was used to locate the position of the electrodes in relation to fixed facial landmarks. This enabled the reproduction of the surface electrodes position for each patient during the successive EMG Records. The patient was instructed to chew a sample of hard food (carrot), with dimensions 3 x 1 x 1 cm)[13], till ready for swallow and to chew soft food (one piece of cake) 3 x 1 x 1 cm) till ready for swallow. A 2-minutes as a resting period was allowed between each recording. The order of presentation of foods was randomized. Analysis of EMG interference signals was performed with programs of EMG equipment MEB-9400K (NIHON KOHDEN Inc, Tokyo, Japan). EMGs were amplified and filtered (20 Hz to 10 KHz), full wave rectified and smoothed electronically to record the peak amplitude (µV) measured as the difference between the –v and +ve peak.

2.3 Surgical procedures

- For each patient, tissue supported maxillary and mandibular sterolithographic stents were constructed for exact sites and right angulations of dental implants. A universal surgical kit was supplied with the stereolithographic stent of successive diameter drill sleeves with horizontal indicators were used during the consecutive drilling procedures to accommodate successive increasing in drill diameter.
- Under local anesthesia, two osseointegrated implant fixtures, of 3.6mm width and 13mm length, were installed in the canine areas of the edentulous mandible using flapless surgical protocol. Also, four implants of variable sizes according to the available bone volume anterior to the maxillary sinus were installed in the anterior the maxillary area in a quadrilateral distribution using flapless surgical protocol. The implants position and orientation were verified by panoramic radiograph. After soft tissue healing of the implant sites, the patients were recalled to reline the dentures by soft liner.
- After the osseo-integration period of the mandibular implants, the cover screws were replaced by healing abutments for two weeks and the denture fitting surfaces were relieved around the healing abutmentsand relined with soft liner.
- The locator abutments were screwed into the two mandibular implants and the fitting surfaces of the mandibular dentures were prepared to functionally pick up the retentive caps by using autopolymerized acrylic resin.

2.4 Study design and patients grouping:

According to the attachment design used to assist the maxillary denture, the patients randomly used two

attachment designs; the splint bars used for three patients then replaced by locator attachments after three months denture insertion and two weeks intervening rest period. The other three patients used locator attachments at first and for three months and two weeks intervening rest period then replaced by bar attachments. The masticatory activity and biting force were measured after each study period of maxillary overdenture insertion for all patients. The results were collected and the study groups can recognized as follows:

Group I (Control group): patient used conventional complete denturefor three months.

Group II: patientused maxillary implant overdenture assisted by splint bars attachment against locator retained implant mandibular overdenture for three months.

Group III: patient used maxillary implant overdenture assisted by locator attachments against locator retained implant mandibular overdenture for three months. The chewing efficiency and EMG of masseter muscles were evaluated for **Group II &III** as done in **Group I.**

2.5 Construction of splint bars assisted maxillary over dentures

- After the osseointegeration periods of the maxillary implants, the cover screws were replaced by healing abutments for two weeks. Four long transfer copings were connected to the implants by using the impression posts (Fig.1). The copings were splinted together by using dental floss silk and autopolymerized acrylic resin* (Fig.2,3).The splint were cut between each two transfer copings and then reassembled by the autopolymerized resin (Fig4,5).
- Over all polyvinyl siloxan regular body** transfer impression was recorded on opened maxillary acrylic resin custom tray. The impression posts were unscrewed to remove the impression tray with the transfer copings hold in their position (Fig.6, 7).

Figure 1: The transfer copings connected to the implant fixture

Figure 2: The copings splinted together by using dental floss silk

Figure 3: The dental floss autopolymerized acrylic resin

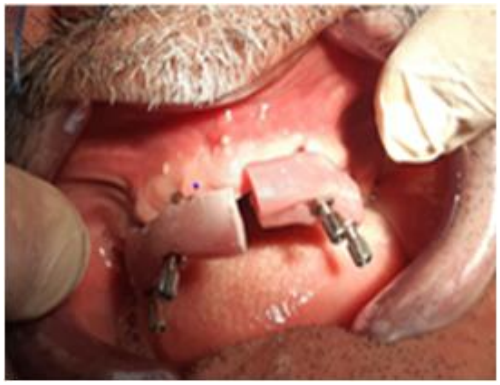

Figure 4: Cut sections in the patient mouth to verify complete passivity

Figure 5: Reassembled sections were then connected together with pattern resin

Figure 6: Open-tray maxilary impression with polyvinyl siloxane material.

Figure 7: Transfer copings picked up in the maxillary impression.

Figure 8: Fixture analogues screwed in to the Transfer copings.

- Fixture analogues were connected to the 4 transfer copings by the impression posts and the impression were poured with gum former layer followed by hard dental stone (Fig.8, 9).
- The cast were scanned and transferred as 3- D image to software of CAD CAM unit***. plastic pattern of bar abutments were selected from the library of CAD CAM unit and connected to the implant fixtures analogs to construct triple plastic milled in egg shaped Dolder bars connected to the four bar abutments provided that 2mm relief areas were left under the bars (Fig 10,11).
- The assembly (the bars with the abutments) was tried in the patient mouth to verify complete passivity during insertion (Fig.12). If any interference exists, the bars were cut down and reassembled in the patient mouth by the pickup acrylic resin. The assembly was scanned to construct titanium**** milled in egg shaped Dloder bar assembly.
- The metal framework was tried in the patient mouth by one screw test to achieve passivity during screwing the bar abutments into the implant fixtures.
- Overall polyvinyl siloxane regular body impression was recorded using opened maxillary acrylic resin custom tray and removed from the patient mouth after unscrewing the bar abutments.
- After pouring the impression, the bar assembly was blocked out for undercut areas and additional wax relief was done to construct autopolymerized acrylic resin maxillary record base. The bar assembly was unscrewed from the cast and screwed into the patient mouth to record jaw relation against the implant retained mandibular overdenture. The bar assembly was rescrewed into its position in the maxillary cast.
- After arrangement of artificial teeth for lingualized balanced occlusion, try in, processing into heat cured acrylic resin, finishing and polishing, the bar assembly was screwed into the patient mouth. All undercut areas related to the bar assembly were blocked out with heavy body rubber base material (Fig.13).
- The bar locations in the fitting surface were relived for 2mm. in the positions of the metal sleeves of the bar retentive clips. Venting palatal holes were prepared opposite to the positions of the bar clips. The bar clips were seated properly into their positions on the bars (Fig.14). Autopolymerized acrylic resin was packed into the prepared locations of the bar clips in the denture fitting surface to functionally pick-up the retentive clips while the patient close in centric position.
- After complete polymerization, excess resin was removed and the fitting surface was checked for any excess resin to be removed.

*pattern Resin made in USA.**Regular Body polyvinylsiloxane Impression materials (Chenesyl-Italy)
***AmannGirrbach5-axis milling and grinding technology(made in Austria)
****Ceramill Map 600 generates open STL or PLY data (made in Austria).

Figure 9: Maxillary cast with gum former layer.

Figure 10: Plastic milled in egg shaped Dolder bars screwed in to the fixture analogue.

Figure 11: Try in of plastic milled in egg shaped Dolder bars.

Figure 12: Undercut areas related to the bar blocked out with heavy body rubber base material.

Figure 13: The metal sleeves and retention plastic clips seated on their position on the bars.

Figure 14: Retention plastic clips and the bars picked up in the fitting surface of the maxillary .denture.

2.6 Locator attachments assisted maxillary implant overdenture (Group III):

- Patients were then recalled, the gingival formers were unscrewed.
- Trans-mucosal tissue height was measured to choose the correct locator abutment height (should be 2 mm above the gingiva).
- Locator abutments were mounted in the internal hex of the implants using the insertion key tool, tightened by the torque rench (35 N torque).

2.6.1 Pick-up procedure:

- The fitting surface of the denture opposite to locator abutments was marked by the aid of an indelible pencil, the markings are then relived (deepened) and widened mesio-distally. In addition, two small holes were made in the palatal surface of the denture for easy escapement of excess acrylic resin material during the pick-up procedure.
- The white locator blocking rings "white processing collars", which block the undercut, were stretched over the locator abutments followed by pressing the metal housings with the black processing nylon inserts directly over their corresponding abutments.(Fig15,16).

2.7 Data collection and statistical analysis

Three recording sessions were done for each denture on different days. Four peaks of EMG muscle activity from each chewing cycle were evaluated and averaged to obtain an average value per session. Then the mean of the 3 sessions for each prosthesis was calculated. The data (UF and EMG) met the normal distribution and were parametric as indicated by Shapiro-wilk test. UF between different chewing strokes (5, 10, 20, 30 and 50 strokes), were compared using theRepeated measures ANOVA followed by paired t-test for multiple comparisons. To compare UF between groups, ANOVA test was used followed by Bonferroni post hoc test. EMG activity between different food textures and between groups were compared using ANOVA followed by Bonferroni post hoc test. The data were analyzed using SPSS® software version 18 (SPSS Inc., Chicago, IL, USA) and SAS® software version 9.2 (SAS Institute, Cary, NC, USA). Statistical significance was set at .05 for all analysis.

Figure 15: Locator attachments withwhite block-out spacer beneath it

Figure 16: The metal housing with black processing inserts picked up to the fitting surface of mandibular denture

3. Results

3.1 Comparison of Chewing efficiency (UF) between groups

Comparison of UF between groups for different chewing strokes is presented in Table 1. There was a statistically significant difference in UF between groups at different chewing strokes ($p<.001$). Multiple comparisons between each 2 groups are presented in the same Table1 and Fig.17. At 5 strokes, Group I (CD) showed the highest UF, followed by Group III (Locator) and group II (bar) showed the lowest UF. There was a statistically significant difference in UF between each 2 chewing strokes. At 10, 20, 30, and 50 strokes, Group I (CD) showed the highest UF, followed by Group III (Locator) and group II (bar) showed the lowest UF. However, no significant difference in UF between Group III (Locator) and group II (bar) was observed.

3.2 Comparison of EMG between different groups

Comparison of EMG between different groups for different food textures is presented in Table 2. There was a significant difference in EMG between different groups ($p<.001$) for all food textures. Multiple comparisons are presented in the same Table2 and in Fig18. Bar group showed the highest EMG activity, followed by Locator group and conventional denture group showed the lowest activity. There was no significant difference in EMG activity between bar and locator groups for all food textures.

Table 1: Comparison of UF between groups for different chewing strokes

Groups	5 strokes Mean ±SD	10 strokes Mean ±SD	20 strokes Mean ±SD	30 strokes Mean ±SD	50 strokes Mean ±SD
Group I (CD)	0.484 ±.013 A	0.455 ±.006 A	0.388 ±.012 A	0.308 ±.007 A	0.257 ±.009 A
Group II (Bar)	0.394 ±.005 B	0.342 ±.006 B	0.294 ±.009 B	0.219 ±.012 B	0.139 ±.004 B
Group III (Locator)	0.423 ±.004 C	0.360 ±.012 B	0.319 ±.010 B	0.237 ±.003 B	0.158 ±.005 B
ANOVA (*p* value)	<.001	<.001	<.001	<.001	<.001

*p is significant at .05. Different letters in the same column indicate a significant difference between each 2 groups (independent samples t-test, $p<.05$)

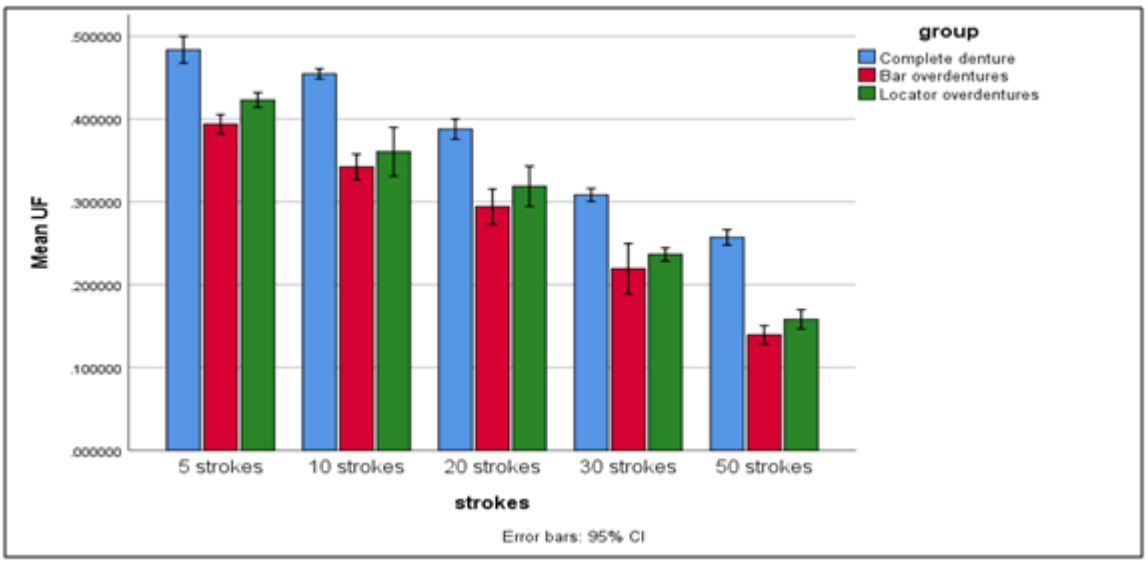

Figure 17: Multiple comparison of UF between each 2 groups for all chewing strokes. Error bars of confidence interval not interfering to each other indicate a significant difference between each 2 groups.

Table 2: Comparison of EMG between the groups for different food textures

Groups	Clenching		Soft food		Hard food	
	Mean	±SD	Mean	±SD	Mean	±SD
Group I (CD)	0.436 A	.064	0.345 A	.086	0.407 A	.063
Group II (Bar)	0.774 B	.031	0.707 B	.080	0.773 B	.031
Group III (Locator)	0.738 B	.026	0.673 B	.075	0.716 B	.034
F	59		26		64	
ANOVA (*p* value)	<.001		<.001		<.001	

*p is significant at .05. Different letters in the same column indicate a significant difference between each 2 groups (independent samples t-test, p<.05)

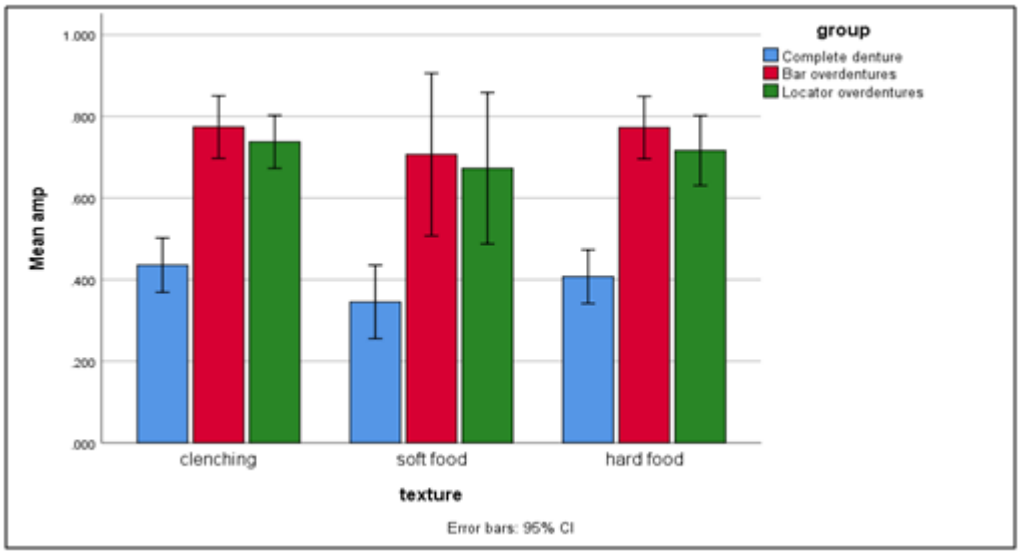

Figure 18: Comparison of EMG between the groups for different food textures. Error bars of confidence interval not interfering to each other indicate a significant difference between each 2 groups

4. Discussion

The selected patients were healthy and free from facial and oral neurological, myoskeletal or TMJ disorders to avoid variations in the recorded UF and muscle activity which are significantly affected by these disorders[14]**.** Geriatric patients were also excluded to eliminate the negative effect on the UF and muscle activity due to loss of muscle tone and muscle flaccidity [15]**.**

This study was designed to be cross over within subject to avoid individual variation as regard to the variables measured in this study which are highly sensitive to change as a day life effect even in healthy individual[14] .Also, no bias was allowed to use one type of attachment to start this study where the patients were randomly classified to start with both attachment systems equally and then replaced each other after sufficient resting period complete muscles recovery to start new UF and muscle activity record .

Flapless surgical protocol was followed in this study because steriolethognathic stents were used to determine the precise implant location. Lack of long crestal incision for the four maxillary implants and suturing procedures minimize the surgical trauma, promote rapid soft tissue healing phase and preserve the supporting tissues [16, 17].

Splinting the long transfer copings with dental floss and Duralayautpolymerized acrylic resin were done in this study to minimize the polymerization shrinkage which might affect the accuracy of the 3- D transfer of the implant fixture position to the working cast[18]**.** However, this procedure is a mandatory in this study to confirm a high degree of passivity of the triple bar construction to avoid transmission of undesirable harmful stresses to the implants during bar insertion procedures [19].

Functional pick up of the bar retentive clips and locator retentive caps was done to reduce rotational forces around attachments during vertical lodging forces [20]. Chewing gum was used in this study to evaluate masticatory efficiency has many advantages. There is no comminution of food particles which may get stuck under dentures or swallowed and there-fore lost for analysis (Liedberg&Owall 1995)[21]. Moreover, the gum has an elastic consistency which allows the use of maximum muscle activity.

Electromyography (EMG) was used for patients evolution in this study because it is considered as one of the instrumental techniques that is feasible for characterization of the eating process, as it is noninvasive and can record the electrical activities of masticatory muscles during eating[22]. The muscle activity is an indicator for the force that a subject can exert during chewing or clenching the teeth together. Good muscle activity is needed for proper chewing movements in

order to cut or comminute the food. This activity has been found to be directly related to the texture of food [22, 23].

The results of this study revealed that there was a statistically significant difference in the mean UF for all food textures and EMG activity of master muscle between conventional complete dentures and both types implant assisted overdentures. This may be related to the improved retention and stability of the implant overdentures compared with the conventional complete dentures. These results are in agreement with Jemt et al. 1985[24]; Jemt & Stalblad 1986 [25]; Akagawa et al. 1989[26]. where they found that stabilization of the overdenture by means of osseointegrated implants has been shown to improve oral function, provide a regular chewing pattern with higher electrical activity of the masseter muscles, and improve mandibular border movements compared with conventional complete dentures (Ottenhoff et al. 1996 [27]; Karkazis 2002[28]; Al-Omiri et al. 2005[29]; van der Bilt et al. 2006 [30]; Feine& Lund 2006) [31]. Moreover, implant-stabilized overdentures increase maximum bite force and masticatory performance, increase patient satisfaction, and minimize pain during mastication (Diaz-Tay et al. 1991[32]; Slagter et al. 1993)[33]. Elsayadet all [34] added that all implant-supported overdentures showed a significant increase in chewing efficiency and EMG values when compared to conventional dentures. They found that these values increased significantly in overdentures supported by four implants when compared to overdentures supported by two implants (with either ball or bar attachments).

As the number of chewing strokes increased, the mean ratio of UF decreased which revealed an increase in the degree of color mixture and mixing ability of the patients. A similar observation was noted in another crossover study conducted on three different attachment systems used for implant-supported mandibular overdentures (Elsyad et al. 2014) [35].

The mean ratio of UF shows characteristics of a logarithmic function on the base of chewing cycles and will decrease for two reasons: a higher degree of color mixture and a reduction in volume of the specimen due to sweetener extraction (Schimmel et al. 2007)[12]. Both are measures for chewing efficiency (Anastassiadou & Heath 2001; van der Bilt et al. 2010) [36, 37].

From the result of this study, it could be considered that the attachment type has no impact on the chewing efficiency and EMG activity of the implant assisted overdenture groups. This was confirmed by the statistically insignificant difference in the UF between both types of attachment after all strokes except the first five strokes where the bar assisted overdenture was more efficient in chewing compared with the locator assisted overdentures. However, controversies exist in the literature regarding the effect of different attachments of implant-retained overdentures on muscle activity. Uçankale et al[38], found a difference in muscle activity between ball and bar attachments of implant-retained overdentures, and they claimed that the type of attachment affects the stability and retention, which affects the chewing process and muscle activity. In contrast, other authors found no influence of attachment type of implant overdentures on muscle activity [39]. In a within-subject clinical trial, van Kampen et al. (2004) [40], found a significant improvement of masticatory efficiency in edentulous subjects receiving two implants regardless the type of the attachment used .

5. Conclusion

Within the limitation of this study including time intervals and patients number it could be concluded that four implant assisted maxillary overdentures opposed by two implant retained mandibular overdentures significantly improve the chewing efficiency and EMG activity of masseter muscle compared with conventional complete dentures regardless the attachment design(splint bar or solitary locator) used for the maxillary overdenture

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