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EFFECT OF PALATAL COVERAGE AND NUMBER OF MINI IMPLANTS USED TO ASSIST MAXILLARY OVERDENTURE: AN IN VITRO STUDY OF RETENTION, CYCLIC FATIGUE AND DEFORMATION OF MAXILLARY OVERDENTURE BASE

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ABSTRACT

Purpose : Prosthodontic complications related to implant assisted maxillary overdentures are reported more often. This in vitro study examined the influence of implant number and palatal coverage on retention, cyclic fatigue and denture base deformation of maxillary overdentures supported by five versus seven unsplinted mini implants.

Materials and methods: An edentulous model of maxillary arch with mini diameter implant dummies was fabricated. The implants were inserted into the anterior, premolar, and molar areas. Maxillary experimental dentures with complete and partial palatal coverage were fabricated. Cyclic dislodging forces were applied to assess cyclic fatigue and the resulting change in denture retention. Strain gauges were used to assess the deformation induced into the dentures when cyclic fatigue test was carried out on overdentures assisted by seven implants and five implants after excluding the posterior implants.

Results: Cyclic fatigue and denture base deformation induced in overdentures with partial palatal coverage assisted by five mini implants were significantly higher than overdentures with complete palatal coverage whether assisted by seven or five implants ($P < .05$). Overdentures with partial palatal coverage assisted by seven mini implants exhibited non-significant changes in retention, cyclic fatigue and base deformation when compared to overdentures with complete palatal coverage assisted by five mini implants.

Conclusion: Maxillary five mini implant assisted overdentures with partial palatal coverage revealed much higher cyclic fatigue and induced denture base deformation than overdentures with complete palatal coverage regardless of the mini implant number. With respect to retention, fatigue failure and denture deformation, maxillary seven mini implant assisted overdentures with partial palatal coverage exhibited no significant difference comparable to five mini implant assisted maxillary overdenture with complete palatal coverage.

Keywords: Mini implant, maxillary implants overdenture, partial palatal coverage, cyclic fatigue, deformation.

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INTRODUCTION

It has always been a defiance to devise and conceive the best way to replace missing teeth. Formerly, conventional dentures were considered the standard way for replacing missing teeth [(1)]. Nowadays, implant supported and/ or retained overdentures treatment is the most reliable and commonplace alternative approach to conventional dentures [(2)]. Two frequently proclaimed benefits of implant supported maxillary overdentures compared to conventional mucosa-borne denture constitute better retention and modification of palatal coverage [(3,4, 5)].

It was agreed that complete palatal coverage by an implant assisted overdenture is crucial to enhance denture support by reducing the load per unit area and hence, the load transmitted to the denture bearing area [(6, 7)]. Additionally, complete palatal coverage enhances retention by creating adequate means of physical retention proportional to the degree of coverage. Controversially, some clinicians believed that reduction of palatal coverage has an impact on denture retention, support and stability, that further gets compromised by flat ridges, lack of vestibular depth and a shallow palatal vault[(8-10)]. Furthermore, it was reported that palateless dentures are more susceptible to deformation and prone to fracture than those with complete palatal coverage [(11)]. However, palateless implant supported and/ or retained overdentures have often been reported to have higher fracture rate especially at the implant sites, besides, the midline [(11-14)].

Conventional sized two piece implants appeared problematic in areas in which resorption of bone had occurred, in cases where edentulous arches exhibit minimal bone in facial- lingual or mesiodistal directions, thus precluding such patients from implant placement [(2, 15)].

Interestingly, the use of mini diameter (single piece) implants (MDIs) to assist overdentures became a technically easier and a rapid replacement to the conventional ones, giving the opportunity for more patients with resorbed ridges to be boosted by implant therapy. MDIs can provide support and stabilization for removable full dentures and characterized by minimally invasive surgical procedure. Eventually, MDIs deemed good to be used in cases where there may be anatomical, medical or financial constraints. MDIs have fewer complications during flapless implant placement, are cost-effective and can obviate the need for bone augmentation or space enlargement [(16, 17, 18)]. Based on patient responses, comfort, denture retention in addition to speaking and chewing ability were all improved when mini implants supported overdentures were used [(19)].

Several researchers suggested a minimum of four MDIs to be installed in maxillary arch when partial palatal coverage is planned [(12,20,21,22)]. Nonetheless, others claimed a minimum of six MDIs for convenient retention of complete removable maxillary overdentures [(16)]. However, Patel [(23)] suggested the use of seven unsplinted MDIs with palateless maxillary overdentures.

With respect to the mechanical point of view, unsplinted attachment systems seem to burden the overdenture with particular stresses, rather than on the implant. Longitudinal clinical studies using these implant systems revealed more complications involving the overdenture, such as denture fracture and necessity for denture reline[(24,25)]. These complications are believed to be an eventual consequence of the denture base deformation. Furthermore, deformation of the overdenture can harm the underlying structures, leading to recurrent ulcer formation, resorption of the residual ridge also, implant overload [(26)].

Therefore, the aim of this study was to evaluate and compare the effect of the degree of palatal coverage and the number of (MDIs) on the retention force, fatigue resistance of attachment system and denture base deformation of maxillary MDIs assisted overdentures, with the null hypothesis implying no differences among them.

MATERIALS AND METHODS

Fabrication of the study (Test) model

- An acrylic resin educational model (Nissin Ltd Inc., Japan) representing a completely edentulous maxilla was selected for this study. The cast represented an average sized edentulous maxilla and U-shaped palatal vault. To imitate the resiliency of maxillary mucosa, the edentulous ridge was covered with a silicone layer of 2 mm thickness (Fit Checker, GC, Japan)
- Seven 2.5 mm. diameter and 13mm. length; single piece dummy MDIs with ball abutments (TUT Dental implants, Egypt) were installed on the model parallel to each other in the following positions:

• Implant number 1 was installed in the midline,

• Implants number 2 & 3 were installed in the canine area on each side,

• Implants number 4 & 5 were installed in the second premolar area on each side,

• Implants number 6 & 7 were installed in the second molar area on each side, **Fig.(1).**

- The dummy MDIs were fixed into position by using resin cement (Superbond CB; Sun Medical, Kyoto, Japan) in order to simulate osseointegrated implants.

Fig. (1) The dummies in their prepared sites in the replica

Fabrication of maxillary overdenture:

- The female housings were positioned on the ball abutments of the MDIs. Wax spacer of 2mm thickness was applied on the assembly and extended below the balls to block out the undercuts. The model was duplicated with agar agar to produce twenty duplicate stone models then twenty duplicate refractory models. Twenty reinforcing chrome-cobalt frameworks were fabricated; ten completely covering the palate (group I) and ten partially covering the palate (group II) were fabricated. Occlusion block with acrylic base was fabricated and attached to the metal framework.
- Twenty semi anatomical acrylic resin teeth (Ruthinium acrylic teeth, Acry Rock Company, Italy) were set up to produce twenty duplicate trial dentures with bases having the same thickness.
- The waxed up trial dentures were processed into heat cured acrylic resin.

According to the palatal coverage, the overdentures were classified into two equal groups as follows:

• Group I: Overdentures with complete palatal coverage.

• Group II: Overdentures with partial palatal coverage.

- According to the numbers of MDIs used to assist the overdentures, each duplicate overdenture for each group was assisted first by seven MDIs to carry out the experimental protocol as follows:
- Seven female housings were seated on the ball attachments on the experimental model and the undercuts below the assemblies were blocked out with wax.

- A pick up procedure was carried out. The recipient sites of the female housing in the fitting surface of the overdentures were ground, picked up with autopolymerized acrylic resin, inserted on the model and held under bilateral finger pressure until complete polymerization.
- Excess resin was removed and the female housings were checked for exact and firm location into their sites, **(Fig.2).**
- Dentures were checked for proper seating on the model.
- After application of the experimental protocol, the two MDIs in the second molar areas were unscrewed from their positions in the experimental model to assist the overdentures by the remaining five MDIs. Then the same experimental protocol was followed.
- According to the number of MDIs used to assist the overdentures, duplicate overdentures for each group were subclasified into:

• Group I A: Overdentures with complete palatal coverage assisted by seven implants.

• Group I B: Overdentures with complete palatal coverage assisted by five implants.

• Group II A: Overdentures with partial palatal coverage assisted by seven implants.

• Group II B: Overdentures with partial palatal coverage assisted by five implants.

The constructed overdentures were used to assess the following:

I- Testing MDIs assisted overdenture retention and fatigue resistance:

- Testing of the degree of retention and the fatigue resistance of the overdenture was carried out by using the Universal testing machine (UTM)[27] (Model LRX-Plus, Lloyed. Instruments, Fareham, UK).
- A horizontal metal cobalt chrome plate with a grasping hook in the middle, was attached by auto-polymerized acrylic resin in the center of gravity of each overdenture, **(Fig.3).**
- Drops of artificial saliva (1.5mm Ca, 3.0 mm P, and 20.0 mm Na Hco3, PH 7.0) were applied beneath the overdentures. Each cast with its implant supported overdenture was attached by cyanoacrylate glue to the lower fixed compartment of the UTM.
- A wire loop (0.019) attached to the upper movable compartment of the testing machine was connected to the metal hook of the centrally positioned bar to facilitate loading. A tensile load (5 KN) with pull out force was applied at a crosshead speed of 5 mm/min. Dislodgement cyclic forces were applied in a vertical direction, **(Fig.4).** The recorded forces applied were the minimum required to dislodge the overdentures assisted by seven implants (Groups IA, IIA).

Fig. (2): Female housings were picked up to all the intaglio surfaces of overdentures of both groups

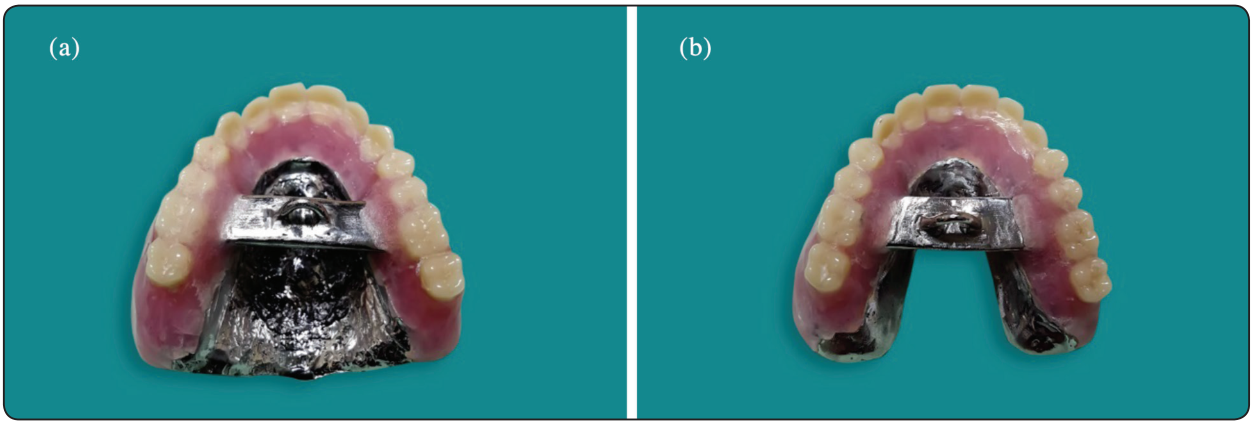

Fig.(3): Horizontally attached metal bar. (a) For group I dentures (b) For group II dentures

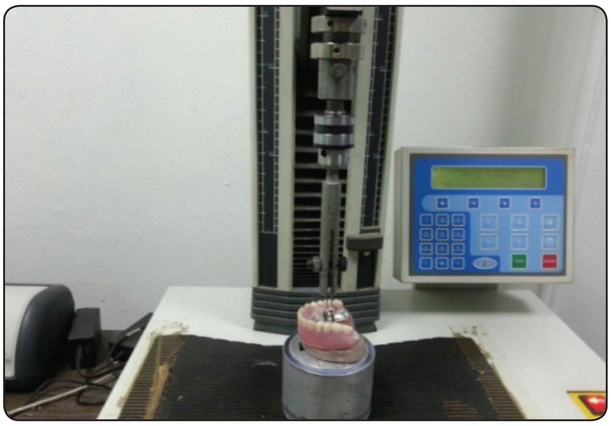

Fig. (4): Testing the retention and fatigue resistance using (UTM).

The load required for initial dislodging (unseating) the denture was recorded for all study samples in Newton. The data were recorded using computer software (Nexygen-MT-4.6; Lioyd Instruments).

Changes in retention were assessed after an average number of insertion and removal cycles per day as previously recommended [27]. Retention was assessed before applying dislodging cycles as a base line for the primary retention. Also, after 120, 720, and 1440 cycles that respectively correspond to one, six and twelve months of simulated clinical use of a denture.

The ideology behind selecting the number of cycles being if a patient inserts and removes his dentures for at least four times daily. So keeping this count of 120(per month), 720(6 months) and 1440 cycles of insertion and removal that would occur annually [27,28].

II- Testing MDIs assisted overdenture base deformation:

Testing of overdenture base deformation for all groups was carried out using UTM [14]. The horizontal metal bar was removed. Five linear 1mm length strain gauges (KFG-1-120-C1-11 LIM2R, Japan) with strain resistance 119.8± 0.2Ω, gauge factor 2.13±1.0%, adaptable thermal expansion =11.7 PPM/°C and temperature coefficient of gauge factor+0.008%/°C) were installed on upper denture base by adhesive cement (Kyowa CC-33A, EP-34B Japan) on the five following positions, **(Fig.5):**

Position (1): On the incisal foramen area in the fitting surface.

Position (2): On the incisal foramen area on the polished surface.

Position (3): On the midline of the labial flange.

Position (4): On the lateral flange in the second premolar area.

Position (5): On the palatal side in the second premolar area.

UTM was used to apply vertical bilateral load of 100 N with rate of 1mm/min was applied on the second premolar first molar area. After each loading; the induced strains were recorded for the five gauges, **(Fig.6).** Maxillary overdentures assisted by seven implants (groups IA, IIA) base deformation measurements were recorded at each point of the mounted strain gauges. All measurements were repeated five times for each group.

The two MDIs in the second molar areas were unscrewed from their positions in the experimental model. Twenty maxillary overdentures assisted by five implants, (groups IB, IIB) were assessed in the same way as (groups IA, IIA). The same procedure of retention, cyclic fatigue and denture base deformation measurements for (groups IA, IIA) were repeated for (groups IB, IIB).

Statistical Analysis

Data analysis was performed using statistical software (SPSS for Windows, v. 21.0; SPSS, Inc, USA). Data were tested for normality before statistical analysis.

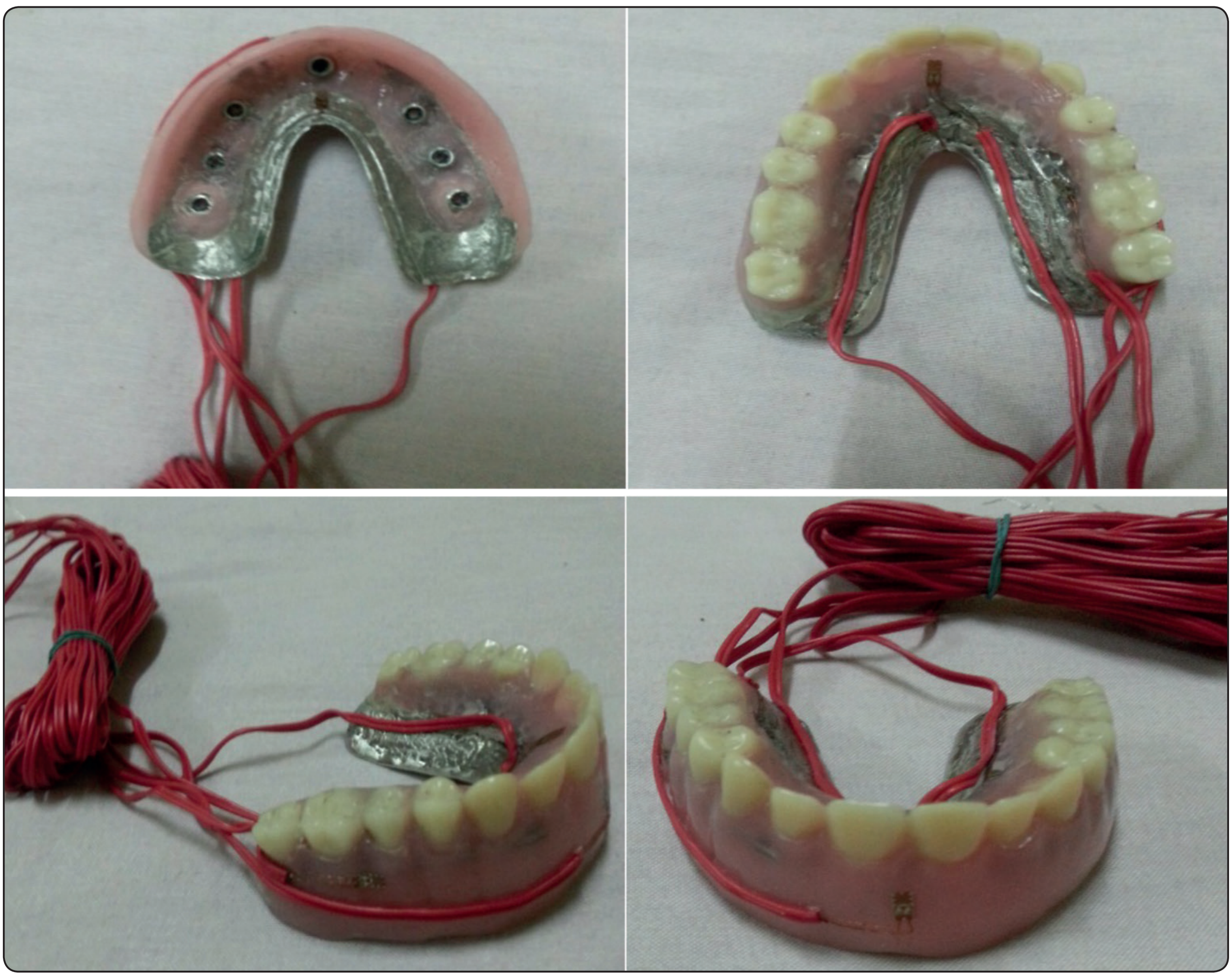

Fig.(5): linear strain gauges were cemented to the determined positions.

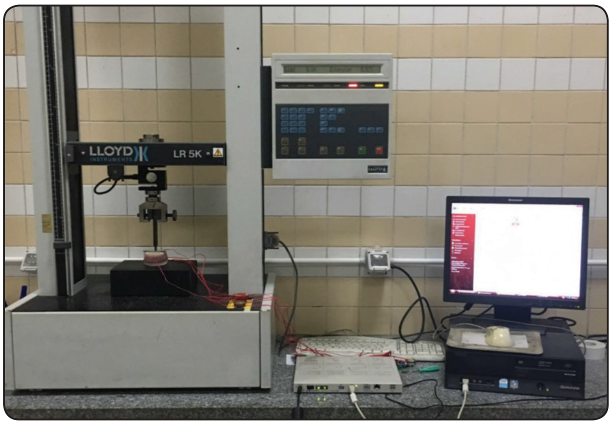

Fig. (6): The strainometer measurements were recorded from all the five gauges.

Absolute force (AF) at 0 cycles (initial dislodging force) and the measured forces in Newton at pull number required to dislodge the attachments were expressed as mean and standard deviation of the reduction in force. One-way analysis of variance (ANOVA)test was used to compare between all groups along with the number of applied cycles (0, 120, 720, and 1440).

Pair wise comparison between the groups using Post Hoc tests. For abnormality distributing data, mean, median and range were calculated then Mann Whitney and Kruksal Wallis tests were used for analysis. All tests were performed at the 0.05 significance level.

RESULTS

Overdenture retention:

The results of this study revealed decrease in the forces required to dislodge the overdentures by increasing the number of dislodging cycles in overdentures with complete and partial palatal coverage, whether assisted by seven or five MDIs (all groups). These changes were statistically extremely highly significant along with 0, 120, 720, and 1440 cycles respectively as evident in **Table (1).** Also, statistically extremely highly significant difference was observed when comparing the four tested groups at each cycle.

Table (2): For seven implants (subgroups A), Pairwise comparison by post hoc Scheffe test between the cycles was used. Except for dislodging force values between (0 cycle &120 cycles) for both complete and partial coverage overdentures (group IA & group IIA), all other dislodging force values (0 cycles &720 cycles), (0cycles&1440cycles), (120 cycles to720 cycles) and (120 cycles to 1440 cycles) were extremely highly significant (P=0.000).With respect to (720 cycles to 1440), for group IA & group IIA, there were significance (P=0.01) and highly significance reductions (P=0.003) in the retention force respectively.

TABLE (1): Mean and standard deviation of the denture dislodging forces at different dislodging cycles.

	Complete palatal coverage (group I)		Partial palatal coverage (group II)		F (P value)
	Seven implants (group IA)	Five implants (group IB)	Seven implants (group IIA)	Five implants (group IIB)	
	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	
Zero cycle	70.08±12.33	49.13±7.55	50.59±11.85	36.06±9.04	57.85(0.000)***
120 cycles	70.05±4.54	48.87±8.40	50.30±6.43	35.15±7.55	33.56(0.000)***
720 cycles	40.99±4.41	29.31±2.45	30.23±6.44	12.22±1.03	50.37(0.000)***
1440 cycles	23.14±5.55	15.88±0.721	16.08±2.79	7.41±1.29	46.51(0.000)***
F (p value)	31.12(0.000)***	23.01(0.000)***	24.49(0.000)***	47.00(0.000)***	

SD: Standard deviation ****: Extremely high significant at p level≤0.05* *F: One way ANOVA test values*

Table (3): For five implants (subgroup B), Pairwise comparison by post hoc Scheffe test between the cycles was used. Except for dislodging force values between (0 cycle &120 cycles) for both complete palatal coverage and partial palatal coverage overdentures (group IB & group IIB), all other dislodging force values (0 cycles &720 cycles), (0 cycles &1440 cycles), (120 cycles to720 cycles) and (120 cycles to 1440 cycles) were extremely highly significant (P=0.000).While when comparing the reduction in the retention force from (720 cycles to 1440)for group IB & group IIB , there were significance reductions (P= 0.05) for both.

Table (4) shows comparisons between different groups at different dislodging cycles. Statistically extremely highly significant are reported among all groups except for Group IB vs Group IIA (overdentures with complete palatal coverage assisted by five implants vs. overdentures with partial palatal coverage assisted by seven implants).

Table (5) shows descriptive analysis of denture strain of complete palatal coverage overdentures (group I) at different measuring points. There were extremely highly significances for both seven and five MDIs overdentures (p=0.000) with respect to all measuring points. It was observed that the mean values of seven MDIs overdentures(G IA) at all positions were lower than the corresponding values of five MDIs overdentures(G IB) at the same positions. Moreover, higher mean values at the midline of the labial flange (Position 3) followed by the incisal foramen area on the polished (Position 2) and fitting surfaces (Position 1) respectively were revealed for both groups in comparable to the other positions.Also,it was found that strain values at the palatal positions(1,2,5) were compressive in nature(-ve), whereas strain values at positions(3,4) were tensile(**+**ve) in nature

Table (6) shows descriptive analysis of denture strain of partial palatal coverage overdentures (group II) at different measuring points. There were extremely highly significances for both seven and five MDIs overdentures (p=0.000) with respect to all measuring points. It was observed that the mean values of seven MDIs overdentures(G IIA) at all positions were lower than the corresponding values of five MDIs overdentures(G II B) at the

TABLE (2): Pairwise comparison by post hoc Scheffe test between the cycles for both; group IA and group IIA.

Cycles number	Group IA (Complete palatal coverage assisted by seven implants)	Group IIA (Partial palatal coverage assisted by seven implants)
Zero cycle versus 120 cycles	1	0.530
Zero cycle versus 720 cycles	0.000***	0.000***
Zero cycle versus 1440 cycles	0.000***	0.000***
120 cycles versus 720 cycles	0.000***	0.000***
120 cycles versus 1440 cycles	0.000***	0.000***
720 cycles versus 1440 cycles	0.01*	0.003**

***** Significant at p level≤0.05*** ****Highly significant at p≤0.001*** *****Extremely high significant at p≤0.000***

same positions. In addition, it was noticed that strain values at the palatal positions (1, 2, 5) were compressive in nature (-ve), whereas strain values at positions (3, 4) were tensile (+ve) in nature

Table (7) demonstrates comparisons between different groups at different positions. There were statistical significances ranged between non significance, significance, highly significance and extremely highly significance. When comparing complete palatal coverage assisted by five implants (group IB) to partial palatal coverage assisted by seven implants (group IIA), no statistical significances were shown at all positions. However, an extremely highly significance was observed when comparing Group IA to Group IIB.

TABLE (3): Pairwise comparison by post hoc Scheffe test between the cycles for both group IB and group IIB.

	Group IB (Complete palatal coverage assisted by five implants)	**Group IIB (partial palatal coverage assisted by five implants)**
Zero cycle versus 120 cycles	0.418	0.259
Zero cycle versus 720 cycles	0.000***	0.000***
Zero cycle versus 1440 cycles	0.000***	0.000***
120 cycles versus 720 cycles	0.000***	0.000***
120 cycles versus 1440 cycles	0.000***	0.000***
720 cycles versus 1440 cycles	0.05*	0.05*

* Significant at p level≤0.0 **Highly significant at p≤0.001 ***Extremely high significant at p≤0.000

TABLE (4): Pairwise comparison using Mann Whitney test between each two groups regarding different dislodging cycles.

Groups	Zero cycle	120 cycles	720 cycles	1440 cycles
Group IA Vs Group IB	0.000***	0.000***	0.000***	0.000***
Group IA Vs Group IIA	0.000***	0.000***	0.000***	0.000***
Group IA Vs Group IIB	0.000***	0.000***	0.000***	0.000***
Group IB Vs Group IIA	0.644	0.370	0.749	0.862
Group IB Vs Group IIB	0.000***	0.000***	0.000***	0.000***
Group IIA Vs Group IIB	0.000***	0.000***	0.000***	0.000***

**** Significant at p level≤0.05 **Highly significant at p≤0.001 ***Extremely high significant at p≤0.000***

TABLE (5): Descriptive analysis of denture strain of complete palatal coverage overdentures (group I) regarding different measuring points.

Measuring positions	Group IA (Complete palatal coverage assisted by seven implants)			Group IB (Complete palatal coverage assisted by five implants)		
	Mean	**Median**	**Minimum -maximum**	**Mean**	**Median**	**Minimum -maximum**
Position (1) On the incisal foramen area in the fitting surface.	-3.84 ± 1.99	-10	(-80 – 5)	-5.92± 3.93	-15	(-25 – 0)
Position (2) On the incisal foramen area on the polished surface.	-10.85±2.78	0.00	(-15 – 125)	-12.21± 8.61	10	(-25 – 25)
Position (3) On the midline of the labial flange.	12.85±4.39	0.00	(-15 – 125)	14.21± 7.53	10	(-25 – 25)
Position (4) On the lateral flange in the second premolar area	0.05± 0.53	5	(5 – 25)	4.66± 6.20	-5	(-60 – 15)
Position (5) On the palatal side in the second premolar area.	-1.15±3.66	0.00	(-5 – 15)	-3.13± 1.28	5	(-65 – 120)
P value	0.000***			0.000***		

P value of Kruksal Wallis test significant at p level ≤0.05

TABLE (6): Descriptive analysis of denture strain of partial palatal coverage (group II) overdentures regarding different measuring points.

Measuring positions	Group IIA (partial palatal coverage assisted by seven implants)			Group IIB(partial palatal coverage assisted by five implants)		
	Mean	Median	**Minimum -maximum**	**Mean**	Median	**Minimum -maximum**
Position (1) On the incisal foramen area in the fitting surface.	-6.19± 12.28	5	(-115 - 5)	-10.01± 9.16	0	(-45 –5)
Position (2)On the incisal foramen area on the polished surface.	-13.14± 25.5	5	(-80 – 15)	-17.07±11.54	5	(-145 – 15)
Position (3) On the midline of the labial flange.	14.05± 8.19	-10	(-80 – 25)	20.26±12.68	-15	(-5 – 30)
Position (4) On the lateral flange in the second premolar area	5.18± 3.78	5	(0.00 – 40)	10.35± 2.70	15	(15 – 25)
Position (5) On the palatal side in the second premolar area.	-3.1± 1.62	0.00	(-5 – 5)	-8.36 ± 4.48	5	(-10 – 20)
P value	0.000*			0.000*		

P value of Kruksal Wallis test significant at p level ≤0.05

TABLE (7): Pairwise comparisons using Mann Whitney test between each two different groups at different measuring points.

	Position (1) On the incisal foramen area in the fitting surface.	**Position (2) On the incisal foramen area on the polished surface.**	**Position (3) On the midline of the labial flange.**	**Position (4) On the lateral flange in the second premolar area**	**Position (5) On the palatal side in the second premolar area.**	**Total**
Group IB Vs Group IA	0.05*	0.03*	0.05*	0.05*	0.01*	0.058
Group IB Vs Group IIB	0.02*	0.000***	0.000***	0.601	0.001*	0.001*
Group IB Vs Group IIA	0.09	0.193	0.814	0.327	0.428	0.521
Group IIB Vs Group IIA	0.000***	0.048*	0.000*	0.03	0.000*	0.001*
Group IA Vs Group IIB	0.000***	0.000***	0.000***	0.000***	0.038*	0.000***
Group IA Vs Group IIA	0.05*	0.05*	0.007**	0.000***	0.01*	0.001**

**** Significant at p level≤0.05 **Highly significant at p≤0.001 ***Extremely high significant at p≤0.000***

DISCUSSION

Maxillary overdentures assisted by conventional dental implants are increasingly being used and have been shown to be a predictable method for long-term rehabilitation of the edentulous maxilla [22]. However, because of their diameter, conventional implants may not be good choices in resorbed ridges and in cases with low sinus level. Based on that, the use of mini implants as alternatives has raised significant attention [2,15] .

The use of MDIs to support complete dentures has gained momentum after numerous reports have been published suggesting MDIs as permanent rather than temporary implants. Hence, complete dentures assisted by MDIs have become one of the most sought after treatment modalities [19, 23, 29].

Researchers have been increasingly interested to carry out studies to reveal beneficial applications of MDIs in the conservative rehabilitation of edentulous ridges. Hence, this study was carried out to assess the feasibility of successfully using dentures with partial palatal coverage when dentures are assisted by MDIs. Also, since it has not been clarified in the dental literatures the ideal number of implants that can be successfully used to assist maxillary dentures especially dentures with partial palatal coverage, hence, this study was prompted.

Dentures with minimal palatal coverage have often been used for improving the wearer's oral sensory function, patients with large tori and in nervous patient unable to tolerate palatal coverage[30]. However, limited physical retention and denture deformation compared to dentures with complete palatal coverage were reported. These raised the idea of assisting dentures with partial palatal coverage with MDI to enhance retention [11,21,26,31]. However, the number MDIs sufficient to compensate for complete palatal coverage was controversial hence, this study was conducted.

For maxillary implant assisted overdentures, previous investigators have recommended a variety of implant numbers and distributions, ranging from one to six implants [3, 4,24,32]. This study was concerned about using adequate number to provide superior retention that could compensate for palatal coverage hence; five and seven implants assisting maxillary overdentures were assessed.

Slot et al. [3], in a systematic review, proved that maxillary overdentures supported by six connected implants resulted in the greatest implant and overdenture success, followed by four connected implants. For overdenture design with partial palatal coverage, a minimum of four unsplinted implants is crucial so stresses over each implant would be clinically acceptable [7,21,33]. Even though the use of seven MDIs with unsplinted maxillary partially covered overdenture was reported and recommended [23]. Nonetheless, Takahashi et al.,[14] revealed in their study the importance of anterior implants under maxillary IODs. They assured that the shear strain was significantly lower in dentures supported by anterior implants than in other configurations. Moreover, palateless IODs also displayed this tendency,

Patently, unsplinted overdentures typically represent the least expensive option and are easiest to fabricate, while offering potential esthetic, phonetic, and maintenance advantages [34].

Since, attachments as bar and clip require additional space within the fitting surface of the overdenture implying a greater liability for overdenture fracture, complex laboratory procedures, difficulty of cleaning by patients [28,35-37], ball attachments were thus used in this study to overcome these problems.

Based on previous studies, the decision was made to assess and compare the use of seven mini implants supporting dentures with complete palatal coverage with the otherwise conservative use of five implants to support dentures with both complete and palatal coverage.

Since, it is important for patients to perceive their dentures highly retentive, initial retention obtained by the assistance of implants with ball attachments to maxillary overdentures were assessed. This is also proved by the statistically significant retention values obtained in this study. This observation is in agreement with the results of previous studies [12, 23, 28].

The inclusion of retention of various attachment systems to tooth or implant supported overdentures were proved to exhibit almost similar initial values thereby, offering optimum patient compliance. However, it was important to know whether these retention values remain the same or change over a substantial period of time and to assess the development of fatigue that builds in due to constant insertion and removal cycles [38]. This provoked the idea of this study especially with the use of mini implants and dentures with partial palatal coverage.

The results of this study revealed that the force required to dislodge dentures with complete or partial palatal coverage whether assisted by seven or five mini implants were significantly reduced by increasing the number of cycles except for 120 cycles. This finding is possibly attributed to the dominant mechanical retention by the implant superstructure irrespective to the physical retention gained by conventional dentures. This could be in consistent with El Mekawy et al [10].

The significant reduction in the dislodging force values after each loading cycle compared to the initial value and which represent retention of overdentures, whether assisted by sever or five min implants could attribute to the wear of the attachments. This wear was reported to occur by time due to the multiple insertions and removals of dentures when in use. Also, due to the stresses applied on dentures and on attachments during function. This wear is due to friction between the base and attachment and leads to lowering of the retention values. This concept could explain the decreased retention force with an increase in the number of cycles in the present study. This is concurred with the results of in-vitro studies investigating the retentive properties of attachment systems [10, 33, 38, 39].

The results of this study also, revealed that the force required to dislodge dentures with partial palatal coverage assisted by seven mini implants was significantly reduced by increasing the number of cycles compared to dentures with complete palatal coverage assisted by seven implants. This proves the role offered by complete palatal coverage in enhancing the physical retention and the role of posterior palatal seal that could have compensated for the attachments wear. This is in consistent with the results of many studies [6-10].

It was noted that the use of seven MDIs for assisting dentures whether complete or partial palatal coverage exhibited higher retentive values along with all cycles in comparison to the five MDIs. This observation assured the role of increasing number of implants in retention enhancement. This finding is consistent with the findings of a previous study that recommended the use of six implants instead of four in rehabilitations of patients included for partial palatal coverage[4]. This is also in agreement with another study where it was reported that using seven MDIs which assist overdentures with partial palatal coverage can provide clinical benefits and restore function and confidence in patients together with improvement in retention and function when partial palatal coverage is indicated [23].

These results imply that the null hypothesis that there are no differences between the groups of overdenture designs before and after fatigue testing can be rejected, since significant differences were observed as retention force values decreased.

However, forces used in this study were extremely simple and were exclusively applied in the path of insertion regardless of the horizontal and lateral forces that are applied clinically which represents masticatory and parafunctional forces. Under clinical conditions, the load is far more complex and various clinical measurements have proven that three-dimensional loads regularly occur. Thereby lack of consideration of the masticatory chewing cycle force can be a limitation for this study. This idea was shared by the authors of a previous study [27]. Hence, clinical studies are recommended to reinforce the data obtained in this study.

Comparing the induced denture deformation in overdentures, the strains were much higher in denture with partial palatal coverage than in dentures with complete palatal coverage. These results are consistent with previous studies [11,14]. This would probably enhance the probability of denture base deformation and fracture. Hence, it could be suggested that the most favorable configuration to prevent complications in maxillary assisted implant overdentures is complete palatal coverage supported by more than four widely distributed implants. Additionally, these results demonstrated that overdentures with partial palatal coverage transmit more stress to the underlying structures and may thus cause complications. Therefore, to prevent these problems, metal reinforcement embedded in the denture base or a rigid palatal metal frame is recommended. This is in agreement with previous recommendations [40].

In dentures with complete or partial palatal coverage, the strains induced in all positions tended to be greater when being supported by five MDIs. Thus the strains induced in the assisted overdentures are inversely proportional to the number of implants. This finding was consistent with many studies that recommended the use of more than four implants to assist maxillary overdenturs [21, 23, 41]. However, this finding was not in agreement with the speculations that there is no association between the denture induced strains and the number of implants **[14]**. Moreover, this result was not in accordance to the conclusion of a previous study that demonstrated that the transmitted load was not significantly lower when four implants compared to eight implants were used [33].

The results obtained from this study revealed that high strain values were recorded anteriorly in the incisal foramen and on the midline anterior flange comparable to other positions. This appeared to be consistent with the results of Mizuno et al., [11] . Also, this result seemed to be concurrent with Takahashi et al.,[22] who concluded that strains induced to implants supporting partial palatal coverage dentures exhibited higher strains than those under dentures with complete palatal coverage and they reported that anterior implants exhibited higher palatolabial strains than other implants. Therefore they recommended that maxillary implant overdentures should be supported by six implants with support extending to the distal end of the arch.

Comparing the results obtained from both groups at different measuring points revealed statistically significant differences.

Yet the extremely higher significance was presented when comparing complete palatal coverage assisted by seven implants versus overdentures with partial palatal coverage assisted by five implants, this revealed that increasing the number of implants besides, palatal coverage is more preferable with respect to denture strain. This is concurred with Takahashi et al., [22].

In the present study, the recorded strain values at the palatal positions were compressive in nature, whereas strain values at the labial and buccal flange sides were tensile in nature. These results might be similar to the study of Glantz and Stafford [42].They reported that the functional deformation pattern of a maxillary complete denture was complex with a fairly high compression at the oral and polished surfaces in the region of the incisal foramen, while the anterior portion of the midline showing tension.

CONCLUSION

Within the limitation of this study, it can be concluded that:

1. Maxillary mini dental implants (MDIs) assisted overdenture with complete palatal coverage exhibited the the highest retention and lower induced denture deformation compared to maxillary MDIs assisted overdenture with partial palatal coverage regardless of the mini implant number.
2. Maxillary overdentures assisted by seven MDIs exhibited better retention and less induced denture deformation compared to maxillary overdenture assisted by five MDIs.
3. Overdentures with partial palatal coverage and assisted by seven MDIs exhibited comparable retention, cyclic fatigue and induced strain to overdenture with complete palatal coverage assisted by five MDIs.
4. Whenever partial palatal coverage is planned to restore maxillary edentulous ridges, overdentures assisted by seven MDIs are advisable.

Recommendation

More clinical short term and long term studies are thus required to validate the results of this in vitro study.

COMPETING INTERESTS

The authors report no conflicts of interest related to this study.

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