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DIGITAL OCCLUSAL ANALYSIS, PATIENT SATISFACTION AND PROSTHODONTIC MAINTENANCE OF MINI-IMPLANT VERSUS STANDARD DIAMETER IMPLANT OVERDENTURES: A TWO-YEAR FOLLOW-UP STUDY

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ABSTRACT

Purpose: The purpose of this clinical study was to use the digital occlusal analysis to compare the maximum occlusal force and occlusal force distribution in mini-implants and standard-diameter implant mandibular overdentures. Also, to compare patient satisfaction and prosthodontic maintenance after two years of function. **Materials and methods:** Twenty–two edentulous patients were randomly divided equally into two groups. MIO group (test group) received mandibular overdentures retained by four mini-implants, and SDO group (control group) received mandibular overdentures retained by two standard diameter implants. Digital occlusal study was done to evaluate occlusal force distribution, maximum occlusal contact force, and tooth contact number. Patient satisfaction was assessed using a visual analogue scale questionnaire. Prosthodontic maintenance measures were analyzed. The follow-up period was two years after overdenture insertion. **Results:** Insignificant differences were found in occlusal force parameters between both groups. All domains of patients' satisfaction increased significantly in MIO and SDO groups. There were insignificant differences in patient satisfaction between both groups. Prosthodontic maintenance requirements for both groups were comparable during the two-year follow-up. The most frequent prosthodontic complication was the wear of female housing. This was followed by dislodgement and replacement of female parts. **Conclusion:** Within the study's limitations, mini-implants can improve mandibular overdenture performance regarding maximal occlusal force and tooth contact number without impairing force distribution by employing digital occlusal analysis. Mandibular overdentures retained by mini-implants can achieve similar outcomes as standard-diameter implant overdentures in terms of patient satisfaction and prosthodontic problems.

Keywords: mini-implant, overdenture, standard diameter implant, digital occlusal analysis.

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INTRODUCTION

For nearly a century, traditional dentures have been used to restore completely edentulous people. Although maxillary dentures often meet patients' needs, mandibular denture users frequently experience discomfort.[1] Clinical research over the last decade has shown that the implant mandibular overdenture is an economic substitute for the management of edentulous patients. This method of treatment is better than traditional full dentures in terms of chewing efficiency, patient satisfaction, and quality of life enhancement.[2] According to international consensus, a two implants retained overdenture is the standard therapy for patients who have lost their teeth. Several investigators have reported high patient satisfaction rates and implant survival rates for two-implant mandibular overdentures. [3-5] Even though implant overdentures are helpful, they are only used in a few situations, like elderly patients, patients with systemic diseases that may limit surgical procedures and time, or if cost is a limiting factor.[6] Moreover, the size of standard-diameter implants restricts their use in narrow ridge cases. Although ridge augmentation is an option in those cases, it comes with greater expenses, more patient discomfort, and a higher risk of post-surgical complications. In these circumstances, mini-implants are thought to be a good substitute for standard-diameter implants.[7,8]

A mini-implant is described as an "implant constructed of the same biocompatible materials as conventional implants but with a diameter of less than 3 mm".[9] The main benefits of mini-dental implants are simpler treatment protocols and lower costs than standard-diameter dental implants. They also require less invasive surgery as they can be inserted using a flapless surgical procedure. This reduces post-surgery complications, patient discomfort, and healing time.[10] Furthermore, their ability for immediate loading provides the patients with immediate satisfaction without the lags in therapy as required by healing of standard-diameter implants. Mini-implants also have the benefit of being able to be implanted in narrow ridge cases. This offers a better alternative, especially in elderly edentulous patients with chronic diseases.[11]

Mini-implants are mainly used when there is insufficient room or inadequate bone to accommodate a conventional diameter implant.[12] Because of their tiny size, their insertion procedures are quite easy with no need for bone augmentation. The use of mini-implants for overdenture retention is extensively documented. When compared to conventional implant therapy, the mini-implant treatment option is affordable and immediate. The survival rates for mini-implants utilized for overdenture stabilization exceeded 90%. [13,14]

Digital occlusal analysis is a significant method to measure the improvement in function after utilizing implant overdentures. It is used in the assessment of the magnitude of biting force and the pattern of occlusal force distribution.[15,16] The force distribution of implant-overdenture is critical to the treatment's success. To improve denture wearers' masticatory efficiency, occlusal force should be evenly distributed.[17] Furthermore, occlusal force overloading on implants must be prevented. So, occlusal analysis has become a crucial tool in implant therapy success to avoid overloading difficulties. [18,19] Articulating paper is the most popular way to assess occlusion. But it can be interpreted in different ways, and it doesn't show occlusal force magnitude or contact time.[20]

The T-Scan digital occlusal analysis tool has been established to objectively analyze occlusion and disocclusion times and sites of occlusal contacts in three-dimensional distribution. This quantitative method uses a piezoelectric transducer to measure timed occlusal force, occlusal force distribution, and dynamically evaluate the occlusal interferences. [21,22] The T-Scan also measure occlusal metrics like the occlusal force center and symmetry, the initial contact, and the maximum occlusal contact force.[23-25] It can identify premature contacts in dynamic rather than static occlusion. It can show the distribution of forces per tooth as well as the two halves of the jaw.[26-28] It has been found that T scan is accurate and reliable and can be applied in several prosthetic applications, including complete denture and overdenture prosthodontics.[29-31]

T-Scan determines the proper occlusal pattern, resulting in high-quality treatment results that were previously not achievable. It measures occlusal parameters and maintains the information on the computer system. This information can be played in a video using the software for data analysis. The sensor is the most important component of T-scan. There are two sizes of T-Scan sensors available: big and small.[32-34]

Patient satisfaction is a key factor influencing the effectiveness of overdenture therapy.[35] Implant overdentures increase patient satisfaction in many aspects, including mastication, speech, appearance, retention, and also improve quality of life. [36-38] Patient satisfaction was assessed in a meta-analysis of a systematic review comparing mini-implants retained overdentures versus those retained by conventional implants, and the results suggested that mini-implants provide good patient satisfaction. [7]

The prosthodontic maintenance needed for implant overdentures involves enormous laboratory and clinical implications as well as financial consequences.[39] The frequency of post-insertion aftercare impacts not just prosthetic success but also patient satisfaction and expenditures. [35] There is minimal scientific evidence in the literature about the outcomes of mini-implant retained mandibular overdentures. Patient-based treatment outcomes and prosthesis aftercare are still needed to evaluate the effectiveness of this therapeutic approach. [40,41] However, due to the scarcity of data included in studies, more research is needed to compare mini with conventional diameter implants in overdentures.[7]

Reviewing the literature revealed a limited availability of research that compares the occlusal forces of mini and conventional implants retaining overdentures using digital occlusal analysis. Only one clinical study compared the occlusal force distribution between mini-implants and conventional complete denture.[16] Moreover, Elsayed et. al. 2016[42] recommended that well-controlled randomized clinical studies are required to compare patient satisfaction and prosthodontic outcomes of both types of implants used for overdenture retention.

Hence, the study's goal was to use the digital occlusal analysis to compare the maximum occlusal force and occlusal force distribution in mini-implants and standard-diameter mandibular implant overdentures. Also, to compare patient satisfaction and prosthodontic maintenance after two years of function. The null hypothesis was that there would be no difference between mini-implants and standard-diameter implants concerning the occlusal force pattern, patient satisfaction, and prosthetic maintenance.

MATERIALS AND METHODS

I) Patients' selection and enrollment:

This randomized clinical trial recruited 22 individuals who were fully edentulous (10 females and 12 males). Their age range was from 49 to 65 years with an average of 57 years. The patients were chosen from the Removable Prosthodontic Department's outpatient clinic. The inclusion criteria were: 1) all participants complained of a lack of retention of mandibular dentures; 2) adequate bone volume and density in the inter-foraminal area to permit the placement of a 12 mm implant length; and 3) class I Angel`s classification. The exclusion criteria involved: 1) smoking habits; 2) parafunctional habits; 3) neuromuscular disorders such as Parkinson's disease; 4) bone metabolic diseases such as diabetes mellitus and hyperparathyroidism; 5) systemic diseases that can complicate implant placement or osseointegration; and 6) patients receiving radiation treatment to the neck and head area. The sample size calculation was done (G Power program, University of Düsseldorf, Düsseldorf, Germany). Twenty-two patients were calculated to yield a power of 80% based on the results of a previous research [43] (effect size=1.28, α=0.05). At least 20 subjects were needed for the study. To account for the 20% dropout rate, the number of participants was increased to 22. The study was conducted following Helsinki principles for ethics and was authorized by a local ethical review board to assure the participants' safety. After explaining the study procedures, the recruited participants signed an informed consent form.

II) Prosthodontic procedures:

Conventional procedures were used to construct new full dentures for all patients. The dentures were fabricated with semi-anatomical teeth arranged in a bilateral balanced occlusal scheme and delivered to the patients. Prostheses were revised several times until patients were completely satisfied with their dentures. Each patient's mandibular denture was duplicated in a transparent resin to create a radiographic stent with a gutta percha radiopaque marker at the proposed implant sites. Cone-beam CT was obtained after inserting the stent intra-orally. The radiographic stent was turned into a surgical stent by removing the gutta-percha out of the acrylic channels.

III) Patients' grouping:

Patients were randomly classified into two groups using random numbers generated in an excel sheet (Microsoft office). The patients were categorized according to the baseline characteristics, which are age, sex, mandibular anterior ridge height, and time since being edentulous. A non-significant difference in baseline characteristics was found as a result of balanced randomization:

Mini-implants overdenture group (MIO) (test group): they received four mini-implants (12 mm length and 2.5 mm diameter, one piece, ball-type, Slimline, Dentium Co. Ltd., Korea.) in the inter-foraminal region.

Standard-diameter implants overdenture group (SDO) (control group): they received two standard diameter implants (12 mm length and 3.6 mm diameter, Superline, Dentium Co. Ltd., Korea) in the inter-foraminal region.

IV) Implant installation and prosthetic loading

The following surgical procedures were performed with the assistance of the surgical stent:

MIO group

The insertion of mini-implants was performed using the flapless surgical technique. Implants were installed five mm anterior to the mental foramen, and five mm were left between each mini-implant. Using the surgical stent, these locations were then transferred to the gingiva of the patient and identified with bleeding spots. To pierce the mucosa and cortical plate, a pilot drill sized 1.1 mm was utilized (at 1000 rpm, with intermittent motion, and under copious irrigation using sterile saline). To attain initial stability for mini-implants, bone drilling was restricted to half the length of the implant. Because of its self-tapping capability, each mini-implant was then manually self-tapped with an implant cap. This cap disengages from the fixture after reaching five Ncm of tightening force. A finger driver and then a ratchet were used for additional implant instalments. An insertion torque of a minimum of 35 Ncm was required for immediate loading. A post-surgery panoramic x-ray was done to assess the implant location. ***(Fig. 1-A) (Fig 2-A)***

The dentures were functionally loaded on the same day that the mini-implants were placed. After mini-implants placement, female housings were secured firmly over the mini-implant balls. Recesses for female housings were cut into the mandibular denture's fitting surface. Adequate relief was checked by the absence of denture rocking, correct occlusal relation, and pressure indicating paste. During the pickup operation, rubber dam sections were inserted into the mini-implant heads to prevent the self-cured resin material from latching onto implant surfaces. The denture was then inserted intra-orally after putting the resin on the areas of the overdenture that had been relieved. While the patient was closing in centric occlusion at the correct vertical dimension, the resin was left to polymerize. The overdenture was then removed and the attachment matrices were picked up on its tissue surface. The extra resin was reduced, the occlusion was adjusted, and the overdenture was finished before being delivered to the patient.

SDO group

Standard diameter implant insertion was performed following a one-stage non-submerged surgical technique. After achieving the primary stability, the transmucosal healing abutments were screwed. To avoid implant overloading during the osseointegration period, the areas of the denture's fitting surface corresponding to implants were relieved. A panoramic radiograph was done to evaluate the implant's location. Patients were recalled for follow-up visits. After a three-month healing period, implant osseointegration was assessed by means of periapical film and intra-oral examination. Then implants were loaded using a delayed loading protocol ***(Fig. 1-B) (Fig.2-B).*** After osseointegration, the complete seating of the abutments on their corresponding implants was verified by periapical radiographs. Under the closed-mouth technique, direct pick-up was done through the relief spaces made opposite the paired attachment sites using self-cured resin.

Follow-up visits were scheduled for patients in both groups one week (T1), 3 months (T2), 6 months (T3), 12 months (T4), and 24 months (T5) after prosthesis loading. Patients received denture and oral hygiene instructions at each follow-up appointment.

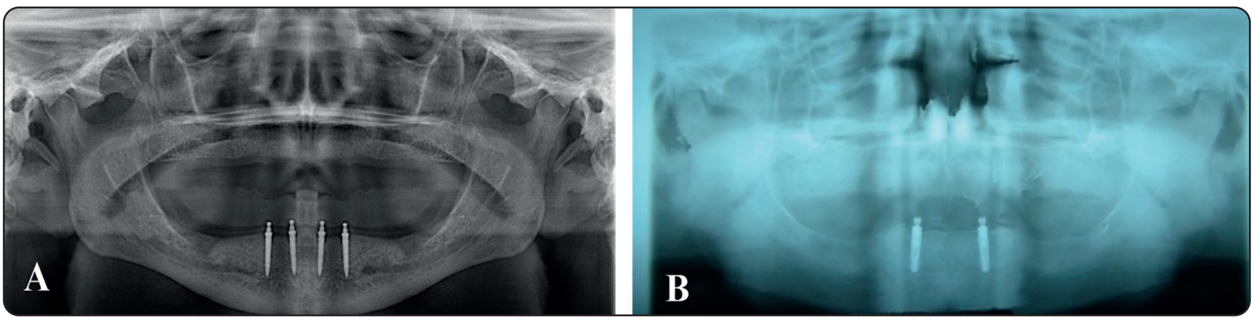

Fig. (1): Post- operative panoramic radiograph in both groups:(A): MIO group, (B): SDO group

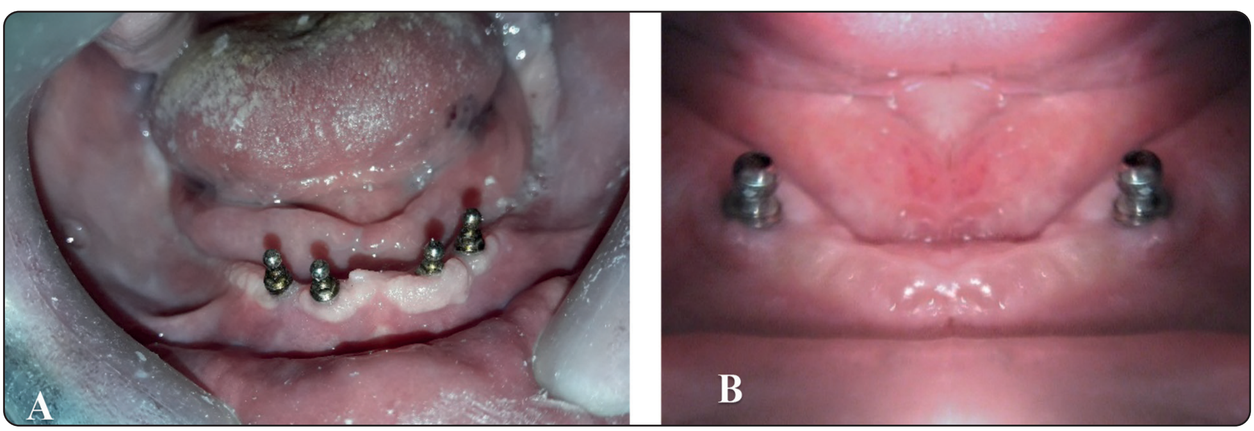

Fig. (2): (A) Four mini- implants installed in MIO group. (B) Two standard diameter implants installed in SDO group.

V) Outcomes measures

The digital occlusal analysis was evaluated as the primary outcome, while the patients' satisfaction and prosthodontic maintenance were evaluated as the secondary outcomes.

1- Digital occlusal analysis

A T-Scan III system (Tekscan Inc., South Boston, MA, USA) was used for digital occlusal analysis. It includes a sensor with a handle, the system unit that is operated by computer software (T-Scan 8, Software version 8.0.1, Tekscan, Inc.), and a printer. A T-scan sensor of suitable size was selected according to the patients' arch size. The patient was asked to sit upright with the Frankfurt plane (FH) horizontal. The sensor was inserted intra-orally between the dental arches. Its center line coincides with the upper incisors' midline.

The sensor's sensitivity was adjusted by instructing the patient to bite in maximal intercuspation two to four times before starting the records. To start the records, the patient was instructed to bite on the sensor until maximum intercuspation was reached. After that, he was instructed to keep intercuspation for one to three seconds before disoccluding it and biting on the sensor again at maximum intercuspation.

Once occlusal contacts showed on the computer screen, the handle switch was clicked, and therefore the arch model was generated. Recordings were processed by the software for graphical display in two and three dimensions ***(Fig. 3).*** Each reading was done three times for each patient, and an average reading was taken. The measurements obtained from T-scan were the force distribution and maximum occlusal contact force. The force distribution was examined in three ways: degree of force distribution, number of tooth contacts, and bilateral force difference. For measuring the degree of force distribution, the dental arch was divided into four sections, the cuspids and premolars in one and the molars in the other. The tooth contact number was calculated using the amount of the tooth contact that exists between the cuspid and the second molar. The bilateral force difference is the percentage difference in chewing regions between both arch sides from the cuspid to the second molar.[42] Digital occlusal analyses were performed before implant installation (T0), then one week (T1), three months (T2), six months (T3), twelve months (T4), and twenty-four months (T5) after prosthesis loading.

2- Patient satisfaction

Patient satisfaction was assessed before implant installation (T0), then after each of six months (T3), twelve months (T4), and twenty-four months (T5) from overdenture loading. Patients were given

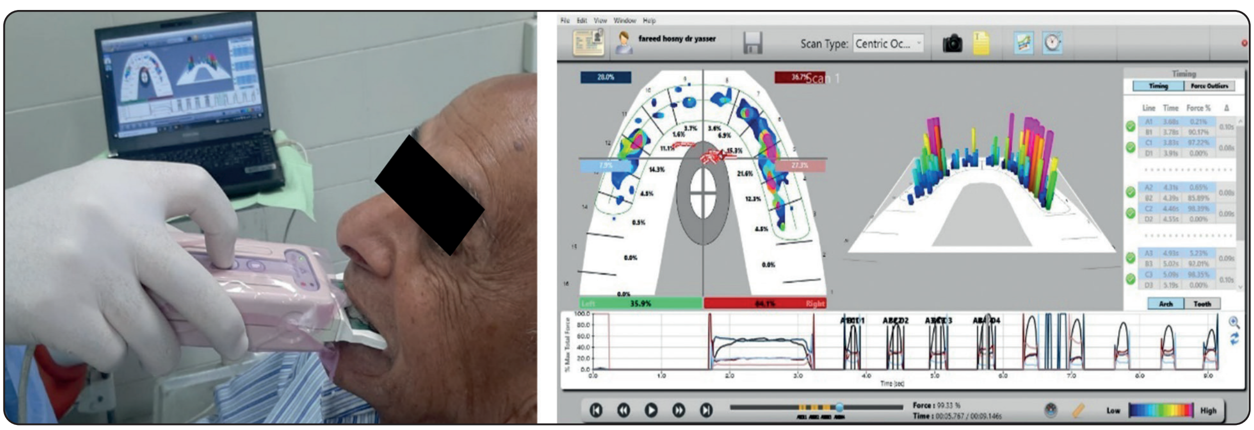

Fig. 3: Digital occlusal analysis using T-scan

a Visual Analogue Scale (VAS) questionnaire to score their satisfaction in the following five areas: chewing ability, retention / stability, speech, comfort, and overall satisfaction. Patients were encouraged to mark a line on a 100-mm scale to represent the satisfaction level, with the right side ending with a (100) representing fully satisfied and the left side ending with a (0) value representing fully dissatisfied. Patients were given questionnaires in Arabic. All questionnaires were obtained by the same study interviewer, who was blind to the kind of prosthesis.

3- Prosthodontic maintenance

Prosthodontic maintenance was performed during the 24-month follow-up interval, and the prosthodontic problems were identified using the previously reported approach by Naert et al. 2004 [35]. The prosthetic complications include the mechanical complications that occur with the dentures, attachments, and implants. Soft tissue complications of the denture bearing regions that include ulceration, soreness, flabby tissue, and hyperplasia. The prosthetic complications were recorded using a chart.

4- Statistical analysis

To assess data normality, Shapiro-Wilk and Kolmogorov-Smirnov tests were utilized. Occlusal force analysis data showed parametric distribution while patient satisfaction and prosthetic complications showed non-parametric distribution. Occlusal analysis data was statistically evaluated using an independent t-test to compare the two groups. For time-based comparisons within the same group, Repeated Measures ANOVA test followed by Tukey's Post Hoc test were used. Patients satisfaction data was analyzed using the Mann–Whitney test for comparison between groups. While Kruskal-Wallis test, followed by Dunn's test, to evaluate the same group over time. The chi-square test was employed to compare prosthesis complications across groups. P is considered significant if it is less than 0.05 with a 95% confidence interval. The statistical analysis was carried out using a statistical package for social science software (SPSS, Version 22, Inc., Chicago, IL, USA).

RESULTS

After two years, the success rate of both mini-diameter and standard-diameter implants was 100%, based on the criteria for success that had been described in the literature.[3]

I) Results of digital occlusal analysis

The data from occlusal analyses was normally distributed. The percentage of maximum occlusal force increased significantly from (71.52± 3.31), (74.89± 3.61) at T0 to (88.16± 2.82), (87.20± 3.57) at T5 in MIO and SDO groups, respectively (P <0.0001). ***(Tab.1) (Fig.4)***. Intergroup and intragroup comparisons revealed insignificant differences in the degree of force distribution, bilateral force

TABLE (1): Percent of maximum occlusal contact force between both groups

Group	T0	T1	T2	T3	T4	T5	P value
MIO	71.52 ± 3.31[a]	80.29 ± 3.78[b]	84.59 ± 3.04[c]	86.07 ± 3.10[d]	87.75 ± 3.02[e]	88.16 ± 2.82[e]	<0.0001
SDO	74.89 ± 3.61[a]	78.89 ± 3.61[b]	82.89 ± 3.89[c]	84.61 ± 2.69[d]	85.49 ± 3.01[e]	87.20 ± 3.57[e]	<0.0001
P value	0.153	0.432	0.315	0.300	0.129	0.521	

Values are means ± standard deviation. Vertically: * significant at p ≤ 0.05 using Independent t-test.

Horizontally: Means with different lower-case letters are statistically significant at p ≤ 0.05 using Repeated Measures ANOVA test followed by Tukey's Post Hoc test.

difference, maximum occlusal contact force, and tooth contact number data obtained prior to implant placement and subsequent follow-up visits (P > 0.05). ***(Tab. 2-4) (Fig. 5-7)***.

II) Results of patients' satisfaction

All domains of patients' satisfaction increased significantly ($p < 0.05$) in MIO and SDO groups at T5. After 24 months in MIO group, the median values of the comfort domain were increased from (63.25) to (82.75), the speech domain enhanced from (67) to (95), the chewing ability changed from (71.25) to (92), retention and stability from (74.25) to (84.75), and overall satisfaction from (69) to (92) ***(Tab. 5)***. In SDO group, the median values of the five patient satisfaction domains, which are comfort, speech, chewing ability, retention and stability, and overall satisfaction, were increased respectively from (66.75), (70.5), (74.75), (77.75), and (72.5) to (80.75), (93), (90), (82.75), and (90) after 24 months. ***(Tab. 6)*** During the two-year follow-up, there were statistically insignificant differences in patient satisfaction between both groups. ***(Tab. 7)***

TABLE (2): Percent of bilateral force difference in both groups

Group	T0	T1	T2	T3	T4	T5	P value
MIO	28.99±8.65[d]	33.99±9.93[d]	34.34±9.46[d]	36.53±9.62[d]	40.42±9.92[d]	40.51±9.82[d]	<0.0001
SDO	27.03±10.23[h]	30.14±9.98[h]	31.85±9.54[h]	32.32±9.53[h]	34.42±9.73[h]	34.76±9.92[h]	<0.0001
P value	0.43	0.14	0.32	0.16	0.24	0.36	

Values are means ± standard deviation. Vertically: * significant at p ≤ 0.05 using Independent t-test.
Horizontally: Means with different lower-case letters are statistically significant at p ≤ 0.05 using Repeated Measures ANOVA test followed by Tukey's Post Hoc test.

TABLE (3): Degree of force distribution in both groups

Group	T0	T1	T2	T3	T4	T5	P value
MIO	3.52± 0.61[a]	3.75± 0.52[a]	3.88± 0.50[a]	3.98± 0.53[a]	4.13± 0.40[a]	4.39±0.51[a]	<0.0001
SDO	3.62± 0.64[b]	3.89± 0.56[b]	4.01± 0.47[b]	4.11± 0.47[b]	4.19± 0.38[b]	4.32± 0.44[b]	<0.0001
P value	0.78	0.70	0.79	0.58	0.78	0.75	

Values are means ± standard deviation. Vertically: * significant at p ≤ 0.05 using Independent t-test.
Horizontally: Means with different lower-case letters are statistically significant at p ≤ 0.05 using Repeated Measures ANOVA test followed by Tukey's Post Hoc test.

TABLE (4): Tooth contact number in both groups

Group	T0	T1	T2	T3	T4	T5	P value
MIO	4.77±0.77[a]	6.57±0.77[b]	7.72±0.60[c]	7.94±0.83[d]	8.16±1.23[e]	8.28±1.51[e]	<0.0001
SDO	4.32±0.74[a]	6.12±0.78[b]	7.24±0.70[c]	7.54±1.20[d]	7.96±1.45[e]	8.08±1.74[e]	<0.0001
P value	0.30	0.23	0.31	0.40	0.75	0.64	

Values are means ± standard deviation. Vertically: * significant at p ≤ 0.05 using Independent t-test.
Horizontally: Means with different lower-case letters are statistically significant at p ≤ 0.05 using Repeated Measures ANOVA test followed by Tukey's Post Hoc test.

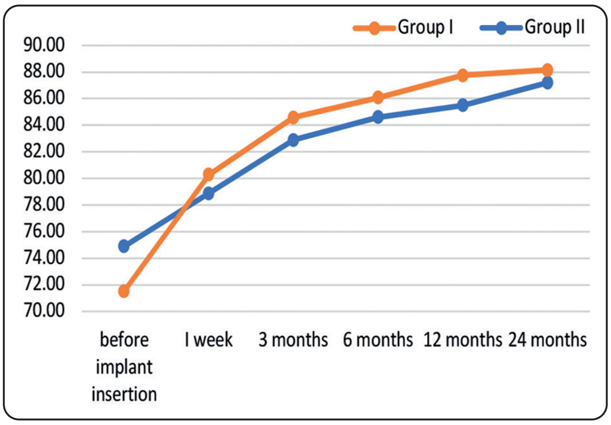

Fig. (4): Line chart showing percent of maximum occlusal contact force

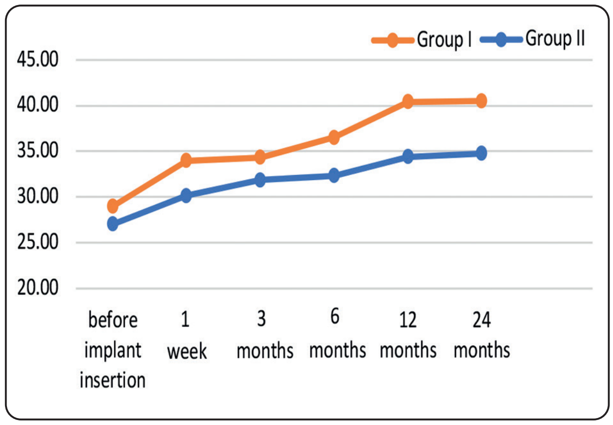

Fig. (5): Line chart showing percent of bilateral force difference.

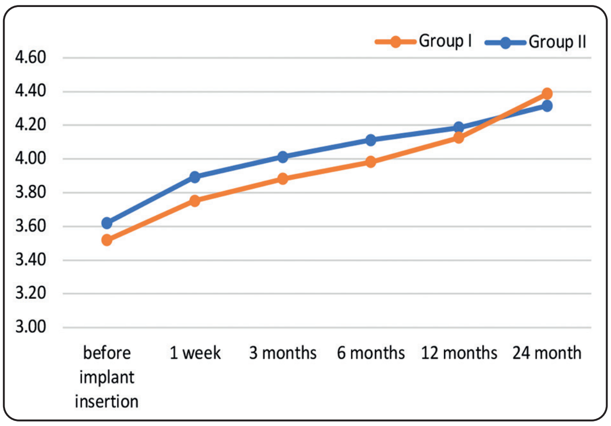

Fig. (6): Line chart showing degree of force distribution

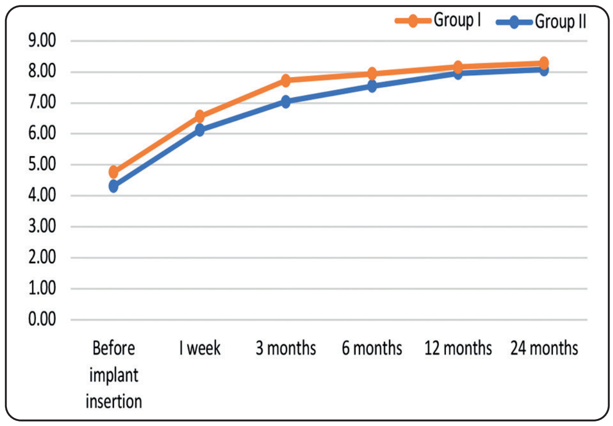

Fig. (7): Line chart showing tooth contact number

TABLE (5): Patients' satisfaction using visual analogue scale (in mm) in MIO group during different follow up periods.

Patient satisfaction domains	T0	T3	T4	T5	P value
Comfort	63.25[a]	74.25[b]	83.25[b]	82.75[b]	0.0001
Speech	67[a]	78[b]	94[b]	95[b]	<0.0001
Chewing ability	71.25[a]	82.25[a]	89.5[b]	92[b]	<0.0001
Retention/stability	74.25[a]	85.25[a]	82[a]	84.75[b]	0.001
Overall satisfaction	69[a]	80[b]	89.5[b]	92[b]	<0.0001

Horizontally: Means with different lower-case letters are statistically significant at $p \leq 0.05$ using Kruskal-Wallis test, followed by Dunn's test.

TABLE (6): Patients' satisfaction using visual analogue scale (in mm) in SDO group during different follow up periods.

Patient satisfaction domains	T0	T3	T4	T5	P value
Comfort	66.75[a]	70.75[a]	80.75[b]	80.75[b]	0.0001
Speech	70.5[a]	74.5[a]	91.5[b]	93[b]	<0.0001
Chewing ability	74.75[a]	78.75[a]	87[b]	90[b]	<0.0001
Retention/stability	77.75[a]	81.75[a]	79.5[b]	82.75[b]	0.001
Overall satisfaction	72.5[a]	76.5[a]	87[b]	90[b]	<0.0001

Horizontally: Means with different lower-case letters are statistically significant at p ≤ 0.05 using Kruskal-Wallis test, followed by Dunn's test.

TABLE (7): Patients' satisfaction using visual analogue scale (in mm) in both groups after two years.

Patient satisfaction domains	MIO	SDO	P value
Comfort	82.75	80.75	0.00
Speech	95	93	0.63
Chewing ability	92	90	0.75
Retention/stability	84.75	82.75	0.69
Overall satisfaction	92	90	0.68

**** Significant if p ≤ 0.05 according to Mann–Whitney test.***

III) Results of prosthodontic maintenance:

(Tab. 8) and ***(Tab. 9)*** present prosthodontic complications at T4 and T5. In the current study, there were no statistically significant differences between groups or observation times in terms of maintenance or complications. The majority of cases reported minimal denture adjustments, but two cases in SDO group and one case in MIO group presented with denture fracture at the area of female housing during the whole follow-up period. The number of mandibular overdenture fractures in SDO group is insignificantly greater than in MIO group.

The most frequent prosthodontic complication was the wear of female housing that represented (21.43%), (17.14%) of the total complications in groups MIO and SDO, respectively, at T4 and (24.49%), (11.32%) in MIO and SDO, respectively, at T5. This was followed by dislodgement and replacement of female parts, which occurred in (14.29%) and (11.43%) of complications in MIO and SDO groups, respectively at T4, and (4.08%) and (11.32%) in MIO and SDO groups, respectively at T5. Ball abutment fractured occurred in (2.04%) in MIO group and (1.89%) in SDO group at T5. Loosening occurred in (16.33%) male abutments in MIO group and (7.55%) in SDO group.

Mandibular overdenture relining times were (4.08%) in MIO group at T5, (3.77%), and (2.86%) in SDO group at T4 and T5, respectively. Prosthesis teeth fracture were (n = 3) in each group, and prosthesis teeth worn (n=1) in each group. Regarding maxillary dentures, the numbers of events in each group at T5 were (n= 3) relines, denture teeth fracture (n=2), and denture base fracture (n=1). Soreness and ulceration are the most common soft tissue complications in both jaws, while flabby ridge occurred in one case in SDO group at T5.

TABLE (8): Prosthodontic complications from the time of prosthetic loadimg till T4 in both groups

Prosthetic complications	MIO group		SDO group	
	Number of complications (n=28)	**Percent of complications (n/28)**	**Number of complications (n=35)**	**Percent of complications (n/35)**
Mandibular overdenture				
– Attachment (male) fracture	0	0%	0	0%
– Attachment (male) loosening	0	0%	0	0%
– Wear of female housing	6	21.43%	6	17.14%
– Dislodgment of female housing	4	14.29%	4	11.43%
– Prosthesis teeth fracture	2	7.14%	2	5.71%
– Prosthesis teeth worn	0	0%	0	0%
– Overdenture fracture	0	0.00%	1	2.86%
– Overdenture modification	2	7.14%	3	8.57%
– Overdenture relining	0	0.00%	1	2.86%
– New overdenture	0	0.00%	0	0.00%
– Soreness	2	7.14%	4	11.43%
– Ulceration	3	10.71%	3	8.57%
– Flabby tissue	0	0%	0	0%
– Hyperplasia	0	0%	0	0%
Maxillary denture				
– Base fracture	0	0%	0	0%
– Teeth fracture	0	0%	0	0%
– Relining	0	0%	0	0%
– New denture	0	0%	0	0%
– Soreness	4	14.29%	5	14.29%
– Ulceration	5	17.86%	6	17.14%
– Flabby tissue	0	0%	0	0%
– Hyperplasia	0	0%	0	0%
Mean no of complication	28		35	

**** Significant if $p \leq 0.05$ according to Chi-square test.***

TABLE (9): Prosthodontic complications from T4 to T5 in both groups

Prosthetic complications	MIO group		SDO group	
	Number of complications (n=49)	Percent of complications (n/49)	Number of complications (n=53)	Percent of complications (n/53)
Mandibular overdenture				
– Attachment (male) fracture	1	2.04%	1	1.89%
– Attachment (male) loosening	8	16.33%	4	7.55%
– Wear of female housing	12	24.49%	6	11.32%
– Dislodgment of female housing	2	4.08%	6	11.32%
– Prosthesis teeth fracture	1	2.04%	1	1.89%
– Prosthesis teeth worn	1	2.04%	1	1.89%
– Overdenture fracture	1	2.04%	1	5.66%
– Overdenture modification	4	8.16%	4	7.55%
– Overdenture relining	2	4.08%	2	3.77%
– New overdenture	3	6.12%	3	5.66%
– Soreness	1	2.04%	3	5.66%
– Ulceration	2	4.08%	2	3.77%
– Flabby tissue	0	0%	0	0.00%
– Hyperplasia	0	0%	0	0.00%
Maxillary denture				
– Base fracture	1	2.44%	1	1.89%
– Teeth fracture	2	4.88%	2	3.77%
– Relining	3	7.32%	3	5.66%
– New denture	0	0%	1	1.89%
– Soreness	3	6.12%	6	11.32%
– Ulceration	2	4.08%	3	5.66%
– Flabby tissue	0	0%	1	1.89%
– Hyperplasia	0	0%	0	0.00%
Mean no of complication	49		53	

**** Significant if p ≤ 0.05 according to Chi-square test.***

DISCUSSION

Many studies have shown that overdentures that are held in place by mini-implants have a high rate of success. [12,37, 44] According to the implant success criteria, the two-year implant success rate in our research was 100%. Many factors influence treatment success, including proper denture design and construction, adequate tissue support, and stress reduction through regular maintenance.[3] The findings of our study demonstrate that utilizing mini-implants for retaining overdentures yielded positive results. However, regular overdenture aftercare and long-term attachment component maintenance are critical to success. [39]

Occlusal analysis to ensure the proper overdenture occlusion is a critical step in implant prosthesis success. To evaluate different occlusion variables, digital occlusal analysis with a T- scan device was introduced.[45] T-scan was used in this study to assess the degree of force distribution, bilateral force difference, tooth contact number, and maximum occlusal contact force in overdentures retained by mini and standard-diameter implants.

In our study, the occlusal analysis of overdentures retained by mini and standard-diameter implants was compared before and after implant insertion. Maximum occlusal contact force is an important indicator for measuring overdenture function. According to our findings, the maximum occlusal contact force before implant insertion was approximately 71.52% in MIO group and 74.89% in the SDO group. Using mini or standard diameter dental implants to retain overdentures increases the maximum occlusal contact force significantly, up to 88.16% in MIO group and 87.2% in SDO group at two years of function. The slightly increased occlusal force in MIO group more than SDO group with an insignificant difference may be attributed to the increased stability and retention in overdentures retained by four mini-implants compared to those retained by two standard-diameter implants due to the increased number of ball attachments.

The bilateral balanced occlusion scheme is evaluated by force distribution. This occlusal design has the advantage of distributing occlusal forces evenly and provides denture stability. Also, patients can use their dentures more efficiently with this occlusal scheme. According to our findings, using mini or standard-diameter implants did not jeopardize the balanced occlusion that was designed during denture construction.[16]

In both groups, there were insignificant differences in bilateral force difference and degree of force distribution obtained before implant placement and during different follow-up periods. This could be explained by the value of T-scan analysis in measuring the percent of force distribution and detecting unseen premature contacts that articulating paper could not detect due to mucosal redundancy. As a result, force distribution patterns on both arch sides are improved, with a reduction of the occlusal load shared by the anterior region. The results revealed that tooth contact numbers increased significantly in both groups during the follow-up periods, which could be attributed to occlusal adjustment using T-scan and improved overdenture function following implant insertion.[45]

Evaluation of patients' satisfaction concerning their oral condition has proved recently to be as important as evaluating the mechanical behavior of the dentures. In order to evaluate patient satisfaction, the assessment tool has to cover the prosthesis's function and allow the patient to present his experience with the denture in an objective form to exclude any form of bias. In our study, patients' satisfaction with overdentures was evaluated using a VAS questionnaire [39,46] that was given to them in Arabic to be understood easily. The results of this study showed that overall patient satisfaction in both groups was significantly increased by time. This finding is consistent with previous research comparing mini-implant overdentures with complete dentures, and the results showed that mini-implant-retained overdentures significantly increased overall patient satisfaction.[47-49]

The increased patient satisfaction could be attributed to the patients' neuromuscular control of their dentures and the elimination of any evolving problems during the post-insertion recall visits. Overdenture stability, which is affected by the presence of balanced occlusal contacts, has a direct impact on patient satisfaction. According to Tomasi et al [38], overall satisfaction with mini-implants was due to enhancements in retention, speaking, and chewing. Scepanouic et. al.[37] reported in their study an increase in patient satisfaction after the insertion of mini-implants retained overdentures. They suggested that this improvement could be due to increased stability and retention of the prostheses due to an increase in the prosthesis adaptation, which decreased the patient's discomfort. According to the findings of our study, there was an insignificant difference in patient satisfaction between the two groups. On the other hand, some studies have found that patients are more satisfied with overdentures that are held in place by mini-implants than by standard-diameter implants.[7,10,12]

In the current study, there were insignificant differences in prosthodontic maintenance and complications between mini and standard diameter implant overdentures. This study's maintenance and complication events are comparable to previous studies.[50,51] The majority of patients reported minor denture modifications, with only two cases in SDO group and one case in MIO group being presented with a fracture in the implant-housing areas of the mandibular denture.

The number of fractures of mandibular dentures in SDO group is insignificantly higher than that of MIO group; this may be attributed to the larger metal housings in group II, as mini-implants have a smaller diameter than standard-diameter implants. As a result, the thickness of the acrylic resin of the overdenture over the housings in SDO group is less than that of MIO group. The implant-housing area is a denture's weak point and is easily fractured.

Overdenture fracture can occur as a result of the initiation and propagation of cracks caused by stress concentration in the thin acrylic resin layer around the head of attachment. [39,52,53] Preoteasa and colleagues[40] reported that mandibular overdenture fracture is a common problem. Aunmeungtong and colleagues[12] attributed denture fracture to the decrease in denture base thickness resulting from the space provided for the attachment housing and the presence of self-cured resin used for picking-up of the attachment.

Overdenture retention loss is a regular event that necessitates the replacement of attachment housings owing to their deterioration or dislodgement from the overdenture base. In a prior study on attachment efficiency, the most common complications were loss of overdenture retention and problems with attachment housings.[12,54] It was suggested that replacing the chairside attachment housing pick-up approach with an indirect laboratory technique might lower the frequency of matrix-related incidents significantly. The presence of saliva or soft tissue healing time during matrix pick-up has no effect in this situation.[54] The increasing occurrence of attachment wear and replacement might be a result of stress factors and conditions of the environment, such as high temperature and friction. Furthermore, the lack of implant parallelism impedes prosthesis insertion and removal, resulting in increased attachment degradation.[55]

Abutment loosening can occur as a result of failure to tighten the abutments according to the manufacturer's specified torque or abutment loosening with overdenture use during function. Some authors observed loosening of the ball attachments, suggesting that this issue might be the cause of overdenture fractures.[38,56,57] So, monitoring of abutment stability should be checked at the follow-up visits to prevent unnecessary fracture episodes.

Several studies on mini-implants have found an increase in the frequency of mandibular overdenture relining. [37,40] This might be because mini-implants only offer overdenture retention and do not support prostheses due to the presence of an occlusal gap in between the attachment head and the mini-implants.[40] The occlusal gap, along with greater masticatory ability, increases the loading of residual ridge and ridge resorption and is also responsible for denture tooth wear. However, relining of maxillary dentures may reflect the high forces exerted by mini or standard-diameter implants retained mandibular overdentures on maxilla [35]. These forces induce loss of maxillary bone and subsequent flabby tissue development and maxillary denture instability. Soreness and ulceration under overdentures occurred as a result of overdenture rotation around implants and denture settling, which enhanced ridge overloading and irritation of soft tissue. As a result, denture border adjustments are required at follow-up visits.

Hence, these findings supported the null hypothesis that there was no difference between overdentures retained by mini-implants and standard-diameter implants in terms of occlusal force pattern, patient satisfaction, and prosthodontic maintenance. The parameters collected by T-Scan represent one of the study's limitations. It only displays occlusal force readings in percentages and cannot display the force's actual numerical value in Newton. Further research using different tools that allow comprehensive analysis of the occlusal force is necessary. To support the findings of this study, more randomized clinical trials would need to be done with different implant systems, larger sample sizes, longer follow-up times, and different ways of rehabilitating the opposing arch.

CONCLUSION

Within the study's limitations, mini-implants can improve mandibular overdenture performance regarding maximal occlusal force and tooth contact number without impairing force distribution by employing digital occlusal analysis. Mandibular overdentures retained by mini-implants can achieve similar outcomes as standard-diameter implant overdentures in terms of patient satisfaction and prosthodontic problems.

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