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ONE-YEAR FOLLOW-UP RESULTS OF A RANDOMIZED CONTROLLED TRIAL OF POSTERIOR ATROPHIC MANDIBLES REHABILITATED WITH DIFFERENT PROSTHESES SUPPORTED BY FOUR SHORT IMPLANTS

Nermeen A. Rady*, Ahmed H. Weheda* *and* Ahmed A. Abdel Hakim**

ABSTRACT

Purpose: The study was conducted to clinically evaluate and compare splinted and unsplinted four short implants used to support mandibular overdentures in cases with atrophic mandible.

Materials and Methods: A prospective randomized controlled trial (RCT) was conducted in which a total of 48 short implants (5.5mm in length and 5mm in diameter) were inserted in 12 completely edentulous male subjects using a flapless surgical approach with the aid of a partially guided CAD-CAM surgical guides. Subjects were equally allocated into a test group A where patients' implants (n = 24) kept unsplinted with ball and socket attachments and a control group B in which patients' implants (n = 24) were splinted with a customized bar with ball attachments for retaining the mandibular overdenture following the delayed loading protocol. Clinical parameters including peri-implant probing depth (PIPD) and modified gingival index (MGI) were evaluated at time of prosthetic loading (baseline), 3, 6, and 12 month intervals.

Results: By the end of 12 month, there was a statistically significant difference between the two groups regarding PIPD and MGI values (P =.038,.004) respectively.

Conclusion: For atrophic mandibles, the use of four unsplinted short implants is a predictable alternative to splinted ones to retain a mandibular overdenture.

KEYWORDS: Short dental implants, atrophic mandible, splinted implants, unsplinted implants, CAD-CAM, guided implant surgery

* Lecturer of Prosthodontics, Faculty of Dentistry, Alexandria University
** Professor of Prosthodontics, Faculty of Dentistry, Alexandria University

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INTRODUCTION

Edentulism is a debilitating condition that directly interferes with patient's masticatory efficiency, speech, and esthetics which has a negative effect on the general and psychological health. Although its prevalence has declined over the last decade, edentulism remains a major disease worldwide which affected almost 10% of adults over 50 years.[1]

Edentulous patients who need to restore the function and improve their appearance have traditionally received Complete denture (CDs). However, a wide sector of a wide sector of CD wearers is unable to adapt owing to the fact of reduced chewing capacity, denture movement, and traumatic inflammation which leads to insecurity and low self-esteem.[2]

Alveolar bone resorption is a progressive process that happens when the teeth were lost, with a longer period of edentulism, a greater amount of bone resorption is anticipated. As a result, severely resorbed mandibular alveolar ridges are a common finding among the older generations, which further complicates the use of conventional CD.[3]

Implant-assisted overdentures have become an increasingly accepted alternative for oral rehabilitation of edentulous patients, especially in cases of mandibular arches.[4]

Despite the solid foundation of using implants for prosthetic restoration of edentulous patients, the presence of a sufficient volume of healthy bone remains the most important prerequisite for implant success which is not the case with severe mandibular residual ridge atrophy.[5]

Pre-prosthetically, different treatment approaches can be used to enable implants to be placed in atrophied ridges. These approaches include either bone augmentation, or utilization of the remaining bone. None of these alternatives is considered the gold standard for rehabilitation of atrophic mandible as they have many disadvantages including aggressive surgical protocols needed, high technical demand, prolonged healing periods, increased surgical morbidity, time consuming, and higher costs to most of patients.[6, 7]

According to the 11th European Consensus Conference 2016 in Cologne, implants with 8mm or less in length and 3.75 mm or more in diameter were considered short implants.[8]

Short implants offer the clinicians a pragmatic alternative to aggressive surgical approaches. The use of short implants achieves the objectives of contemporary implant dentistry, namely, to reduce morbidity, complications, invasiveness of the procedures, treatment time, and cost.[9-11]

Computer-guided implant surgery is advocated to allow accurate implant placement with decreasing the probability of damaging the adjacent vital structures. The virtual planning to utilize the available bone optimally followed by flapless technique offer a minimally invasive approach which is the aim with short implants.

Traditionally, short implants supporting overdentures were splinted to each other using bar attachments. In one of its designs, adding a stud attachment on the bar joining the implants provides the retentive component of the attachment. This design comes with the downside of requiring more restorative space, being initially more expensive, technically more complex, requiring more frequent follow-ups and maintenance and finally results in less favorable soft tissue response.[12]

On the other hand, it has been revealed that solitary ball attachments are cheaper, easier to clean than bars with reduced the likelihood for mucosal hyperplasia. In addition, from a clinical point of view, resilient ball attachments allow for equal tissue and implant support which in turn protects the implants against overloading as most of the masticatory stresses are transmitted to the ridge.[13]

It has been well documented that the use of short implants in cases with severe mandibular

ridge atrophy has numerous advantages over other regenerative procedures. However, to the best of our knowledge, the number of short implants needed, the need of their splinting as well as the mechanism of attachment have been issues that are scarcely discussed in literature, with controversial results regarding success rates and stresses created around implants [14,15].

Therefore, this RCT aimed to evaluate the use of four splinted short implant to retain mandibular overdentures in edentulous patients with severe mandibular ridge atrophy as opposed to using the same implants without splinting regarding to the peri-implant soft tissue changes after one-year follow-up. The null hypothesis was that there would be no difference between four splinted and unsplinted short implants supporting a mandibular overdenture in regard to the clinical parameters.

MATERIALS AND METHODS

This RCT was conducted after reviewing and approval from the ethical scientific research committee of Faculty of Dentistry, Alexandria University, Alexandria, Egypt (International number: IORG 0008839) and the implant's research committee. In addition, this clinical trial is registered in www.ClinicalTrials.gov (ID: NCT04582162). This RCT was conducted based on the good clinical practice guidelines and following the principles for clinical research outlined in the Declaration of Helsinki.

Participant Selection

Twelve edentulous male subjects were recruited from the diagnostic clinic at Prosthodontic Department, Faculty of Dentistry, Alexandria University. The sample size was calculated using the PASS program (version 20) in reference to Calvo-guirado et al. The mean age of the selected subjects was 55 years. Subjects with a resorbed mandibular alveolar ridge (maximum height of 10 mm and a minimum width of 7 mm) were enrolled in this RCT. All selected subjects were; free from systemic diseases contradicting the implant placement, had adequate zone of keratinized mucosa, class I ridge relationship, and U-shaped mandibular arches. Senile patients with impaired neuromuscular control, heavy smokers, and non-compliant patient based on their dental history were excluded from the study. All aspects of the procedures performed including surgical and prosthetic steps, follow-up periods as well as possible complications and side effects were clearly explained to all the participants and a written informed consent was obtained from each one.

Pre-surgical and Prosthetic Phase

Prior to any treatment approach, all enrolled subjects were thoroughly evaluated clinically, and radiographically then new maxillary and mandibular CDs were fabricated according to the standardized conventional technique. A cone beam computerized tomography (CBCT) was done to evaluate the proposed implant placement sites and to locate the vital anatomical structures. Dual scan technique was used to fabricate a partially guiding CAD-CAM surgical guide. Notches were made by a round bur on the polished surface of the mandibular denture in which gutta-percha markers were placed. A silicone interocclusal bite registration index was constructed to ensure the denture is properly seated in its position in correct centric relation during the scans. First scan was taken with the patient wearing the denture and biting on the interocclusal bite registration index to allow for visualization of three-dimensional (3D) anatomical data of the mandibular bone while second scan was for the denture outside the patient's mouth. The two scans were superimposed using the Bluesky software with the aid of the radiographic markers. 3D implant planning using the Bluesky software, four Dentium Superline implants (7 mm length; 5.5 mm intrabony, 1.5 mm soft tissue and

5 mm width) were placed in the canine and premolar region with regards to the bone dimensions and anatomical limitations (Fig. 1). A stereolithographic sleeveless partially guiding surgical guide was fabricated according to the planned implant positions, depth, and angulation (Fig. 2). Antibiotic therapy (1 g Amoxicillin and Clavulanic acid) was prescribed 2 days preoperatively to be taken every 12 hours and was continued for 3 days postoperatively. Chlorohexidine (0.12%) mouth rinse was started 3 days before the surgery and continued after the surgery as an oral hygiene regime.

Surgical Phase

All implants were inserted under local anesthesia via flapless computer partially guided surgery using a 3D printed surgical guide. According to the 3D planning, osteotomies were prepared in the canine and premolars region using the In2Guide Universal Surgical kit. Progressive drilling was followed with a depth of 6.5 mm to ensure that the implant level will be acceptable after the anticipated bone loss. The guide's fixation screws were then retrieved to remove the surgical guide, and osteotomies were finalized with Dentium's kit final drill. (Fig. 3) The implants were rotated clockwise using the hex

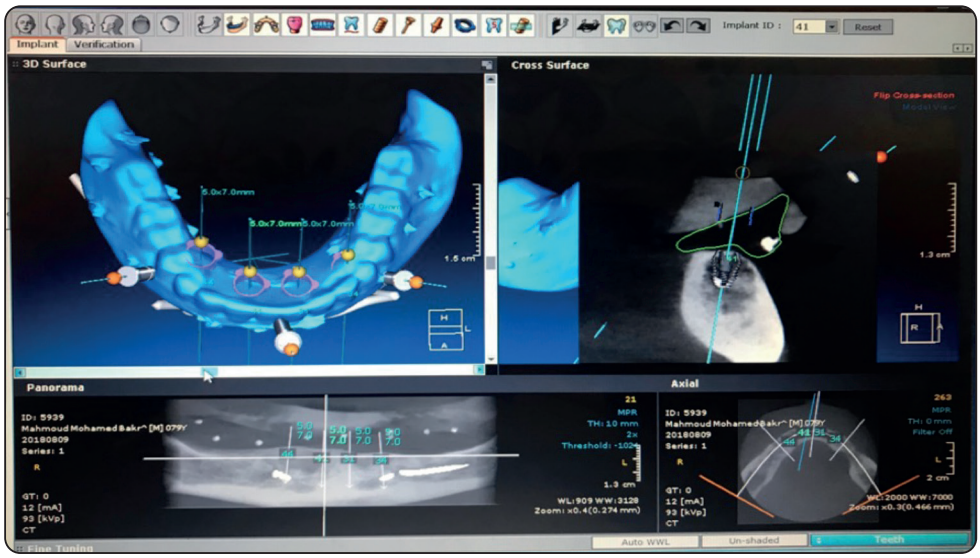

Fig. (1): Virtual Planning.

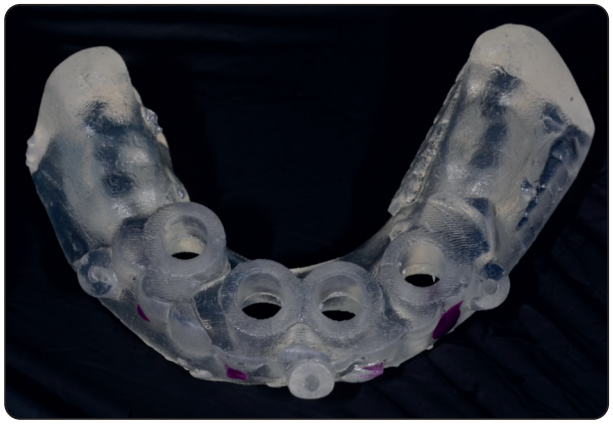

Figure (2):3D printed surgical guide.

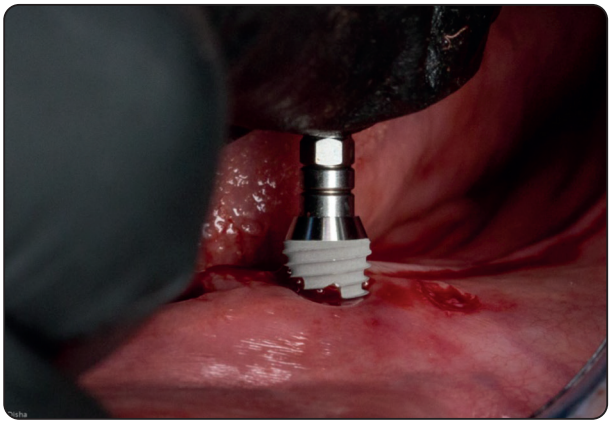

Fig. (3): Insertion of implant in osteotomy.

drivers while exerting downward pressure until noticeable bony resistance was encountered, then the implants were screwed to their final depth using a ratchet wrench. Cover screws were screwed on each implant and patients were not allowed to wear their mandibular dentures for 2 weeks postsurgically to avoid loading on implants. All participants were referred to the radiology center to have a CBCT scan on the mandible to validate the final positions of the implants. After 2 weeks, the dentures were adjusted to accommodate the newly placed implants.

Final Prosthetic Phase

This phase commenced 2 months after placement of the implants as a part of a delayed prosthetic protocol. It involved constructing an implant-assisted mandibular overdenture with a maxillary CD. At this stage, participants were blinded to which group they belong**. For the control group,** cover screws were removed, and direct open tray implant level preliminary impression was made using irreversible hydrocolloid. On the primary cast, the implant analogs were splinted using fast set inlay pattern self-cure resin (Duralay). After polymerization, the splinted bar was sectioned between the implants and each section was numbered. Intra-orally, each section of the bar with the impression coping was secured on its corresponding implant, and the bar was reattached into one unit using a fresh mix of Duralay. (Fig. 4) A final open tray impression was registered using polyether impression material (3MESPE Impregum). Record blocks were constructed on the master model with relief in the fitting surface to the area to be occupied by the bar. Centric and facebow records were taken and models were mounted on a Whipmix fully adjustable articulator. Wax wafers were used for protrusive and lateral records, and after adjustments of the angles on the articulator 20° acrylic teeth were set in bilateral balanced occlusion. After try in of the teeth, the area occupied by the bar on the model was blocked out with plaster in order to maintain the relief area in the final denture. A rubber base index determining the position of the denture was made on the model. Dentium casting abutments were placed on each of the 4 implants. Wax was used to connect the abutments with Rhein83 castable bar connectors. Three Rhein83 OT Cap plastic pattern were placed on the desired location of the bar using a surveyor to ensure parallel placement. The bar connectors were then waxed up to the desired shape and dimensions within the confines of the index made by the denture. The bar was then sprued, invested and casted in Nickel-Chromium alloy. (Fig. 5) After finishing and polishing the bar was tried in on the model then tried in intra-orally, to ensure passive and complete fit, the Sheffield test was done.[16]

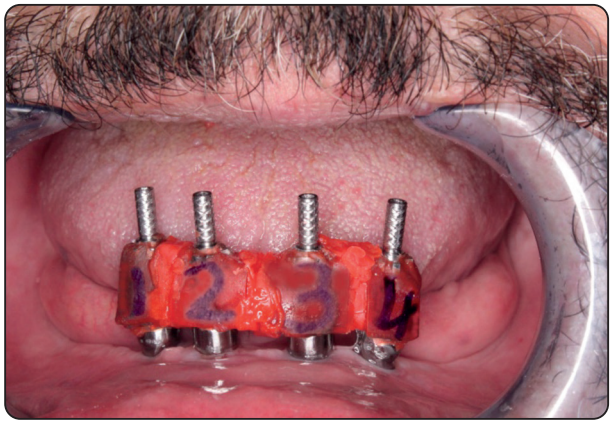

Fig. (4): The Duralay re-assembled intra-orally.

Fig. (5): Finished bar.

The bar was screwed on the implants using a torque wrench up to the recommended torque (35Ncm). Housings of the 3 Rhein83 ball attachments were placed on their respective ball attachments on the bar and undercuts in and around the bar were blocked out using flowable composite. A rubber base interocclusal index with the denture in occlusion was made for incorporation of the attachment housing in the denture. Self-cure acrylic resin was placed in the fitting surface of the denture corresponding to the ball attachment positions, and the denture was placed intraorally with the patient biting on the interocclusal index. After setting of the acrylic resin, the denture was retrieved, and excess resin flashes were finished and polished. Flowable composite used for block out was removed, and minor occlusal adjustment was completed by selective grinding. Patients received instructions for proper use, maintenance and care.

For the test group, cover screws of the implants were removed and Dentium ball abutments were screwed on the implants to a torque of 35Ncm using a torque wrench. (Fig. 6) Preliminary impressions were taken with a stock tray and irreversible hydrocolloid, the impressions were poured and a special tray was constructed on the resulting model. Before final impressions were recorded, the housings were placed on the ball abutments and wrapped with Teflon. Then final impressions using Zinc-oxide eugenol impression material (SS White) were taken. Record blocks were constructed and used to obtain centric and facebow records. After mounting on a Whipmix fully adjustable articulator, wax wafers were used to obtain protrusive and lateral records and the angles were adjusted on the articulator. 20° acrylic teeth were set with a bilateral balanced occlusal scheme and the trial dentures were tried in intra-orally. Final dentures were then obtained after conventional processing steps. Final insertion and pick up of housings were done by blocking the undercuts around the ball abutments using a piece of rubber dam and Teflon, and housings were placed on the abutments then the dentures were seated in place and a rubber base interocclusal index was made to ensure complete seating of the dentures during pick up. Self-cure acrylic resin was used to pick those housing up in the fitting surface of the denture while the patient was biting on the interocclusal index. Excess acrylic resin flashes were finished, and polished and minor occlusal adjustments were completed using selective grinding. Patients received instructions for proper use, maintenance, and care.

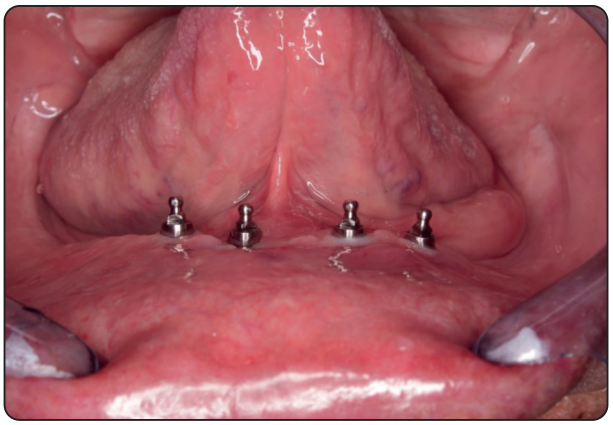

Fig. (6): Ball abutments in place.

Evaluation Phase:

Clinical parameters including PIPD and MGI were evaluated at the time of prosthetic loading (baseline) and at 3, 6 and 12 month intervals.

The PIPD was measured as the distance between the gingival margin and the most apically probable portion in millimeters (mm) using a graduated plastic periodontal probe. The probe was held parallel to the long axis of the implant and introduced to the peri-implant sulcus until slight resistance was felt. (Fig. 7) Measurements were taken at four sites around each implant: labial/buccal, lingual, mesial and distal. Probing depth of 1 mm or less was recorded as "1mm", and those exceeding 1 mm, but less than 2 mm were recorded as "2mm" and so forth. The mean records for each implant and consequently for each patient at each evaluation interval were then calculated.[17]

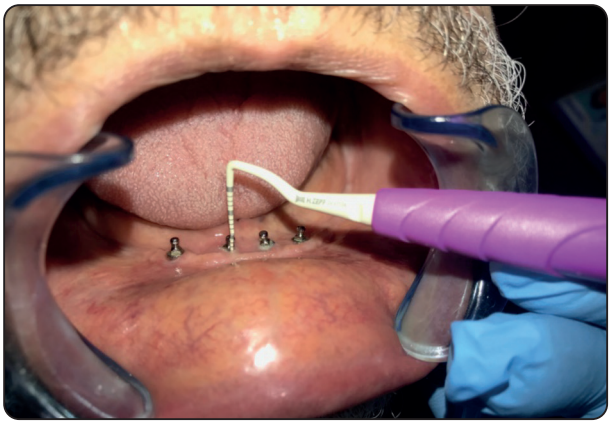

Fig. (7): Probing depth measurements.

For MGI, the peri-implant mucosal tissues around the implants were assessed using Apse's modification of Löe and Silness index at four sites around each implant; labial/buccal, lingual, mesial and distal.[18]

The sum MGI score was calculated from all these surfaces and then divided by 4 to obtain the MGI for each implant. A score from 0.1-1.0 = mild inflammation; 1.1-2.0 = moderate inflammation, and 2.1-3.0 signifies severe inflammation.

Statistical Analysis

IBM SPSS software package version 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Quantitative variables were checked for normality using Shapiro Wilks tests, histograms and QQ plots. All variables showed normal distribution, so means and standard deviation (SD) were calculated, and parametric tests were used. The *t* test was used for comparing the two study groups at each follow up period. Repeated-measures analysis of variance (ANOVA) was used for comparing variables in each group at different follow-up periods. These were followed by Bonferroni adjustment for multiple pairwise comparisons used adjusted significance levels. The significance level was set at $P < .05$.

RESULTS

All the participants in this study received the proposed treatment protocol. The 48 implants were clinically stable and free of symptoms. All participants were evaluated during follow-up periods revealing stable prostheses with no complications. The peri-implant soft tissues were evaluated clinically at the baseline, 3, 6 and 12 months follow up periods.

Peri-implant Probing Depth. Tables 1 shows the comparison between the two groups regarding the change in the mean scores of PIPD from the baseline to the 12 month follow-up. At the baseline, the mean peri-implant pocket depth was 1.65mm ± 0.08 while that of the test group was 1.52mm ± 0.14 with no statistically significant difference between them

TABLE (1): Comparison between the control and test groups in mean peri-implant probing depth throughout the different follow up periods.

	Control (Splinted) n=6	**Test (Unsplinted) n=6**	**Test value (p value)**
	Mean (in millimeters) ± SD		
Baseline a	1.65± 0.08	1.52± 0.14	1.9 (0.094)
3 months [a]	2.54±0.23	1.72±0.24	6.03 **(<0.001*)**
6 months [a]	2.42±0.5	2.13± 0.0	1.43(0.213)
12 months [a]	2.02±0.16	1.7±0.28	2.48 **(0.038*)**
Mean difference [b] **(12 months from baseline)**	0.38±0.11	0.18±0.41	-0.08(0.936)
Repeated measures ANOVA (p value)	461.59 **(<0.001*)**	844.21 **(<0.001*)**	

(*P* =.094). At the 3 months follow up, the mean PIPD of the control group was greater than the test group with a statistically significant difference (*P* <.001), while at the 6 months interval there was no statistically significant difference (*P* =.213), but by the 12 month, the value was greater in the control group once again with a statistically significant difference (*P* =.038). Although there was a statistically significant increase in the mean PIPD within each group throughout the 12 months period, the mean differences of the two groups by the end of the 12 month showed no statistically significant difference when comparing them (*P* =.936).

Regarding the difference in PIPD between each follow up period within the control and test groups, in the control group, statistically significant differences were noted between baseline and the 3, 6 and 12 months marks, as well as between the 3 months and 6 months follow ups. While in the test group, statistically significant difference was only recorded between baseline and the 6 months follow up and between the 3 month and 6 months follow ups as shown in table 2. ***Modified Gingival Index.*** The difference in MGI was statistically insignificant (*P* =.078) at the baseline, with a mean of 0.31± 0.96 and 0.22± 0.07 for the control and test group respectively. Each group showed a statistically significant increase throughout the 12 months follow up, and at the 3, 6 and 12 months the values were greater in the control group than the test group with a statistically significant difference. Moreover, by the end of the 12 month, the mean increase of the control group was 1.21 ± 0.09 and that of the test group was 0.38 ± 0.42 yielding a statistically significant difference (*P* =.004) as shown in table 3.

TABLE (2) Post-hoc multiple comparisons of mean peri-implant probing depth between different follow up periods using Bonferroni adjustment (within group)

Group		Compared to	P value
Control (Splinted) n=6	Baseline	3 months	**<0.001***
		6 months	**0.049***
		12 months	**0.002***
	3 months	6 months	0.98
		12 months	**<0.001***
	6 months	12 months	0.455
Test (Unsplinted) n=6	Baseline	3 months	0.98
		6 months	**0.001***
		12 months	0.99
	3 months	6 months	**0.05***
		12 months	0.98
	6 months	12 months	0.076

TABLE (3) Comparison between the control and test groups in mean modified gingival index throughout the different follow up periods.

	Control (Splinted) n=6	Test (Unsplinted) n=6	T test value (p value)
	Mean ± SD		
Baseline	0.31± 0.96	0.22± 0.07	1.96 (0.078)
3 months	0.96±0.18	0.31±0.07	8.23 (<0.001*)
6 months	1.08±0.31	0.53± 0.17	3.84 (0.005*)
12 months	1.52±0.03	0.59±0.45	5.09 (0.004*)
Mean difference (12 months from baseline)	1.21±0.09	0.38±0.42	4.82 (0.004*)
Repeated measures ANOVA (p value)	7452.08 (<0.001*)	24.97 (0.005*)	

In addition, for the control group, statistically significant increases occurred between baseline and the 3,6 and 12 months follow up as well as between the third and twelfth month follow up. While in the test group, statistically significant differences occurred between the baseline and the 6 and 12 months follow ups in addition to between the third and sixth month with statistically insignificant changes occurring in the first three months as shown in table 4.

TABLE (4): Post-hoc multiple comparisons of mean modified gingival index between different follow up periods using Bonferroni adjustment (within group)

Group		Compared to	P value
Control (Splinted) n=6	Baseline	3 months	0.001*
		6 months	0.002*
		12 months	<0.001*
	3 months	6 months	0.98
		12 months	0.001*
	6 months	12 months	0.091
Test (Unsplinted) n=6	Baseline	3 months	0.103
		6 months	0.021*
		12 months	0.465
	3 months	6 months	0.021*
		12 months	0.761
	6 months	12 months	0.99

DISCUSSION

Implant-retained and supported overdentures has been the minimum standard of care for edentulous mandibles overcoming common mishaps of conventional CDs. This fact was the foundation of choosing this line of treatment in this RCT being profoundly supported in literature. [4,7,12]

According to the McGill consensus, the use of two conventional length (8 mm or more) implants is considered the gold standard for implant-retained mandibular overdenture.[19] However, a common problem presented in edentulous patients is the mandibular ridge atrophy which interferes with straight foreword implant placement. The use of short implants has been highlighted in literature, as a method which provided a simple and safe line of treatment with more predictable results than other more aggressive surgical methods. [14,15,20,21]

In most studies mentioned earlier evaluating the use of short implants in overdentures, the implants were splinted owing to suggestions in literature that splinting leads to prevention of micro-movements and non-axial load as well as more favorable distribution of torqueing forces.[22,23]

In this RCT, the use of four unsplinted short implants to retain an implant overdenture was evaluated following in the footsteps of other studies such as that reported by Helow and AbdelMonaem where six and eight short implants were used to support an overdenture [14] and Kovacic et al who published a case report in 2018 describing the use of four short and narrow implants to retain a mandibular overdenture, but no follow-up was reported.[15]

To carry out this RCT, An adequate amount of keratinized mucosa was essential, it was strongly demonstrated in literature that keratinized mucosa provides a strong barrier to mucosal recession which reduces the risk of peri-implantitis and improves the implant prognosis. [24]

The maximum bone height of the edentulous mandibles of patients included in the study was 10mm in length allowing for a 2mm of surgical error leaving 8mm of bone height to place implants safely.[15]

Wide implants were chosen for this study based on the conclusion of Yang et al that strain on implants was significantly reduced by increasing the width of the implants.[23]

Superline Dentium short implants were selected as they have platform switching which reduces marginal bone loss, as well as a tapered double threaded design with micro-craters and micro-pits which

increases the implant's primary stability and increases the surface area to improve osseointegration, and finally an Sandblasted, large grit, acid-etched implant surface which enhances its osseointegration capacity. (25)

During the surgical phase, A flapless implant placement technique was chosen due to two main advantages; firstly, preservation of periosteal vascularity which reduced initial marginal bone loss and secondly, its minimally invasive nature which reduces the surgical trauma, operative time, postoperative complications, postoperative healing time ultimately resulting in a less painful surgery and better patient comfort. (26)

3D printed CAD-CAM surgical guides were virtually designed as it was essential for safer flapless placement of implants especially in distal implants which were in proximity of the inferior alveolar nerve. It has been reported that although an angular and linear deviations up to 5 ° and 2.3 mm is expected with CAD-CAM surgical guides, it is still the safest option.(27)

A partially guided surgical approach was preferred because, the maximum width of the sleeve was 5mm to be compatible with the In2guide universal kit which meant that there was a risk of implant contamination if the implant width was 4.5mm or more. Moreover, the largest width of the guided universal kit drills was 4.3mm which meant that the final Dentium Superline drill was needed to finalize the osteotomy in implants greater than 5mm. (28)

In the present study, polyether impression material was used for final impressions of implants to be splinted, this was supported by Papazoglou et al who compared different impression techniques with different impression materials and concluded that polyether impression material with splinted impression copings yielded the most accurate results. (29)

In order to standardize both groups, the bar was customized with Rhein 83 OT cap plastic patterns which are ball and socket attachments to provide a retentive mechanism similar to that of the unsplinted implants which were equipped with Dentium ball and socket attachments. By the end of this study, the cumulative implant survival rate after one year was 97.9% and three patients were presented with a poorly retained mandibular overdenture, this was due to worn out nylon caps which were replaced. This occurrence agrees with Bergendal and Engquist who stated that exchange of the retentive clips or O-rings was the most common prosthetic complication in implant retained overdentures.(30)

Soft tissue profile has been commonly used in literature to evaluate the performance of implants supporting or retaining overdentures. In the present RCT, there was an increase in PIPD for both groups with a statistically significant difference, however the PIPD did not exceed 3mm which rendered those results acceptable according to statements by Salvi et al.(18) For the solitary implants, increased PIPD was mainly a result of peri-implant marginal bone loss while for splinted implants it may have been attributed to both peri-implant marginal bone loss as well as mucosal tissue hypertrophy.(16)

Probing depth values in splinted implants were greater than those of unsplinted values with a statistically significant difference, this result was opposed by results by Naert et al who witnessed no statistically significant difference between splinted and unsplinted implants supporting mandibular overdentures with regards to probing depth over a period of 10 years.(31) The physiologic peri-implant sulcus depth around successful implants has been always a matter of debate as the magnitude of probe penetration into the sulcus depends on the diameter of the probe tip, probing force applied, and roughness of implant surface. (32)

The second aspect of soft tissue profile assessed was the MGI, in patients with bars the MGI was greater than patients with solitary implants with a statistically significant differences, there results agreed with findings recorded in literature by Närhi et al who stated that more mucosal changes occurred

in patients with splinted implants, and 82% of the cases which showed mucosal hyperplasia were patients with bar superstructures. [33]

However, these findings were opposed by Gotfredsen and Holm, although mucosal hyperplasia was only noted in patients with bar superstructures, in three of the cases it even required surgery, there was no statistically significant difference between the two groups regarding MGI.[34] The contrary results may be attributed to the fact that this study involved a five year follow up as opposed to one year, this study involved the use of only two implants in comparison to four in our study and finally this study involved a bar and clip attachment not a customized bar with ball and socket attachments which allowed more movement in the present study.[34]

CONCLUSIONS

Based on the findings of this RCT, the following conclusions were drawn:

1. Short implants provide an effective, safer, and less invasive approach to managing atrophic mandible.
2. Four short implants may be used efficiently without splinting for retaining a mandibular overdenture.
3. Unsplinted implants provide more positive peri-implant clinical results compared to splinted implants without jeopardizing the success of implants.
4. Ball and socket attachments provide sufficient retentive efficiency without transmitting too much stress to the implants; however, replacement of nylon caps is a common prosthetic complication.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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