ORIGINAL RESEARCH

Comparison between Two Design Concepts of Four Implants Placement Used to Support Telescopic Mandibular Overdenture: A Prospective Study of Implant Marginal Bone Height Changes

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Abstract

Aim: The aim of this present study was to compare two placement designs of four implants used to support a telescopic mandibular overdenture regarding the marginal bone height changes.

Materials and methods: Each patient received four implants. Two anterior implants were installed vertically in the canine area. Patients were randomized into two groups according to the direction of posterior implants installed in the premolar area. Group I: where the implants were installed vertically parallel to the anterior implants and group II: where the implants were installed 30° distally. The implants were delayed loaded with a telescopic mandibular overdenture. The implant's marginal bone changes were evaluated after 6 and 12 months of overdenture insertion.

Results: Mean marginal bone loss of anterior implants showed a statistically significant difference between both groups. The vertically parallel posterior implants in group I showed statistically significant higher marginal bone loss than posterior implants in group II after follow-up periods. The 30° distally tilted posterior implants maintained the implant marginal bone after 12 months of overdenture insertion.

Conclusion: Rehabilitation of the edentulous mandible with telescopic overdenture supported by four parallel implants is a promising successful treatment option.

Clinical significance: Tilting the posterior implants will improve the anteroposterior spread that in turn increases the support and the survival rate of the implants. Also, using this technique gives us an opportunity to use fewer implants.

Keywords: Implant, Inclined, Overdenture, Radiograph, Telescopic.

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Introduction

Four implant-supported overdentures could be considered a common treatment plan that could maintain the supporting tissues.[1] The quadrilateral distribution of the four implants, especially those with rigid connections, showed minimal strain compared with curved or linear designs.[2] One particular treatment option is devised and marketed as the All-On-Four concept (Nobel Biocare, Goteborg, Sweden). Maló and colleagues should be credited with the first description of this concept in 2003.[3] The principle of the All-On-Four concept strives to use four implants in the anterior part of complete edentulous jaws to support a prosthesis. The two most anterior implants are placed axially, whereas the two posterior implants are placed distally angled to minimize the cantilever length.[4] It was claimed that tilting the posterior implants by 25–35° will shorten the average lengths of the cantilever and allow for placement of a longer implant that increases the implant's primary stability. Also, it increases the inter-implant space that leads to better load distribution.[5] In a study carried out by Hinze et al.,[6] in 47 patients who underwent treatment with either mandibular or maxillary prostheses supported by two axially inclined and two tilted implants, the 1-year implant survival rates were 96.0% for axially positioned implants and 94.6% for tilted fixations; so that no significant differences were encountered among both types of implants. The combined use of axially placed and tilted implants represents another possible alternative for the treatment of edentulous jaws, which has been extensively documented in recent years.[7] It was found that rigid implant attachments such as bar and telescopic crowns present a rigid anchorage system between the implant and the overdenture and do not need to be held on soft tissues.[8] According to Eitner et al.,[9] it has been suggested that the use of single-attachment systems may provide for better hygienic than connected constructions. 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. However, tilting the posterior implants 30° distally may present additional biomechanical advantages regarding the more

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anteroposterior spread and better stress distribution over a longer area covered by the prosthetic superstructure. So, the purpose of this study was to compare between axial and tilted posterior implant placement for mandibular overdentures supported by four implants with telescopic attachments regarding the implant marginal bone height changes. The null hypothesis was that no difference could be expected.

Materials and Methods

This study is an open-label, single-blinded randomized controlled trial. Permuted blocking randomizing was conducted in block size of two with an allocation ratio of 1:1. The randomization roster was kept with the nurse at the admission office. Concealment of allocation is done as participants were not aware of the group they were assigned to.

Sample-size Calculation

Marginal bone loss in the first year should be in the range of 1–1.5 mm. A mean value of 1 mm was used as the mean value of the control group. We hypothesized that our method would increase the bone mass by 0.2 mm per year. A pooled standard deviation of 0.1 from previous data we have collected in our clinic was used. Independent sample *t*-test in STATA 17 statistical package was used to calculate overall sample size, which yielded a total of 12 patients (six patients per group).

Twelve completely edentulous healthy patients with a mean age of 60 years were randomized to either the control or treatment group. The study was conducted according to the ethical principles stated and approved by the Ethical Committee (No: A12100221) of the Faculty of Dentistry Mansoura University. All patients have sufficient mandibular-restorative space, was at least 15 mm, measured by a tentative jaw relation record.[10] Patients with severe ridge undercuts and bruxism were excluded. Cone beam computer tomography (CBCT)* was done to evaluate the bone quality and quantity and relation of the vital structures to the proposed implant position. A clear acrylic resin radiographic template was duplicated from the mandibular denture. The patients were double-scanned (dual-scan protocol) using CBCT. Based on the CBCT scan, every patient's surgery was virtually planned with the three-dimensional (3D)[†] software to construct an individualized surgical guide (stereolithographic stent)[‡] with four metal sleeves and used to guide the surgical placement of four implants[§] in the interforaminal area. According to the inclination of the posterior implants, the patients were randomized into two groups (six patients per each group) as follows: group I: the two posterior implants were planned to be vertically parallel to the anterior implants and perpendicular to the occlusal plane. Group II: the two posterior implants were planned to be distally tilted forming a 30° angle with the occlusal plane and to the two vertically parallel anterior implants, classification was done by an independent investigator who was not involved in patients' treatment to eliminate any possibilities of selection bias. The implants were confirmed to be safely emerged in the mesial region of the first molar tooth. The fixtures were installed and screwed into their osteotomies at 35 N/cm torque. Postoperative panoramic radiograph was done to verify the implant position. About 1 mm transmucosal height healing abutments were screwed into the fixtures.

Fig. 1: The parallelism was adjusted by the use of a milling surveyor

After 4 months (the osseointegration period), 0° multiunit abutments were screwed into all fixtures in group I and the anterior fixtures in group II. And 30° multiunit abutments were screwed into the posterior implants in group II to be aligned vertically parallel to the anterior implants to allow the long transfer copings to be parallel to each other during transfer impression. An autopolymerized acrylic resin** custom tray was perforated over each abutment and was used to record the final regular body rubber base impression.[††] A scalpel was used to remove the impression material from the perforations over each implant. Long transfer copings were screwed into the multiunit abutments and the tray was reinserted intraorally to inject a light-body rubber base around the copings. Autopolymerized acrylic resin was used to splint the transfer copings. The multiunit abutments were unscrewed from the patient's mouth and screwed into the implant-level analogs. The multiunit abutments with the analogs were connected to the transfer copings. The impression was poured to construct the master cast.

The multiunit abutments were unscrewed from the master cast and UCLA Ti-based plastic abutments[‡‡] were screwed into the implant analogs. About 4–6 mm height primary screw-retained telescopic abutments were fabricated in the same occlusal plane. The surveyor was used to confirm accurate parallelism between the four abutments and to prepare a 7° taper at the occlusal third (Fig. 1). The primary copings were tried in the mouth (Fig. 2). For the fabrication of the secondary coping, the primary copings on the cast were scanned to design and fabricate the secondary copings and the framework that connects the four outer copings using computer-aided design/computer aided manufacturing (CAD/CAM) technology. The primary copings were screwed into the fixtures in the mouth to try-in the secondary copings the passive fit of the outer copings (Fig. 3). Jaw relation was recorded. After try-in, processing into heat-cured acrylic resin was done (Fig. 4). Passive insertion and removal of the mandibular overdenture were checked in, and occlusal adjustment was done. The denture was delivered and the patient was instructed on proper oral hygiene and periodic follow-up.

*I-CAT next generation CBCT machine; Imaging Sciences Company, Pennsylvania, USA.
†OnDemand 3D software, Cybermed Company, Daejeon, Korea.
‡Object30 pro 3D printer, Stratasys Company, California, USA.
§Neobiotech implants, Neobiotech Company, Seoul, Korea.
**Self-cure acrylic resin, Acrostone Manufacturing and Import Company, Cairo, Egypt.
††Addition silicone impression material, Meta bio-med Company, Cheongju-si, Korea.
‡‡UCLA Ti-base abutment, Neobiotech Company, Seoul, Korea.

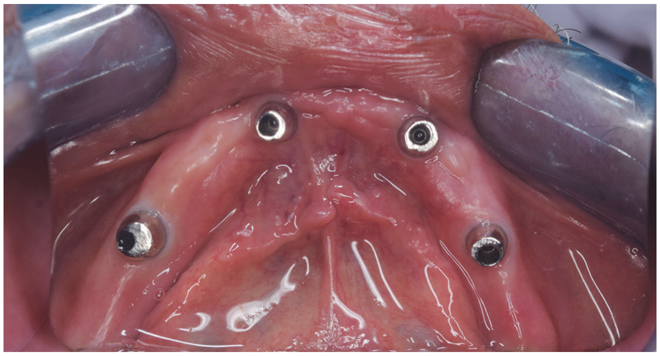

Fig. 2: The primary coping was tried in the patient mouth

Fig. 3: Tryin of the secondary copings and metal framework for group I

Fig. 4: Fitting surface of the finished denture

Evaluation

A standardized long-cone paralleling technique and a film holder designed specifically for implant imaging[§§] were used for intraoral radiographs. Subsequently, reference lines and points were marked using a software program. Detect magnification errors by comparing the implant dimensions in the radiographs with the actual implant dimensions. The peri-implant bone height changes were measured mesially and distally. Measurements were done immediately (T0), 6(T6), and 12(T12) months after denture insertion.

Statistical Analysis

The SPSS Statistical Package for Social Science Version 25*** was used for data analysis. Shapiro–Wilk test was used to assess whether the distribution of our data followed a normal distribution, we created histograms using a bin width of 0.5 and visually inspected the shape and symmetry of the distribution. The data were parametric and normally distributed. Descriptive statistics were performed in terms of mean and standard deviation. Comparison between observation times (T6 and T12) was made using paired-samples *t*-test. Independent samples *t*-test was used to compare bone loss between groups and implant positions (canine ad premolar implants). *P* is significant if <0.05 at a confidence interval of 95%.

Results

After intragroup comparison of bone loss, it was found that the posterior implant marginal bone loss was statistically significant after T6 and T12, $p = 0.001$ for group I and $p = 0.001$ for group II. The mean marginal bone loss was 0.517 ± 0.063 mm for group I and 0.208 ± 0.014 mm for group II after 6 months. After 12 months, the mean was 0.783 ± 0.076 mm for group I and 0.450 ± 0.010 mm for group II (Table 1).

The same results were observed for anterior implants $p = 0.001$ for group I and $p = 0.002$ for group II. From T6 to T12, group I recorded statistically significant higher bone loss than group II ($p = 0.001$ for T6, $p = 0.002$ for T12 for posterior implants, $p = 0.016$ for T6, and $p = 0.006$ for T12 for anterior implants). The mean bone loss for anterior implants after 6 months was 0.383 ± 0.052 mm for group I and 0.250 ± 0.025 mm for group II, and after 12 months was 0.641 ± 0.057 mm for group I and 0.441 ± 0.028 mm for group II (Table 2).

Discussion

Tilting the posterior implants 30° distally may present additional biomechanical advantages regarding the more anteroposterior spread and better stress distribution over a longer area covered by the prosthetic superstructure also allowed for placement of a longer implant that increases the implant's primary stability.

Patients were selected of class I maxillomandibular relations to minimize the harmful stresses transmitted to the implant by classes II and III.[11] In this study, the interarch distance was not less than 15 mm at the interforaminal area so that enough space for placement of the implant attachments and the superstructures was provided. Misch[11] assured that (15 mm) there is sufficient interarch space between soft tissue of the mandibular ridge and the occlusal plane for the setting of denture teeth without modification, providing room for attachments, and providing adequate bulk of acrylic resin to resist fracture. In this study, the canine areas were selected for the location of anterior implant installation. This was in accordance with Misch,[11] who reported that the canine region was selected to place two anterior-splinted implants that could allow proper distance between the centers of implants (24–26 mm). Stereolithographic surgical stent was used to allow accurate 3D placement of the implants in the planned implant position.[12] The one-stage flapless surgical technique was used in this study for implant insertion. The advantages of flapless surgical techniques have been demonstrated

[§§]X-Ray Film Holding Set, Alwings Medical Instrument Company, Shanghai, China.

***SPSS Inc., Chicago, Illinois, USA.

Table 1: Comparison of bone loss (in mm) of both groups at different observation times for posterior implants

	6 months after overdenture insertion (T6)		*12 months after overdenture insertion (T12)*		
	X	*SD*	*X*	*SD*	*Paired samples t-test (p-value)*
Group I	0.517	0.063	0.783	0.076	0.001*
Group II	0.208	0.014	0.450	0.010	0.001*
Independent samples *t*-test (*p*-value)	0.001*		0.002*		

X, mean; SD, standard deviation; **p*-value is significant at 5%

Table 2: Comparison of bone loss (in mm) of both groups at different observation times for anterior implants

	6 months after overdenture insertion (T6)		*12 months after overdenture insertion (T12)*		
	X	*SD*	*X*	*SD*	*Paired samples t-test (p-value)*
Group I	0.383	0.052	0.641	0.057	0.001*
Group II	0.250	0.025	0.441	0.028	0.002*
Independent samples *t*-test (*p*-value)	0.016*		0.006*		

X, mean; SD, standard deviation; **p*-value is significant at 5%

by Campelo and Camara.[13] These advantages were: the elimination of a surgically raised flap with exposure of the underlying bone to place the implant, the increase of patient acceptance and comfort, and the loss of soft tissues was decreased as they heal faster with minimal degrees of complications. Furthermore, they include reduced swelling, pain, and reduced surgical procedure time. Admittedly, the conventional surgical protocol that involves incision and flap reflection may cause crestal bone loss and is accompanied by discomfort, tenderness, and swelling.[14] Cone beam computer tomography provides 3D images and consequently additional information in comparison to the two-dimensional periapical radiographs.[15] Cross-sectional images obtained using CBCT allow visualization of the bucco-lingual bone surrounding dental implants.[12] Angular positioning of a marginal implant is one of the ways to reduce the influence of the cantilever on the peri-implant bone that shortens the cantilever as mentioned by Varinauskas and Diliūnas[16] and Khatami and Smith[17] In this study, an open-tray impression technique using a regular and light-body rubber base impression is used to record the positions of the implants and the soft tissues. This step is one of the most important factors that help in achieving a passive fit between implants and the prosthesis by reproducing the 3D relationship of implants through impression procedures. Regarding the study,[18,19] results on the accuracy of different impression techniques, open-tray pickup technique is the more precise and predictable one and is recommended when there are several nonparallel alignment implants because the difficulty in the repositioning techniques to remove the impression out of the transfer copings and also the abutment transfer copings was splinted with self-cure acrylic resin to avoid any micromovement of the copings during pick-up procedures.[20–22]

The implant marginal bone loss increased significantly after 12 months compared with the bone loss after 6 months for both groups. This might be due to the immediate bone response to healing and reorganization combined with functional stresses as stated by Elsyad et al. and Hohlweg-Majert et al.[23,24] The initial marginal bone-level change occurs as a result of adaptation of the peri-implant bone to the occlusal load.[25]

According to Albrektsson et al.,[26] in the first year, the marginal bone loss should be in the range of 1–1.5 mm, and the annual bone loss should not be more than 0.2 mm. In this study, the mean bone loss for anterior implants after 6 months was 0.383 ± 0.052 mm for group I and 0.250 ± 0.025 mm for group II, and after 12 months was 0.641 ± 0.057 mm for group I and 0.441 ± 0.028 mm for group II. For the posterior implants, the mean marginal bone loss was 0.517 ± 0.063 mm for group I and 0.208 ± 0.014 mm for group II after 6 months. After 12 months, the mean was 0.783 ± 0.076 mm for group I and 0.450 ± 0.010 mm for group II. All values of implant marginal bone loss in this study could be recognized as being acceptable, according to Albrektsson et al.[26]

From T6 to T12, group I recorded statistically significant higher bone loss than group II for all implants. This finding was in agreement with the study,[2] which noted that high strain values were recorded with the curved design (the implants in group I were placed at canine and second premolar areas). This may be attributed to the cantilever action of the denture saddles caused by mucosal resiliency when the occlusal load was applied. Therefore, a situation similar to a class I lever in mechanics is created, where the distal-most implants act as a fulcrum. Such implants counteract the free overdenture rotation during posterior loading and increase the chance of implant overloading.[2] On the other hand, several studies[2,27–29] showed a minimal peri-implant strain when the implants were placed in a quadrilateral design (the implants in group II were placed at canine and first-molar areas) compared with curved design in group I, this finding could be attributed to the wide distribution of forces over a square area, involving more planes, and to the favorable support achieved with the quadrilateral design.

Bevilacqua et al.[30] added that tilting the posterior implants will improve the anteroposterior distribution of the implants supporting a prosthesis, which might reduce the stresses. Krekmanov et al.[31] claimed that tilting the posterior implants, which support a prosthesis by 25–35° will shorten the average lengths of the cantilevered part of the denture and also allow for placement of longer implants. Zampelis et al.[32] demonstrated that the inclusion of cantilever units results in higher stress in the marginal bone around the distal axial implant cervix. This may be due to the rotation momentum generated when applying the occlusal force directly onto the cantilever.

Our study has several strengths, first "to our knowledge", it is the first study to assess the potential role of tilting the posterior implants in quadrilateral-supported telescopic overdenture in enhancement of bone loss after 1 year, and also, our study design was a randomized control trial to ascertain elimination of potential confounders between the two groups. We did our best to maintain the internal validity of the study design by randomization blinding and allocation concealment. However, our study has several limitations, first, it was not a double-blinded randomized control trial because we could not blind the performing surgeons to the treatment group the patients were assigned to, however, this was less likely to affect our results as the patient themselves did not know to which treatment group they were assigned to, and the assessments was performed by an independent investigator who was not involved in patients' treatment and was not aware of the aim of our study, also, this study included only 12 patients, which is relatively low, however, this relatively low number of patients yielded a statistically significant difference between the treatment groups showing a promising treatment option for such patients. Our study results were only valid to the Egyptian populations, and we are not sure that the data are still externally valid to another population, so further studies were needed to insure such external validity. However, the internal validity of our study was kept at the best we could do.

Conclusion

Within the limitations of this study, it could be concluded that rehabilitation of the edentulous mandible with telescopic overdenture supported by four parallel implants could be considered a successful treatment option. However, 30° distally tilted posterior implants maintained the implant marginal bone after 12 months of overdenture insertion compared with vertically parallel posterior implants. We recommend performing several studies with such methods on large treatment groups in different countries.

Clinical Significance

Tilting the posterior implants will improve the anteroposterior spread that in turn increases the support and the survival rate of the implants, also using this technique gives us an opportunity to use fewer implants.

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