EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 2605:2614, July, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 24-04-2024 • Accept Date : 15-05-2024 • Available online: 10-07-2024 • DOI : 10.21608/EDJ.2024.284810.3021

RETENTION AND STABILITY OF DIFFERENT IMPLANT CONFIGURATIONS OF FOUR IMPLANTS SUPPORTING MANDIBULAR IMPLANT OVERDENTURE RETAINED BY TELESCOPIC ATTACHMENTS. IN-VITRO STUDY

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ABSTRACT

Aim: this study aimed at evaluation of retention and stability of four implant supported mandibular overdentures retained by telescopic attachments with different configurations.

Materials and methods: three acrylic models for edentulous mandibular arch, each of which received four implants in; quadrilateral configuration “model A”, curved configuration “model B” and linear configuration “model C”. Five experimental overdentures (acrylic blocks) were made for each model. Resistance to vertical and oblique (lateral, posterior and anterior) displacement forces were recoded to represent retention and stability respectively with directional pull-test.

Results: Model A provided the highest significant retention (p value <0.001). Regarding stability, Model A provided the highest significant lateral and anterior stability (p value <0.001). Model C provided the highest significant posterior stability (p value <0.001.

Conclusion: Quadrilateral configuration of four implant placement in edentulous mandible provided the best retention and stability for mandibular implant overdenture except for posterior stability where linear configuration had the best resistance to posterior displacement forces.

INTRODUCTION

Implant overdenture is considered the one of the most successful solution for rehabilitation of edentulism. It overcomes the lack of proper adaptation, chewing and speech that usually encountered with complete denture due to poor retention, stability, support and other difficulties especially for the mandibular denture.[3,4,7]

Comparing to fixed implant prosthesis, implant overdenture provides easier maintenance, more cost effective, offers more accessibility for oral hygiene measures as well as the provision of a labial flange to improve esthetics in situations of unfavorable jaw relationship.[5-7,10] Retention, support and stability are the three major factors contribute to the success of the implant overdenture.[17] Regarding patient

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satisfaction, stability and retention are crucial for the patient in order to feel comfort the use of over denture.[16]

The use of four implants for supporting mandibular implant overdenture has been proved to be mandatory in cases like resorbed mandibular ridges, easily irritable mucosa, dehiscence of mental nerve, knife edge crest of the mandibular ridge, sharp mylohyoid ridge, opposing natural teeth to distribute stresses widely on the mandibular implants and extreme gaggers.[5-7]

Denture retention is the ability of the prosthesis to resist vertical (axial) displacing forces, while stability is defined as the ability to oppose with forces off-axial displacing forces, including lateral, anterior and posterior forces. Retention and stability of implant overdenture play significant roles in restoring function and patient satisfaction[20]. There are several methods for measurement of retention of removable prosthesis that can be carried out in vitro and in vivo either through subjective methods or objective methods.[30,31]

Various attachments are available for retaining mandibular overdenture such as stud, bar, magnets and telescopic attachment.[18,23] Telescopic attachments present a rigid anchorage system between implants and overdenture protecting the residual ridge from occlusal forces. Along with more freedom in implant placement with better access to oral hygiene and without affecting the required space for the tongue.[9]it has been reported that using telescopic attachment provides a self-finding mechanism that facilities insertion of overdenture, which is beneficial for geriatric patients.[1-3] Besides with the use of telescopic attachments, supporting implants receive the major part of masticatory forces, while the residual alveolar ridge receives minimum part of them[25].The retention and the stability of implant overdenture retained by telescopic attachments are directly related to the number of supporting implants, as well as their distribution, and also to the taper of the inner coping's walls[24]. Other than effect of telescopic attachment on retention, it has been reported that it provides better horizontal stability due to its wall design and better load distribution on the abutments due to their circumferential relation to the outer coping.[28,29]

According to design, telescopic attachments can be classified into three taypes; a. parallel, where retention is gained from friction between parallel walls. b. conical, where inner crown has a cone-like shape. So, the axial surfaces are tapered occlusally in a specific angle called the convergence angle (or taper). Retention is gained when outer crown is fully seated (wedging effect). c. hybrid, retentive feature is added to the design (TC-SNAP system) in what called Marburg double-crown system[32,33].

Different configurations have been suggested for placing four implants in edentulous mandible to support mandibular overdenture. Each of which has a specific indications, however this variation will affect not only the peri-implant stresses but also affect retention and stability provided by the overdenture. These configurations are quadrilateral, curved and linear[13]. Quadrilateral configuration requires bilateral placement of two implants in canine area and two implants in molar area, Elsyad et al reported that is the best configuration regarding distribution of peri-implant stresses compared to curved and linear[13]. Curved configuration requires bilateral placement of two implants in canine area and two implants in premolar area, this configuration is chosen for installment of four implants whenever residual ridge resorption at molar area and/ or the position of inferior alveolar nerve canal complicates the placement of posterior implants in molar area[14]. Linear configuration describes the placement of the four dental implants anteriorly in between the two mental foramens, taking advantage of the better bone quality of the anterior mandibular area[26] which results in high rate of implants success rate of ≥95% without the need for further surgical procedures like ridge augmentation[27].

The impact of distribution and number of implants and attachment systems upon retention and stability of overdentures has been investigated in several studies[13-16] however the effect of different distributions of four implants in mandibular over denture retained by telescopic attachment has not been investigated before.

The aim of this in vitro study was to provide an evaluation of retention and stability of four implant supported mandibular overdentures based on implant location. Null hypothesis of this research, that there will be no significant difference between different configurations of four implants supporting mandibular overdenture retained by telescopic attachment.

MATERIALS AND METHODS:

In this study three study models were made from heat cured acrylic resin (Lucitone 199, Dentsply, USA.) duplicated from a standard stone model of edentulous mandible in the usual manner. Each of the models will receive four implants (Spectra System screw implant, Implant Direct), for each model trial denture base was made to define the exact place for implants defining them fig.1 into:

- Study model A; represent the "quadrilateral configuration" where, two implants in canine and two implants in first molar areas.[13,22]
- Study model B; represent "curved configuration" where, two implants in canine and two implants at second premolar.[13,14,16]
- Study model C; represent "linear configuration" where, two implants at lateral incisor and first premolar areas.[13,14]

Auto polymerizing resilient liner (soft liner, pro-medica) had been used to make layer of 2-mm thickness simulating the oral mucosa covering the edentulous ridge. For each study model five experimental overdentures were made without teeth (acrylic blocks) with four metal hooks projecting from the occlusal surface of the block at the site of canine and second molar bilaterally fig.2, this number of sample size was selected based on a previous study in which the authors used a similar study design[3].

The telescopic attachment for implant consisted of a conical abutment (spectra system screwplant; code8035-22, collar height 2 mm, chamfer finish line 0.5mm, taper 6°, height 6mm, platform diameter 3.5mm) screwed to the implant fixture and a readymade plastic coping (spectra system screwplant; code3047-28) that fits the dimensions of the abutment that was invested and casted into nickel chromium alloy with investment casting technique and attached to the acrylic block via in-lab pick-up with auto polymerizing acrylic resin. fig.2 An acrylic bar projection was constructed at the base of the test model and oriented anteroposteriorly across the center of the cast to fix the model to the base of the universal testing machine.

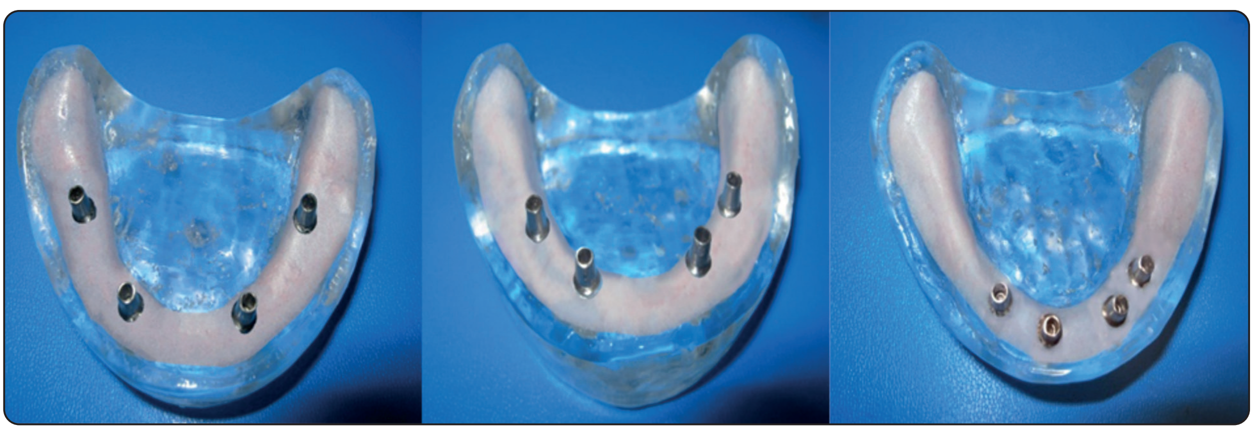

Fig. (1) Model A, B and C respectively.

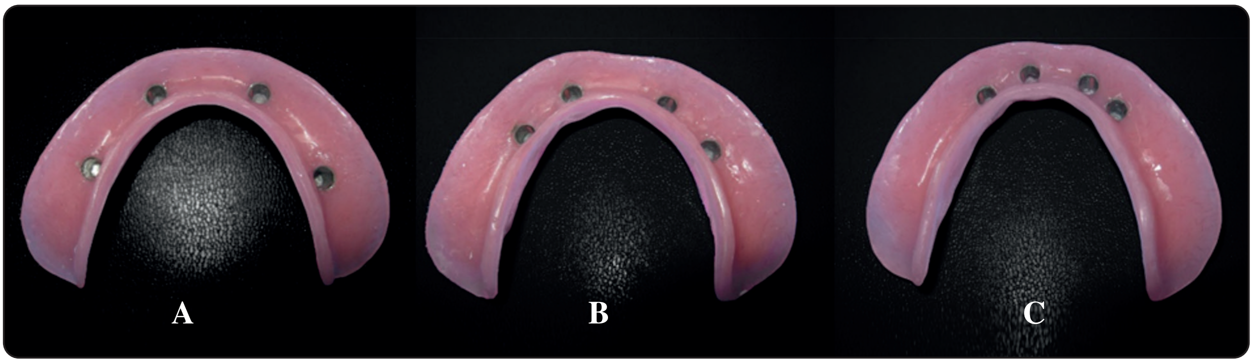

Fig. (2) Acrylic blocks of models A, B and C.

For each metal loop of the overdenture 15-cm metal chain was made to be used in testing. A 5 × 5-cm metal plate with four tapped holes was attached to the end of the chains by adjustable screws. The plate then was connected to the head of a universal testing machine (LLOYD LRX, LLOYD instruments) by a metal chain that is screwed to the center of the plate. The four chains were adjusted by tightening the screws connected to the plate before each measurement to reduce slack to a minimum. Fig.3

For testing, the occlusal plane of the test model was set even with the horizontal plane of the metal plate of the testing machine. The testing machine was calibrated and balanced using a computer algorithm to account for the weight of the simulated prosthesis and chains. The universal testing machine was used to apply vertically oriented four-point tensile loads on the metal plate until the attachments separated from the abutments. The Testing machine was set at a constant crosshead speed of 50 mm/min to approximate the speed of the movement of the denture away from the ridge during mastication. The maximum load needed to dislodge the experimental overdenture in Newtons (N) from the mandibular test model was calculated and displacing forces were applied to perform directional pull-test.

Measurement of Retention:

For application of vertical (axial) displacement force, the four chains were hooked to the acrylic block. The universal testing machine was used to apply vertically oriented four-point tensile loads on the metal plate until the attachments separated from the abutments then the retentive force was calculated. Fig. 4

Fig. (3) Four chains and metal plate that was connected to the testing machine to apply different displacement forces.

Fig. (4) Four hooks are connected to chains for measurement of retention.

Measurement of Stability:

For application of oblique (non-axial) displacement force, three types of oblique displacement were made to test overdenture stability; a. lateral displacement; two chains were hooked to the metal loops in the right side only with the two left loops free so that force was applied in left direction to measure lateral stability. b. anterior displacement; two chains were hooked to the two anterior loops only and the posterior ones free. The force was applied in posterior direction to measure anterior stability. c. posterior displacement; two chains were hooked to the posterior loops only and the anterior ones free. The force was applied in anterior direction to measure posterior stability. The two-point vertical force needed to dislodge the housing was recorded (in N) as an oblique directed retentive force. Fig. 5

Five measurements were performed for all types of displacements with each study model and the mean of the recordings was calculated.

Statistical analysis:

The data were analyzed with prism 10.2.0 software. a one-way ANOVA was used to evaluate the peak loads for the vertical displacement forces to evaluate retention while, two-way ANOVA was used to evaluate the peak loads for the lateral, anterior and posterior directed displacement forces separately for the three A, B and C models. In addition, homogeneity of variances showed that the three groups were the same ($P>0.05$). Thus, Tukey's HSD test was used for paired comparison of the three groups. The results were reported with a 95% confidence interval.

RESULTS

Regarding retention, comparing between models in the resistance to vertical displacement achieved by overdentures was made by one way ANOVA, which revealed that there was a significant difference between the three configurations ($P<0.05$). Quadrilateral configuration (model A) recorded the highest mean force needed for vertical displacement 97.83±0.797 N followed by curved configuration (model B) 86.95±1.313 N, then linear configuration (model C) which recorded the least resistance to vertical displacement 80.46±0.608 N. Multiple comparisons by Tukey`s test also revealed a significant difference in between pairs of groups as presented in Table 1 & Fig. 6

Regarding stability, comparing between models in resistance to oblique displacements achieved by overdentures was made by two way ANOVA, which revealed that, there were statistically significant differences between the three configurations during all oblique displacements ($P<0.05$) where,

Fig. (5): Application of displacement forces, lateral, posterior and anterior respectively.

Table (1): comparison of implant configurations regarding retention.

	Model A	Model B	Model C	F value	ANOVA P value	Tukey`s test
Vertical Displacement	97.83±0.797	86.95±1.313	80.46±0.608	327.9	0.00*	A B C

p<0.05 is significant. Different Upper case letters indicate significant difference between groups

- In lateral displacement; quadrilateral configuration (model A) recorded the highest mean force resistance 57.68±0.734 N followed by curved configuration (model B) 53.51±0.518 N, then linear configuration (model C) which recorded the least mean force resistance to lateral displacement 47.67±0.893 N.
- In posterior displacement; linear configuration (model C) recorded the highest mean force resistance 70.43±0.858 N followed by curved configuration (model B) 64.81±0.739 N, then quadrilateral configuration (model A) which recorded the least mean force resistance to posterior displacement 51.33±0.584 N.
- In anterior displacement; quadrilateral configuration (model A) recorded the highest mean force resistance 47.16±0.905N followed by curved configuration (model B) 42.45±0.582N, then linear configuration (model C) which recorded the least mean force resistance to lateral displacement 39.31±1.411N.

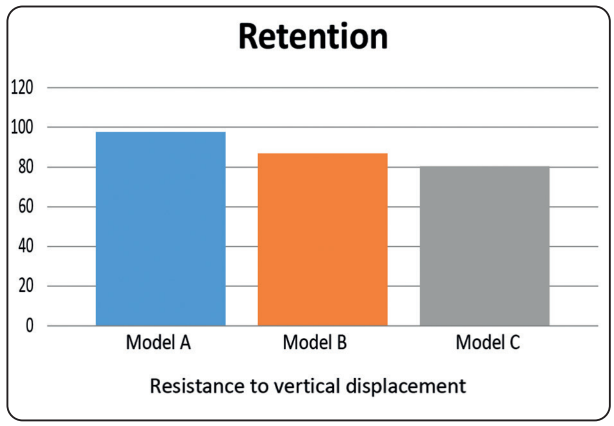

Fig. (6) Mean differences of retention between the implant configurations.

Multiple comparisons made by Tukey`s test revealed that there were significant differences between pairs of groups during oblique displacements as well as presented in table 2 & Fig. 7

Table (2): comparison of implant configurations regarding stability.

	Model A	Model B	Model C	F value	ANOVA P value	Tukey`s test
Lateral Displacement	57.68±0.734	53.51±0.518	47.67±0.893	236.2	0.00*	A B C
Posterior Displacement	51.33±0.584	64.81±0.739	70.43±0.858	891.2	0.00*	A B C
Anterior Displacement	47.16±0.905	42.45±0.582	39.31±1.411	74.35	0.00*	A B C

p<0.05 is significant. Different Upper case letters indicate significant difference between groups

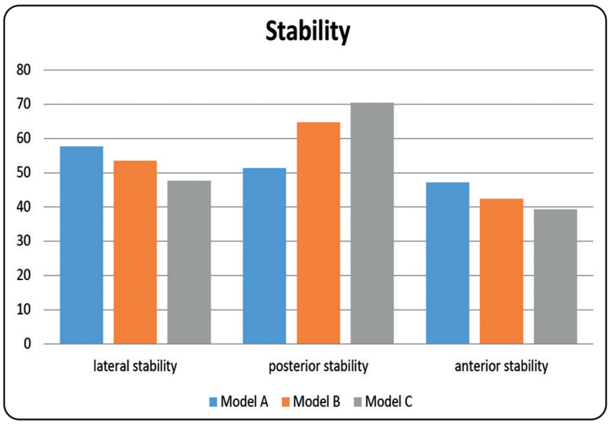

Fig. (7) Mean differences of stability in different directions in implant configurations.

DISCUSSION

In this in vitro study, an attempt was made to identify the best configuration of four implants in edentulous mandibular arch so that telescopic implant overdenture can achieve the best retention and stability by resistance to axial and non-axial displacement forces.

Decision for implant placement has many affecting factors, such as the type and location of implants placed, quality and quantity of bone, and type of superstructure. However, Clinicians mainly consider expected retentive qualities in the selection of implant location and attachment system. So studies are made in order to evaluate the effect of implants` distribution on the retention and stability of implant overdenture.[16, 21]

Biomechanically, quadrilateral configuration by placing two implants at canine area and two implants at the molar area making the removable implant prosthesis similar to that of fixed prosthesis by combining the stability and masticatory performance of fixed prosthesis with hygiene, esthetics and low expense of Overdenture. 12 Placement of two anterior Implants in the canine area and two additional implants in the second premolar position in what called curved configutation, was reported to keep the cantilever in statically favorable length and to make the overdenture totally implant retained over the whole area of function[13,14]. Several authors stated that linear configuration by placement of four implants in the interforaminal region provides for low risk insertion of osseous implants and long term success of the implants due to compact bone structure of this area and no danger of nerve damage [13,14]

Many researches stated that telescopic attachment provide high level of patient satisfaction as well as favorable distribution of forces[8] along with maintaining peri-iplant tissue health[9]. It was reported that rehabilitation of the edentulous mandible with telescopic overdenture supported by four parallel implants provides a unique biomechanical advantage that is the cross-arch stabilization[5].

In order to evaluate overdenture`s retention and stability, all displacement forces have to be measured. As the overdenture moves in various directions during mastication, it was reported that these movements are complex and in order to facilitate their assessment, they should be broken down into four directions of vertical (for evaluation of retention), lateral, anterior and posterior (for evaluation of stability). [1,3,14] Besides, it was mentioned that it's better to investigate the effective factors on retention separately with the least effect from the surrounding variables.[19,20] so this study was made in vitro in order to evaluate resistance to each directional displacing force with directional pull-test[16,34]

Comparing the results of applying different displacement forces on the three models of implant configurations, regarding retention; quadrilateral configuration showed the highest resistance to vertical displacement force. This can be attributed to the fact that by placing posterior implants distally creates a longer resistance arm against displacement, so more power would be required to remove the overdenture which is in accordance with Scherer et al[16]

Regarding stability, during the three different pattern of displacement, quadrilateral configuration showed the highest resistance to lateral and anterior displacements followed by curved then linear configurations this is in agreement with studies[14-16] concluded that wide distribution of the four implant with distal placement of the posterior improves ovendenture`s lateral stability. In anterior displacement more distal placement of the posterior implants makes a class III lever where the resistance arm is much longer than the force arm resisting the anterior rotation of the overdenture.

During posterior displacement linear configuration showed the highest resistance to displacement followed by curved then the least was quadrilateral. This is not in accordance with Alshenaiber et al[14] who reported in his study that close distribution of the implants in four implants supporting mandibular overdenture decrease the resistance to posterior displacement. However telescopic attachment seemed to justify why linear configuration had the highest resistance as Scherer et al[16] mentioned in his study that, moderate or non-resilient attachments in four anteriorly placed implants act as one unit against posterior displacement.

There were some limitations to this in vitro study that did not completely replicate clinical situations as the implant overdenture clinical reality is much more complex. Further clinical studies must be considered to include more factors such as, residual ridge resorption over time and effect of forces by lips, cheeks and tongue on ovedenture displacement. Moreover, the study did not include an opposing arch, which clinically plays a role in denture stability.

CONCLUSION

Within the limitations of this study, it was concluded that:

- Quadrilateral configuration of four implants (model A) provided the highest retention (resistance to vertical displacement) for mandibular telescopic implant overdenture.
- Quadrilateral configuration of four implants (model A) provided the highest lateral and anterior stability (resistance to lateral and anterior displacement) for mandibular telescopic implant overdenture.
- Linear configuration of four implants (model C) provided the highest posterior stability (resistance to posterior displacement) for mandibular telescopic implant overdenture.

Future long-term comparative prospective controlled studies are recommended to evaluate the other involved clinical factors that will be involved in the choice of the appropriate treatment concept.

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