Bite Force and Electromyographic Activity in Maxillary Implant-retained Overdentures: Bar vs. Ball Attachments

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Abstract:

Aim: This study aimed to assess the effects of bar attachments compared to ball and socket attachments in maxillary implant-retained complete overdentures opposing a Kennedy Class I partially edentulous mandible, focusing on biting force and electromyographic activity during clenching. **Subjects and methods**: Twenty-eight patients with completely edentulous maxillae opposing Kennedy Class I partially edentulous mandibular arches were selected from the clinic of Removable Prosthodontic Department, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt. Patients were divided into two groups; Group I (n=14) patients with maxillary overdenture retained by bar and clip attachment system and Group II (n=14) maxillary overdenture retained by ball and socket attachment system. New conventional maxillary complete denture opposing mandibular removable partial denture was constructed for each patient, Four implants were placed in the maxillary canine and premolar regions in accordance with the anteroposterior spread concept. The conventional maxillary denture was subsequently converted into a maxillary overdenture. Electromyographic activity during clenching and maximum biting force (MBF) were evaluated at baseline, 6 months, and 12 months. The data were collected and organized into tables, followed by statistical analysis using SPSS software. **Results:** The results of this study revealed that electromyographic activity during clenching and

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maximum biting force for Group I (bar and clip) were higher than those for Group II (ball and socket), with the differences considered statistically significant as indicated by the independent t-test, where the p-value was less than 0.05. **Conclusion**: This study demonstrated that maxillary implant-retained overdentures utilizing bar and clip attachments were more effective in enhancing electromyographic activity during clenching and achieving greater maximum biting force compared to those utilizing ball and socket attachments.

Keywords: Ball and socket attachment, bar and clip attachment, bite force, electromyography, implant retained overdenture.- -

Introduction:

The evolution of dental prosthetics has markedly improved the management of edentulous patients, especially through the introduction of implant-retained overdentures. These prosthetic solutions not only restore aesthetics and functionality but also significantly enhance the quality of life for individuals who have lost their natural teeth. The maxillary arch presents unique challenges in prosthetic rehabilitation, particularly when opposing a partially edentulous mandible, as observed in Kennedy Class I cases. The stability and retention of maxillary overdentures are crucial for effective function, especially during mastication [1, 2].

Earlier research has shown that the selection of an attachment system can greatly affect how forces are distributed during biting and the related muscle activity, both of which are crucial for efficient chewing and overall oral health [3]. Among the various attachment systems available for implant-retained overdentures; bar and ball attachments are commonly utilized, each offering distinct biomechanical properties and clinical outcomes [4].

Combination syndrome, also known as anterior hyperfunction syndrome, is described in the glossary of Prosthodontic terms as a set of distinctive features that arise when a toothless upper jaw is opposed by natural lower teeth. These features include bone loss from the front part of the upper jaw ridge, enlargement of the tuberosities, excessive growth of the mucosa on the hard palate, protrusion of the lower front teeth, and reduction of alveolar bone and ridge height beneath the bases of removable lower dental prostheses [5].

Due to a lack of bone support, traditional dentures tend to fit poorly on the majority of older edentulous patients, making it difficult for them to chew and eat [6]. Insecurity, ineffective mastication, and general unhappiness with the prosthesis are all caused by denture instability [7]. Therefore, the proper masticatory function is crucial because it affects both quality of life and food digestion [8].

Implant retained overdenture is considered the best treatment plan for the rehabilitation of edentulous patients with bone resorption. In the maxillary arch, implant overdenture requires at least 4 implants placed bilateral of the jaw either splinted together with bar attachment or solitary (unsplinted) attachment such as ball and socket attachment [9].

Integrating prostheses with implants enhances their stability and functionality, leading to increased patient satisfaction. Additionally, implant connections have been observed to improve neuromuscular activity and adaptation, thereby significantly enhancing masticatory function in patients without teeth. Various attachment systems were employed, such as ball and socket, bar and clip, magnets, telescopic crowns, and recently several modifications such as locator and equator but ball and socket attachment has different biomechanical features, availability, simplicity, applicability, the possibility of obtaining a wide range of retention, accessibility to be cleaned by patient and low cost [10].

Bar attachments come in various forms, including prefabricated, custom-made, and milled using CAD-CAM technology. They can be categorized into two primary types based on their shape and function. Bar joints allow for some movement around the bar during chewing, while bar units enable movement around the bar during mastication [11].

Biting force is a key indicator of the overall functionality of the masticatory system. The biomechanical principles of this system and the effectiveness of prosthetic treatments are assessed through biting forces. The most precise measure of occlusal force is the maximum biting force (MBF), which is used to evaluate the performance of the masticatory system [12, 13].

Electromyographic data have been used to study the masticatory muscle behavior of the stomatognathic system under normal or abnormal circumstances such as occlusion and bruxism,

aid in the diagnosis of orofacial pain, and assess the effectiveness of various treatment modalities in patients with temporomandibular disorders because they are repeatable [14].

This study aimed to evaluate biting force and electromyography during clenching of four implant-retained maxillary overdenture with two different types of attachments bar and clip versus ball and socket attachment and opposing mandibular kennedy class I metallic removable partial denture.

The null hypothesis of this research posits that there will be no statistically significant difference in using ball and socket or bar attachment systems for implant retained single maxillary overdenture opposing Kennedy class I partially edentulous mandible on biting force and electromyography during clenching.

Subjects and methods:

Twenty-eight completely edentulous patients were randomly chosen from the outpatient clinic of the Removable Prosthodontics Department at the Faculty of Dental Medicine (Boys), Al-Azhar University in Cairo. The sample size for this study was determined according to the methodology described by Elsyad MA et al. [15] An effect size of 1.16, an alpha error probability (α) of 0.05, and a statistical power of 90% were established as parameters for the analysis. Utilizing G*Power software for power analysis, it was calculated that a minimum sample size of 14 patients per group would be necessary to detect statistically significant differences.

Depending on the attachment used, patients were randomly divided into two groups. Each group included ten patients. Group I (B group): (n=14) The patients will receive maxillary overdentures supported by bar and clip attachment system & group II (BS group) :(n=14) patients will receive maxillary overdentures supported by ball and socket attachment system.

The Criteria for selecting participants for this study comprised male individuals aged 55 to 70 years who presented with complete maxillary edentulism while retaining natural lower anterior teeth and had susceptibility to alveolar bone resorption in the anterior maxilla and development of combination syndrome. Eligible patients demonstrated sufficient alveolar bone dimensions (height and width), covered by healthy, firm mucosal tissue, to facilitate implant placement without requiring adjunctive surgical interventions. Additional inclusion criteria

included the absence of systemic conditions that could influence bone metabolism, the capacity to comprehend and adhere to study protocols, and adequate interarch space to accommodate prosthetic rehabilitation. These parameters were established to ensure participant suitability and methodological consistency in alignment with the study's objectives.

Patients with local or systemic conditions that hinder implant placement and osseointegration were excluded from the study. Additionally, immunocompromised individuals, those currently undergoing chemotherapy or radiotherapy, patients with abnormal jaw relationships, parafunctional habits, temporomandibular joint (TMJ) disorders, or insufficient interarch space were also excluded.

Alveolar ridge height, bone quality, and bone density were evaluated using cone-beam computed tomography (CBCT). Cross-sectional views were utilized to assess bone dimensions and anatomical structures for implant placement planning [16].

For each patient, a new upper complete denture and lower metallic partial denture were fabricated, finished, and polished before insertion. The dentures were assessed for esthetics, retention, stability, occlusion, high spots, sharp edges, and overextensions.

To ensure accurate implant positioning and angulation, a surgical guide was created to direct the initial implant drill. The implant surgical template was constructed using a modified version of Preston's clear splint. An irreversible hydrocolloid full-arch impression (Tropicalgin, Zhermack, Italy) was taken and cast in dental stone. A vacuum-formed acrylic shell (Bioart, Brazil) was then pressed and trimmed on the cast. The occlusal acrylic was removed over the designated and optional implant sites while maintaining the surgical template's facial and facial-occlusal line angles. This method provided optimal flexibility for implant placement and ensured the ideal implant angulation during surgery [17].

The study protocol encompassed two sequential phases. The surgical phase involved the placement of four dental implants (Nucleoss, Menderes, Izmir, Turkey) with a length of 10 mm and, diameter of 3.7 mm were inserted in the maxillary canine and second premolar regions under local anesthesia, utilizing a two-stage flapless surgical approach. During the prosthodontic phase, following a six-month osseointegration period, the implants were surgically exposed, and

the cover screws were replaced with either ball-and-socket or bar attachments, depending on the experimental group. Finally, the maxillary complete denture was converted to an implant-retained overdenture using a direct pick-up technique, wherein self-cure acrylic resin was employed to secure the prosthesis to the attachments.

Biting force was assessed using a bite force meter (NIHON KOHDEN Neuropack, Japan) [(18)] at the time of insertion, and then again at 6 months and 12 months post-surgery.

The maximum bite force of patients using overdentures with two different attachment systems (ball-and-socket and bar-and-clip) was measured with a bite force meter. Masticatory bite force was recorded at the time of attachment insertion, and then at 6 months and 12 months post-insertion. Patients were instructed to bite on the bite fork at the molar region three times with maximum force for 3 seconds, with a 2-minute rest interval between each attempt. The average of the recorded readings was then calculated. Figure (1)

Figure (1): Patient biting on the force meter fork.

Electromyographic activity was evaluated using surface electromyography (sEMG)[(19)]. Electromyographic activities of the masseter muscles were assessed as patients clenched on the right and left sides at various intervals (time of insertion, three months, six months, nine months, and twelve months). Patients were positioned in an upright, comfortable posture with their heads balanced and unsupported, and their mandibular bodies at a 45-degree angle to the ground.

Statistical analysis was conducted using SPSS® version 20. The normality of all quantitative data was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests, with

results presented as minimum, maximum, mean, and standard deviation (SD) values. Statistical significance was set at the 5% level. For normally distributed quantitative variables, the Student's t-test was used to compare the two groups under study.

Results:

A- Maximum Biting force:

Table (1) shows the mean values of biting force for the two groups. A statistically significant difference was found between the two groups during all of the follow-up periods.

Table (1): Maximum biting forces on right and left sides regarding group I (B group) and group II (BS group) at baseline, after 6 months, and after 12 months.

		Group I (B group)		**Group II (BS group)**		**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**		**P-value (Independent t-test)**
		M	SD	M	SD			Lower	Upper	
Right	Insertion	20.720	2.484	21.18	3.27	0.397	1.186	-2.871	2.077	0.741
	After 6 Months	31.540	3.891	29.82	2.82	1.945	1.393	-0.961	4.850	0.178
	After 12 Months	45.960	4.105	37.20	2.08	8.968	1.326	6.203	11.733	0.0001*
Left	Insertion	23.840	4.370	22.92	2.49	0.857	1.448	-2.163	3.878	0.560
	After 6 Months	36.500	4.750	29.84	3.43	6.435	1.691	2.909	9.962	0.001*
	After 12 Months	47.660	3.640	34.32	3.41	13.132	1.435	10.139	16.124	0.0001*
Overall	Insertion	22.280	2.725	22.050	2.285	0.230	1.072	-2.007	2.467	0.832
	After 6 Months	34.020	2.967	29.830	2.455	4.190	1.161	1.768	6.612	0.002*
	After 12 Months	46.810	3.561	35.760	2.233	11.050	1.267	8.407	13.693	0.0001*

* Significant difference as P<0.05

B- Electromyograph:

Electromyographic activities (EMG): Paired t-test was used to compare the electromyographic activities of masseter muscles (right and left) with the two types of attachment used in the study (Group I and Group II). EMG results expressed by root mean square (RMS)uv in microvolt for group I and group II. Electromyographic activities (EMG) (RMS)uv of masseter muscle.

Table (2): clenching in right and left for masseter muscle regarding group I (B group) and group II (BS group) at baseline, after 6 months, and after 12 months.

		Ball (n = 14)	Bar (n = 14)	T	P
Clenching R	Insertion	0.173 ± 0.039	0.238 ± 0.036	2.986*	0.014*
	6 months	0.267 ± 0.036	0.354 ± 0.038	4.052*	0.002*
	12 months	0.402 ± 0.040	0.512 ± 0.016	6.196*	<0.001*
Clenching L	Insertion	0.162 ± 0.036	0.196 ± 0.017	2.064	0.066
	6 months	0.286 ± 0.063	0.392 ± 0.030	3.695*	0.004*
	12 months	0.463 ± 0.051	0.505 ± 0.026	1.800	0.102

p: p-value for comparing between the studied groups

*: Statistically significant at $p \leq 0.05$

Discussion:

Prosthetic rehabilitation of patients with a completely edentulous maxilla opposing a Kennedy Class I partially edentulous mandible presents a significant challenge in prosthodontics. The anterior maxillary segment is particularly prone to unwanted stresses, which can be effectively alleviated through the use of implant-supported maxillary overdentures. Implants placed in the anterior maxillary region enhance patient tolerance, improve proprioception, and reduce damage to the underlying tissues, thereby minimizing bone resorption [(20)]. This study aimed to evaluate the effects of bar-clip and ball-socket attachment systems on maximum biting force (MBF) and electromyographic (EMG) activity, providing valuable insights into their biomechanical and neuromuscular implications.

Ball attachment systems are widely utilized due to their simplicity, low cost, ease of handling, and minimal chairside time requirements. They are applicable to both tooth- and implant-supported prostheses and have demonstrated high implant and prosthetic survival rates, low complication rates, and favorable biological parameters in mid-term follow-up studies [(21-23)]. However, bar-clip attachments offer distinct advantages, including greater retention and stability, the ability to splint implants, and the capacity to mask excessive residual ridge atrophy. Bar attachments are particularly beneficial when implants are not parallel, as they ensure a parallel path of insertion regardless of implant angulation [(4)]. These characteristics make bar-clip systems a robust option for enhancing prosthetic function and patient comfort.

Maximum voluntary bite force is a crucial indicator of the functional status of the stomatognathic system. It is affected by jaw biomechanics, muscle cross-sectional areas, sarcomere length, and reflex mechanisms [(24)].

In this study, maximum bite force (MBF) was measured using a bite force meter positioned at the first molar region. Patients were instructed to bite on the bite fork three times with maximum force for three seconds, with a two-minute rest interval between each recording.

The average of the readings was then calculated for analysis [18]. At baseline, there was no statistically significant difference in maximum bite force (MBF) between the two groups. However, after six and twelve months, the bar-clip attachment group exhibited significantly higher MBF compared to the ball-socket group. This difference is likely due to the splinting effect of bar-clip systems, which improves load distribution and stability.

These findings align with the existing literature; for instance, Helmy et al. [25] reported a higher maximum bite force (MBF) in patients utilizing bar-clip attachments compared to those with ball-socket systems. This improved performance is likely attributable to the augmented stability and support inherent to the bar-clip system, which directly enhances masticatory efficiency. Consequently, these results reinforce the premise that the specific design and biomechanics of bar-clip attachments facilitate superior force distribution and patient comfort during mastication.

Elbeheiry et al. [12] reported a significant longitudinal increase in maximum bite force (MBF) irrespective of the attachment system utilized, whereas Elsyad et al.[26] demonstrated that bar-clip attachments specifically enhance both bite force and masticatory efficiency.

The use of electromyography (EMG) in this study provided an objective assessment of the neuromuscular effects of different attachment systems. EMG quantitatively measures muscle activity, offering insights into the biomechanical efficiency of the stomatognathic system. The bar-clip attachment group exhibited significantly higher EMG activity in the masseter muscles (both right and left) during clenching compared to the ball-socket group. This suggests improved muscle engagement and a more stable, effective masticatory function, likely due to the enhanced support provided by the bar-clip system and the increased patient comfort during mastication. This highlights the importance of EMG in prosthetic dentistry research for evaluating and optimizing prosthetic designs to enhance patient outcomes [27, 28].

Regarding electromyographic activity (EMG) of the masseter muscles (right and left) during clenching, Group I (bar-clip) demonstrated superior results compared to Group II (ball-socket), with statistically significant differences on both sides. This may be attributed to the better support provided by the ridge with the bar attachment system and the comfort experienced

by the patients while eating. These results align with the findings of Abdel-Bary and Alameldeen, who performed an electromyographic evaluation of implant overdentures retained by two different attachment types. They concluded that the highest activity values were observed in the locator attachment group, followed by the ball attachment group[29].

However, Moustafa Elsyad et al. [30] found no discernible difference in the electromyographic activity of the masseter muscle during chewing with three different implant-supported mandibular overdenture designs when comparing chewing efficiency and EMG between bar and ball prostheses. This lack of discernible difference might be attributed to factors such as the inherent variability in individual muscle function, the adaptive capacity of the neuromuscular system, and the specific characteristics of the patient population studied. Additionally, variations in the design and fabrication of the overdentures, as well as differences in study methodologies, may contribute to the discrepancies observed between different research findings.

The results of this study did not align with the null hypothesis, as statistically significant differences in MBF and EMG activity were observed between the bar-clip and ball-socket attachment systems. This reinforces the clinical relevance of attachment system selection in optimizing prosthetic outcomes.

While this study offers valuable insights, several limitations must be recognized. The small sample size and short follow-up period may restrict the generalizability of the findings. Additionally, the absence of blinding in the study design could introduce bias. Future research should address these limitations by including larger sample sizes, longer follow-up periods, and randomized controlled trial designs. Further studies should also investigate patient-reported outcomes, such as satisfaction and quality of life.

Conclusions:

Within the limitations, this study demonstrates that bar-clip attachments significantly enhance maximum bite force and electromyography activity in maxillary implant-retained overdentures compared to ball-socket attachments. These findings support the use of bar-clip systems in scenarios where improved masticatory function and stability are desired. However,

clinicians should consider patient-specific factors, such as ridge morphology, implant angulation, and cost, when selecting an attachment system.

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