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The Effect of Two Different Implant Attachment Designs on Retention and Electromyograph of Narrow Implant Retained Mandibular Overdenture

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ORIGINAL STUDY

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Abstract

Purpose: The purpose of this study is to evaluate the effect of two different implant attachment designs on retention and Electromyographic activity in narrow implant retained mandibular overdentures. **Material and methods:** 10 patients were selected ranging in age from 50 to 70 years. Each patient received two implants with a narrow diameter placed in the canine region of the edentulous mandible. Patients were divided into two groups: group I (Ball and socket group): all patients received ball and socket attachments for 6 months. Group II (Equator Group): all patients received equator attachments for another 6 months with a 1 month washout period. Retention and Electromyographic activity were evaluated at insertion, after three months, and after six months from delivery. **Results:** The descriptive statistics of retention showed statistically significant difference in the retention values at the three periods of time within the same group and also between the two studied groups at each observation time ($P < 0.001$ at the three observation times). Regarding electromyographic activity, there was a statistically significant increase in the muscles activity after using attachment in the studied groups. Nevertheless, the comparison between the two groups at the end of follow up period revealed a statistically insignificant difference. **Conclusion:** Within the limitations of this study, it can be concluded that narrow diameter implants are an effective treatment option that allows us to avoid more invasive procedures. Reduction of retention should be considered when selecting dental attachments. Muscles activity significantly increased after using dental attachments, with no significant differences among the studied attachments (Ball and equator).

Keywords: Attachment, Electromyogragh, Implant over denture, Retention

1. Introduction

Complete denture has been the most common treatment choice for completely edentulous patients. Despite the numerous advantages that complete denture can offer, many patients have complained from loss of retention and stability of mandibular complete dentures and that had an influential impact on patient satisfaction and patient's quality of life [1].

Soft liners, cushions, and denture adhesives have all been used in the past to give support for full dentures, with varying degrees of success [2].

Implant-retained mandibular overdentures (IODs) are an active and reliable treatment option for the edentulous. IODs solve the issues of poor retention and stability that come with mandibular full dentures. IODs have greater survival rates, enhanced oral function, and better patient satisfaction and oral health-related quality of life than traditional full dentures, according to clinical trials. IODs also increase objective chewing ability and maximal occlusal force in edentulous individuals, as well as providing a stable centric occlusion [2–4].

The retention of a full denture in the edentulous mandible requires at least two implants, according to research. Two implants in the interforaminal region, for example, have high implant success rates and improve masticatory function [5].

Bone width is usually insufficient for regular-sized implants in cases of long-term edentulous bone atrophy or bone loss due to periodontal diseases,

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periapical pathologies, and traumatic tooth extractions, because the width of the buccal and lingual bone walls, and especially the height of the buccal socket wall, will be reduced. Placing a standard-sized implant in such conditions may result in significant dehiscence, increasing complications, and failure [6,7].

Two choices exist in the situation of a narrow ridge. The first option is to use a conventional implant following bone augmentation treatments, and the second is to utilize a narrow-diameter implant [8].

Implants with diameters of 3.0 mm or greater and less than 3.75 mm (3.0 mm $\leq$ diameter <3.75 mm) have been considered to be Narrow diameter Implants. Implants with diameters of 3.75 mm or greater and less than 5 mm (3.75 mm $\leq$ diameter <5 mm) have been considered to be regular diameter implants (RDIs) [9].

Narrow implants are especially effective when the extent of the bone crest limits the placement of a conventional diameter implant without the use of regeneration methods [10].

There are numerous types of attachments used to retain an implant over denture, they are generally classified into splinted attachments such as bar attachments or un-splinted attachments such as ball or locator attachments [11].

The un-splinted attachments have been more frequently used than the splinted attachments owing to the smaller space requirements within the prosthesis, more economical, ease of cleaning, and lower sensitivity procedures [11].

Ball attachments were considered the most basic and widely available type of attachment, and they were shown to have favorable clinical performance for various overdenture designs, including standard diameter and mini-implants, as well as for a variety of implant numbers, including single implant retention [12,13].

The Equator attachment has also been effectively evaluated for treatment with overdentures retained by two implants and narrow diameter implants. It is thought to have the shortest height on the market, making it a preferable alternative when vertical space is restricted [13].

Results obtained from previous literatures [14,15] indicated that narrow diameter implants are a predictable treatment option, since they afford clinical results comparable to those obtained with implants of standard diameter.

In a previous study, the author analyzed and compared the retention characteristics of Three different stud attachment systems (Ball attachment and two different low profile stud attachments – Equator and Locator), and found that All tested attachment systems showed a significant decrease in retention value at the end of the simulated period [16].

Also in another study, which compared the electromyographic (EMG) activity of masseter and anterior temporalis muscles when using three different treatment protocols i.e. (conventional CDs, two and four IODs), it was concluded that using narrow diameter implants reduced the invasiveness, cost, and time of bone grafting surgical procedures and in case of a severely resorbed mandible, using only two narrow implants to support overdenture was not enough to reduce oral pain, and the placement of four narrow implants improved the masticatory efficiency, muscle activity and reduced mucosal pain [17].

The authors of the present study have not come across any studies that compared ball and equator attachment with narrow implants assisted over dentures regarding retention and electromyographic activity. So the purpose of this study was to evaluate the retention and Electromyographic activity of different attachments (Ball and Equator attachments) used with narrow-diameter implants, which are used as definitive implants in patients with insufficient bone ridge thickness for placing standard-diameter implants.

The null hypothesis was that there will be no significant differences between the two types of attachment regarding retention and EMG values.

2. Material and methods

2.1. Study design and patient selection

The present study was a randomized, crossover clinical trial. Ten completely edentulous patients (age ranged between 50 and 70 years with a mean of 60 years) were selected from the Outpatient Clinic of Prosthodontics Department, Faculty of Dental Medicine for Girls, Al-Azhar University.

The patients were selected according to the following criteria: 1) Patients with narrow mandibular ridges ($\leq$5.5 mm). 2) Patients were free from any systemic disease that may interfere with dental implant placement and/or Osseo integration, e.g., uncontrolled diabetes, hypertension, blood diseases and bone diseases. 3) Last extraction was at least 6 months before, 4) No neuromuscular and tempromandibular joint disorders.

All patients accepted this dental treatment and were informed about the steps of this study, the advantages and possible risks if present and signed a written consent with the Research Ethics

Committee (REC-PR-22-03) approval of the faculty of dental medicine for Girls, AL-Azhar University.

2.2. Surgical procedures

Preliminary impressions were made and a radiographic stent was constructed on the diagnostic cast. A Cone beam CT was carried out with the stent to evaluate the bone height, width and quality at the proposed implant sites.

Each patient received two tapered self-tapping endosteal implants (multi system, Italy) that were inserted bilaterally at the mandibular canine region.

Conventional flap 2 stages surgical and delayed loading protocols for implant installation were followed. For proper implant parallelism and locations, the radiographic stent was transformed into the surgical guide stent by opening holes in the canine region bilaterally.

Under local anesthesia flap reflection was done. Surgical guide stent was placed in the patient's mouth and bone was marked for implant installation. Drilling sequence was completed with copious external irrigation with up and down motion at a speed of 800 RPM. Implants (11.5 mm in length and 3.2 mm in diameter) were installed parallel to each other in the canine region bilaterally. A three month healing time was provided to ensure full implant bone Osseo-integration.

The normal process was followed for the construction of maxillary and mandibular conventional heat cured acrylic resin full dentures. Final adjustments were done, and the dentures' retention and occlusion were confirmed.

After three months the patients were recalled for implant evaluation. Implant sites were marked using the surgical stent and a punch was used to expose the covering screw which was removed and a healing abutment was placed and stayed for seven days to permit gingival tissue healing.

After seven days the healing abutments were removed and ball and socket attachments with clear nylon inserts (multisystem, Italy) were picked up by direct technique which started by blocking the space around the ball under the metal housing by dental floss to facilitate pick up procedure. Cold cure acrylic resin was placed into relieved areas of the denture and the denture was seated in the patient's mouth. Patient closed in centric occlusion until the acrylic resin polymerized.

The mandibular denture was removed with ball housing which was picked up in the fitting surface. Then the lower denture was finished and polished.

Retention and electromyographic activity of masseter and temporalis muscles were evaluated at delivery, after three months, and after six months from complete denture delivery. These recordings were considered to be a (Ball and socket group).

After six months the ball and socket attachments were removed, the patients were left for one month with healing abutments (wash out period). After one month the healing abutments were removed, and Equator attachments with pink nylon inserts (multisystem, Italy) were used replacing the ball and socket attachments by the same technique. Retention and electromyographic activity of masseter and temporalis muscles were evaluated again at delivery, after three months and after six months from complete denture delivery with the new attachments. These recordings were considered to be the (Equator Group).

2.3. Testing procedure

2.3.1. Retention

Baseplate wax was used to block any undercuts inside the mandibular denture's fitting surface. After that, a plaster mixture was poured over the denture's fitting surface, and a base was built with another mix. On the polished surface of the denture, the retromolar pad centers and also the midline were marked, and then three lines were drawn in the cast base, producing a triangle that corresponded to these markings.

On the cast base, three lines were drawn that bisected the triangle's three angles. The denture's geometric center was thought to be the intersection of these three lines, which were maintained by securing a metallic rod to the base and suspending its upward from the marking.

On the polished surface, three depressions were made. One was produced on the lingual flange, just below the central incisors, at the midline. The other two depressions were made at the retromolar pad region, just distal to each side's second molar.

The center of a wrought wire (1 mm) was bent and adjusted such that it did not interfere with the tongue space and ran 2 cm above the occlusal plane from one side's retromolar pad depression to the other side's retromolar pad depression.

After that, a second wrought wire of the same diameter was modified to extend 2 cm above the occlusal plane from the depression at the lingual flange.

The two wrought wires were then twisted in opposite directions until they met at the geometric center that had been determined. One end of the second wire was bent to make a c-shaped loop around the first wire, and the other end was placed in the depression made right below the central incisor.

The free ends of the two wires were then fixed to the polished surface of the mandibular denture by self-cured acrylic resin. Excess acrylic resin was then removed and the denture surface was refinished and polished (Fig. 1).

Digital Force Gauge (Ebalance, China) was used to assess retention. The metallic probe of the digital force-meter was attached to the c-shaped loop created at the geometric center of the mandibular dentures and a vertical pulling force was applied to measure denture retention. Retention strength was measured in newton. Five readings were taken and the average value was recorded.

2.3.2. Electromyographic activity

Computer electromyography-based data acquisition system (Nemus 2, Italy) was used to capture EMGs, which were represented as root mean square (RMS). The EMG offers a safe, simple, and non-invasive method for objectively measuring the bioelectric activity of the jaw muscles.

Banana and carrots were utilized in standard proportions and sizes. These test food samples represented soft and hard food, respectively.

The patients were seated in an upright position. The skin over the muscles was cleaned with ethanol. Surface electrodes were placed on the bellies of the masseter muscle. The active electrodes were positioned on mid-longitudinal fibers of the muscle parallel, and the reference electrode was placed on the patient's forehead.

For temporalis muscle while the patient clenching the position of the surface electrodes were determined through an imaginary horizontal line drawn from the outer canthus of the eye to the upper margin of the external auditory meatus. The electrodes were placed about 3 cm vertically upward from the midpoint of the horizontal line. Electro conductive gel was put to the electrodes before they made contact with the skin, and they were stuck with adhesive tapes (Fig. 2).

The patients were asked to chew the food samples with their implant-supported over-dentures which resulted in an area of facial muscle activation that

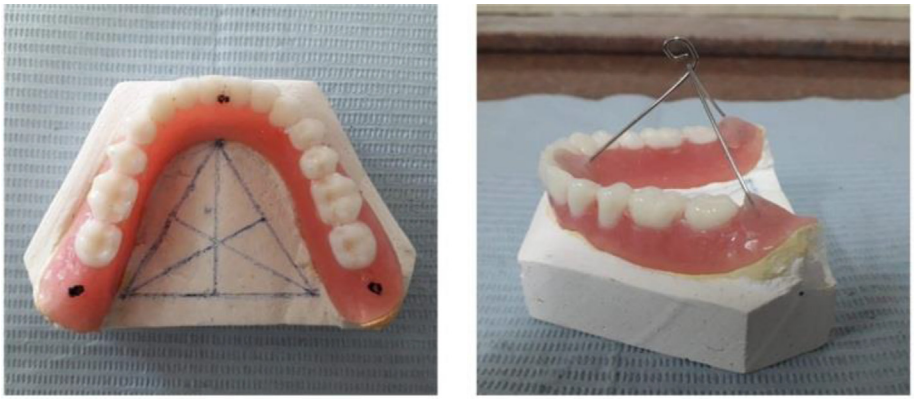

Fig. 1. Geometric center of the mandibular denture.

Fig. 2. Electromyographic evaluation for masseter and temporalis muscles.

produces impulses. A laser printer was used to print these impulses.

2.4. Statistical analysis

The data was collected, tabulated, and analyzed using IBM SPSS version 23 (Statistical Package for Social Science). The quantitative information was presented as means and standard deviations. The comparison between two groups with quantitative data and parametric distribution were done by using Independent t-test.

The comparison between more than two paired groups with quantitative data and parametric distribution were done by using Repeated Measures ANOVA test followed by post hoc analysis using Bonferroni test.

The margin of error acceptable was set to 5%, and the confidence interval was set to 95%, therefore the *P*-value was judged significant at the level of 0.05.

3. Results

All patients attended all follow up periods with no drop outs (Tables 1–3).

3.1. Results of retention

(1) The descriptive statistics of retention showed statistically significant decrease in the retention values through the three follow up periods within the same group based on repeated ANOVA test which revealed significant difference between them as $P < 0.05$ followed by Post hoc test for multiple comparisons which revealed significant difference between the three interval follow up periods.
(2) Statistics analysis based on Independent t-test showed significant difference in the retention values between two studied groups with higher retention values for ball attachment than equator attachment at each observation time as $P < 0.05$ at delivery, after 3months and after 6months.

3.2. Results of electromyograph

3.2.1. Masseter muscle

(1) Statistical analysis revealed that there was significant increase in masseter muscle activity within same group with passage of time. Comparison between three follow up periods were

Table 1. Mean Retention values (in newton) of ball and socket group and equator group.

Time interval Retention		Ball and socket attachment group No. = 10	Equator attachment group No. = 10	Test value	*P*-value	Sig.
0 month	**Mean±SD**	$36.49^{aA} \pm 5.37$	$23.26^{aB} \pm 1.39$	7.540	<0.001	HS
3 months	**Mean±SD**	$30.71^{bA} \pm 3.48$	$19.74^{bB} \pm 1.07$	9.518	<0.001	HS
6 months	**Mean±SD**	$28.46^{cA} \pm 3.37$	$16.97^{cB} \pm 1.56$	9.776	<0.001	HS
Repeated ANOVA test	**Test value**	108.107	114.272	–	–	–
	***P*-value**	<0.001	<0.001	–	–	–
	Sig	HS	HS			

P-value >0.05: Non significant; *P*-value <0.05: Significant; *P*-value <0.01: Highly significant.
Different small letters in each column indicate significant difference within each group.
Different capital letters in each row indicates significant difference between the two groups.

Table 2. Mean EMG values of masseter muscle of the two studied groups.

Masseter muscle	Ball and socket attachment group Mean ± SD	Equator attachment group Mean ± SD	*P*-value	Sig.
Hard food				
0month	$220.86^{aA} \pm 9.21$	$219.60^{aA} \pm 9.46$	0.767	NS
3months	$239.14^{bA} \pm 7.44$	$234.60^{bA} \pm 7.18$	0.182	NS
6months	$258.68^{cA} \pm 10.0$	$259.85^{cA} \pm 9.27$	0.789	NS
Repeated ANOVA test	<0.001 HS	<0.001 HS	–	–
Soft food				
0month	$108.12^{aA} \pm 6.12$	$100.31^{aB} \pm 5.39$	0.007	HS
3months	$126.35^{bA} \pm 4.63$	$121.49^{bB} \pm 5.04$	0.038	S
6months	$138.53^{cA} \pm 5.93$	$138.74^{cA} \pm 6.43$	0.940	NS
Repeated ANOVA test	<0.001 HS	<0.001 HS	–	–

P-value >0.05: Non significant; *P*-value <0.05: Significant; *P*-value <0.01: Highly significant.
Different small letters in each column indicate significant difference within each group.
Different capital letters in each row indicates significant difference between the two groups.

Table 3. Evaluation of the EMG values of Temporalis muscle of the two studied groups.

Temporalis muscle	Ball and socket attachment group Mean ± SD	Equator attachment group Mean ± SD	*P*-value	Sig.
Hard food				
0month	190.20^{aA} ± 15.36	189.28^{aA} ± 7.96	0.868	NS
3month	208.25^{bA} ± 10.67	210.15^{bA} ± 9.93	0.684	NS
6month	226.66^{cA} ± 6.90	230.25^{cA} ± 14.51	0.489	NS
Repeated ANOVA test	<0.001 HS	<0.001 HS	–	–
Soft food				
0month	86.67^{aA} ± 6.76	89.38^{aA} ± 8.50	0.440	NS
3month	101.42^{bA} ± 9.66	104.34^{bA} ± 7.53	0.461	NS
6month	114.87^{cA} ± 5.42	118.13^{cA} ± 4.49	0.160	NS
Repeated ANOVA test	<0.001 HS	<0.001 HS	–	–

P-value >0.05: Non significant; *P*-value <0.05: Significant; *P*-value <0.01: Highly significant.
Different small letters in each column indicate significant difference within each group.
Different capital letters in each row indicates significant difference between the two groups.

performed using repeated ANOVA test followed by Post hoc test for multiple comparisons which revealed significant difference between the three interval follow up periods as ($P < 0.05$). This was true for both food types.

(2) Statistical analysis using Independent t-test showed no statistical differences in masseter muscle activity between two groups during chewing hard food throughout all observation periods, while there was significant higher masseter muscle activity of ball attachment than Equator attachment group during chewing soft food at insertion and after three months and became non-significant after six months.

3.2.2. Temporalis muscles

(1) Statistical analysis revealed that there was significant increase in temporalis muscle activity within same group with passage of time. Comparison between three follow up periods were performed using repeated ANOVA test followed by Post hoc test for multiple comparisons which revealed significant difference between the three interval follow up periods as ($P < 0.05$). This was true for both food types.

(2) Statistical analysis using Independent t-test showed no significant differences between the two attachments in temporalis muscle activity for both hard and soft food throughout all observation periods.

4. Discussion

The null hypothesis that there would be no differences in retentive force or electromyographic activity among the two types of attachment systems was rejected regarding retention results and accepted regarding electromyographic activity.

The within-patient study design (patients compared within themselves) help to standardize patient and prosthetic factors and make retention and EMG measurements more reliable.

Dental implants have had a high success rate in edentulous patients, and they have considerably improved patient satisfaction and full denture prosthetic results Rashad and colleagues [18].

Insufficient bone width for the insertion of dental implant of conventional size is the most common problem in implant dentistry. In cases where bone width is narrow, local bone augmentation to enable the use of standard-size implants may be compromised due to several complications; the other treatment option is the use of smaller diameter implant that is less invasive Teranelly and colleagues [17].

The purpose of this study was to see how two alternative implant attachment designs affected the retention and electromyography of narrow implant-retained mandibular overdenture.

As the study denotes a decrease of retention during the follow-up period that coincides with many researches Rocha, Sharaf and colleagues, Manimala and colleagues, Passia and colleagues [19–22] Explaining loss of retentive force over time is inevitable. This loss of retention has been attributed to wear of attachment components, which can be associated with deformation which happens during insertion and removal of the prosthesis.

According to other researches Choi and colleagues [23] resilient attachments exhibit wear under functional loading or after many cycles of insertion and removal which may be due to friction between male and female components.

The results of this study showed that Ball and socket attachment system used with clear nylon inserts showed superior retentive properties in comparison to equator pink nylon inserts which can be

attributed to the character of mechanical interlocking between male and female parts. Ball attachments come in the form of a ball and socket, which is made up of a titanium ball and a platinized socket with no gap between them. The socket's lateral flanges make tight contact with the ball, ensuring great retention and stability with no lateral movement Sharaf and colleagues, Elsyad and colleagues [20,24].

The findings of this study revealed that muscular activity in the masseter and temporalis muscles increased significantly over the follow-up periods in the two study groups. This result is not unpredicted and is in line with the findings of other earlier research Elsyad and colleagues, Hussain and colleagues [25,26]. In comparison to implant supported overdentures without attachments or conventional dentures, one of these research found that implant retained overdentures with locator attachments are favored in terms of enhancing masseter and temporalis muscle activation Mohamed [27]. Similarly, another research investigated electromyographic connectivity of the Masseter muscle with different retentive attachments for implant overdentures and found that, irrespective of the type of attachment employed, two implant overdentures reported greater muscle functions than traditional dentures Elsyad and colleagues [24].

The improved muscle function associated with implant overdentures might be related to the use of implants and attachments which aided in the development of neuromuscular coordination and masticatory efficiency by enhancing the prosthesis' support, stability, and retention to a level equivalent to healthy dentate persons. When implants were employed, it seems that muscular activity in both the anterior temporalis and the superficial masseter muscles was focused toward masticatory function, and no effort was required to hold or keep the prosthesis. Moreover, implant stabilized overdentures, elevate bite force and chewing performance, improve patient satisfaction and decrease discomfort during chewing Mohamed, Mahmoud and colleagues [27,28].

The presented data showed no statistical differences in temporalis muscle activity between the two attachments types while chewing soft and hard food and also statistical analysis showed no statistical differences in masseter muscle activity between the two groups during chewing hard food throughout all observation periods, while there were significant higher masseter muscle activity of ball attachment than Equator attachment group during chewing soft food at insertion and after three month and became non-significant after six months.

This finding could be attributed to patient adaptation and increased control on the dentures because of the enhanced denture support, retention and stability provided by the implants. This consequently allowed the patients to be more comfortable, and hence muscular effort is directed mainly towards chewing rather than stabilizing the denture in place Teranelly and colleagues [17]. And the difference between ball attachment group and Equator attachment group in masseter muscle activity during chewing soft food at insertion and after three months of the observation period this may be attributed to the high retention obtained by ball attachment compared with equator attachments as proven by this study and other studies Sharaf and colleagues, Elsyad and colleagues [20,24] or may be due to sensitivity of EMG as no template was used for placing the electrodes in the same position during recording the EMG signals for each group which may cause a variability of the measured absolute voltages [29].

4.1. Conclusion

With the limitations of this study, it can be concluded that narrow diameter implants are a valid therapeutic option in cases in which there is not enough bone volume in the horizontal direction to place a standard diameter implants. Attachment wear causes loss of retention in dentures retained with attachment which was consider a major clinical problem that required periodic follow up of implant-assisted overdentures. Ball attachment provided higher retentive values than the equator attachment. Electromyographic activity improved after using both attachments with no significant differences between them.

4.2. Recommendation

For future research, it is recommended to increase the number of the samples and the follow-up period.

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Conflicts of interest

There are no conflicts of interest among the authors relevant to this study.

References

[1] Kattadiyil MT, AlHelal A, Goodacre BJ. Clinical complications and quality assessments with computer-engineered complete dentures: a systematic review. J Prosthet Dent 2017; 117:721–8.

[2] Zhou H, Jiao Y, Ma CF, Wang C, Zhao SJ, Tian M, et al. Clinical outcomes of implant-retained mandibular overdentures using the bar and magnetic attachment systems: an up to 5-year retrospective study. Ann Transl Med 2020;8:1360.
[3] Passia N, Wolfart S, Kern M. Ten-year clinical outcome of single implant-retained mandibular overdentures-A prospective pilot study. J Dent 2019;82:63–5.
[4] Sharka R, Abed H, Hector M. Oral health-related quality of life and satisfaction of edentulous patients using conventional complete dentures and implant-retained overdentures: an umbrella systematic review. Gerodontology 2019;36:195–204.
[5] El Mekawy N, Elhawary MY. Clinical evaluation of inter-implant distance influence on the wear characteristics of low-profile stud attachments used in mandibular implant-retained overdentures. J Clin Exp Dent 2019;11:33.
[6] González-Valls G, Roca-Millan E, Céspedes-Sánchez JM, González-Navarro B, Torrejon-Moya A, López-López J. Narrow diameter dental implants as an alternative treatment for atrophic alveolar ridges. Systematic review and meta-analysis. Materials 2021;14:3234.
[7] Schiegnitz E, Al-Nawas B. Narrow-diameter implants: a systematic review and meta-analysis. Clin Oral Implants Res 2018;29:21–40.
[8] Storelli S, Caputo A, Palandrani G, Peditto M, Del Fabbro M, Romeo E, et al. Use of narrow-diameter implants in completely edentulous patients as a prosthetic option: a systematic review of the literature. BioMed Res Int 2021;2021:5571793.
[9] Ma M, Qi M, Zhang D, Liu H. The clinical performance of narrow diameter implants versus regular diameter implants: a meta-analysis. J Oral Implantol 2019;45:503–8.
[10] Corcuera-Flores JR, Pérez-Fierro M, Blanco-Carrión A, Torres-Lagares D, Castellanos-Cosano L, Machuca-Portillo G. Bone loss around narrow implants versus standard diameter implants: retrospective 2-years case-control study. J Clin Exp Dent 2020;12:79–84.
[11] Nabi A, Mahmoud N. The effect of two different attachments on patient satisfaction in mandibular class II and III ACP ridges with single implant-retained mandibular overdentures. Egypt Dent J 2020;66:2503–17.
[12] Matthys C, Vervaeke S, Besseler J, Doornewaard R, Dierens M, De Bruyn H. Five years follow-up of mandibular 2-implant overdentures on locator or ball abutments: implant results, patient-related outcome, and prosthetic aftercare. Clin Implant Dent Relat Res 2019;21:835–44.
[13] Taha NE, Dias DR, Oliveira TM, Souza JA, Leles CR. Patient satisfaction with ball and Equator attachments for single-implant mandibular overdentures: a short-term randomized crossover clinical trial. J Oral Rehabil 2020;47:361–9.
[14] Sierra-Sanchez JL, Martinez-Gonzalez A, Garcia-Sala Bonmati F, Manes-Ferrer JF, Brotons-Oliver A. Narrow-diameter implants: are they a predictable treatment option? A literature review. Med Oral Patol Oral Cir Bucal 2014;19: 74–81.
[15] Barbosa FT, Zanatta LC, de Souza Rendohl E, Gehrke SA. Comparative analysis of stress distribution in one-piece and two-piece implants with narrow and extra-narrow diameters: a finite element study. PLoS One 2021;16:0245800.
[16] Gonuldas F, Tokar E, Ozturk C. Evaluation of the retention characteristics of various stud attachment systems for implant retained overdenture. Acta Bioeng Biomech 2018;20: 135–41.
[17] Teranelly MM, Gad MA, El Ashwah AA, Fahmy RA, Elemary WS. EMG comparison between masticatory muscles when using narrow diameter implant assisted mandibular overdentures. Alex Dent J 2019;44:22–7.
[18] Rashad EF, El-Fattah A, Ahmad A, Kholief DM. Evaluation of two different types of attachment systems in midline implant-retained mandibular overdentures. ADJG 2018;5:477–84.
[19] Rocha EP. Assessment of satisfaction level of edentulous patients rehabilitated with implant-supported prostheses. Int J Oral Maxillofac Implants 2016;31:884–90.
[20] Sharaf MY, Bakry E, Abdall MF. A comparison of the retentive force of ball and socket attachment versus magnet attachment in mandibular overdentures: a randomized control trial. J Int Oral Health 2020;12:420.
[21] Manimala M, Vidhya J, Azhagarasan NS, Jayakrishnakumar S, Hariharan R, Vallabh M. Effect of height differences on the retention and wear behaviour of ball attachment system over mandibular dual implants. J Dent Oral Hyg 2021;4.
[22] Passia N, Ghazal M, Kern M. Long-term retention behaviour of resin matrix attachment systems for overdentures. J Mech Behav Biomed Mater 2016;57:88–94.
[23] Choi JW, Bae JH, Jeong CM. Retention and wear behaviors of two implant overdenture stud-type attachments at different implant angulations. J Prosthet Dent 2017;117:628–35.
[24] Elsyad MA, Ibrahim AE, Nawar NH, Belal TM. Electromyographic connectivity of masseter muscle with different retentive attachments for implant overdentures in patients with atrophied mandibular ridges: a crossover study. Int J Oral Maxillofac Implants 2019;34:1213–22.
[25] Elsyad MA, Shawky AF. Masticatory functions with ball and resilient telescopic anchors of mandibular implant overdentures. A cross over study. Quintessence Int 2017;48: 615–23.
[26] Hussain MA, Bhat N, Gani SA, Nagarajappa R. Comparative evaluation of masticatory efficiency between conventional complete dentures and implant retained over dentures using color-changing chewing gum. J Datta Meghe Inst Med Sci Univ 2020;15:426.
[27] Mohamed S. Electromyographic evaluation of the masseter and temporalis muscles activity in patients with complete denture, implant supported and implant retained mandibular overdentures. a cross-over study. Egypt Dent J 2021;67: 699–709.
[28] Mahmoud NS, El Mahdy MM, El-Masry SM, Elsayed ME. Effect of two different implant locator nylon inserts on masticatory muscle activity in mandibular implant retained overdenture wearers. Ann Romanian Soc Cell Biol 2021;25: 15955–65.
[29] Elsyad MA, Hegazy SA, Hammouda NI, Al-Tonbary GY, Habib AA. Chewing efficiency and electromyographic activity of masseter muscle with three designs of implant-supported mandibular overdentures. A cross-over study. Clin Oral Implants Res 2014;25:742–8.