10.21608/adjc.2023.212712.1321 Advanced Dental Journal
Volume 5 (2023) | Issue 4| Pages 723 - 733

Original Article

Peri-Implant Marginal Bone Height Change and Patient's Satisfaction Rehabilitated with Ball and OT Equator with Smart box Attachment for Retaining Mandibular Implant Overdenture

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Submitted: 30-5-2023
Accepted: 4-9-2023

Abstract

The purpose*:* This study evaluated the amount of peri-implant bone height change and patient satisfaction with two attachments (OT equator with smart box and Ball and socket) for retaining mandibular implant overdenture.

Material and methods*:* From the outpatient clinic of the prosthodontic department, Faculty of Dentistry, October 6 University, fourteen male patients with edentulous mandibular and maxillary ridges aged between 50 to 65 years were selected to participate in this study. Each patient received two implants placed bilaterally in the canine regions with adivergence angle of 10 degrees. According to the type of attachment, the patients were divided into two groups, Group I: an OT equator with a smart box attachment (OT) was used. Group II, ball and socket attachments (BS) were used. The parallel technique (Digora software) was used to assess the amount of vertical bone height changes throughout the follow–up period (0, 3, 6, and 12 months). The patient's subjective evaluation of satisfaction using a questionnaire based on the VAS includes speech, chewing, comfort, aesthetics, oral hygiene, and general satisfaction was recorded. The data were collected and statistically analyzed.

Results: Comparison between different groups was performed by using the Independent t-test. In contrast, a comparison between different intervals was performed using the One-Way ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons. Regarding qualitative data, all comparisons were performed by using the Chi-square test.

Conclusion: Within the limitation of this study, an OT equator with smart box attachment is preferable to ball and socket attachment systems in rehabilitating nonparallel implants up to 10 degrees inter-implant divergence angle.

Recommendation: Evaluation with greater angles is recommended

Keywords: OT equator with smart box attachment, ball and socket attachments, nonparallel implants, overdenture.

I. INTRODUCTION

Implants are regularly used nowadays to restore missing teeth or stabilize, retain, or support dentures [1]. In the maxilla and mandible, implant-retained overdentures are an effective alternative to fixed implant prostheses. The most extensive improvement for improving patient satisfaction and the outcomes of mandibular implant overdenture treatment is thought to be increasing retention and stability of the prosthesis [2].

To ensure enough thickness for the restorative material, room for the retentive elements, aesthetics, and cleanability during rehabilitating the edentulous arch, a specific amount of vertical space between the opposing arches is necessary. For an implant-retained overdenture, 12 to 14 mm of inter-arch space must exist between the implant shoulder and the incisal edge. Above the implant, soft tissue typically has a thickness of two to three millimeters [3]. It was frequently argued that resilient retention mechanisms should be used to disperse tissue and implant support for overdentures [4].

Even though implant placements in implant-retained overdentures should be perpendicular to the occlusal plane, parallel to each other, and in the path of prosthesis insertion, the procedure is limited by the bone quality, anatomical structure, and clinical practice, all of which tend to cause implant inclination towards the ideal path of insertion [5].

An overdenture is subjected to several forces in various directions during oral function. Depending on the type of attachment used and the variations in the stress distribution around implants under occlusal loading, lateral forces will develop around the attachment assemblies and implant when attachment systems are utilized to apply retentive forces to resist withdrawal along the path of insertion and stabilize the overdenture during function. The excessive lateral force applied to an implant would increase the mechanical risk, including attachment assembly wear or fracture. It would also put more stress on the surrounding bone, which could contribute to increased vertical bone loss [6]. While such angulated implants are exposed to lateral forces, they cause the implant and the surrounding bone to undergo excessive stress [7, 8]. An ideal attachment mechanism should deliver a greater retentive force with a reduced lateral force to the implant during repeated dislodging. Consequently, our working assumption is that alternative designs of unsplinted anchorage attachments for implant-retained overdentures will impact the retentive and lateral forces of the implant inclination [9]. When prosthetic space is limited, and stress distribution is necessary to improve implant serviceability, using a low-profile attachment like the OT Equator proved to be a more practical choice [10]. The OT Equator®Smart Box is a housing made of titanium for retentive caps. It has a creative design enables passive cap insertion even in extreme divergence conditions up to 50 degrees, owing to a tilting mechanism with a pivoting fulcrum. The direct OT Equator attachment is compatible with the Smartbox. The gingival heights for the OT equator range from 0.5mm to 7.0mm, with various implant platforms [11].

The most often used overdentures have a ball attachment (O-ring attachment), which has a ball shape for retention. Its benefits include an uncomplicated manufacturing process, a wide range of movement provided, cost-effectiveness, simplicity of use and maintenance, provision of good retention, preservation of hygiene, and high patient satisfaction [12]. However, the ball attachment abutment necessitates parallel implants, and if parallelism is lost, it may be difficult to insert and remove the prosthesis or to fracture the abutment. The O-ring must also be replaced because it will eventually wear out [13, 14].

This study assessed the effects of the OT Equator with Smart Box and Ball and Socket attachments on crestal bone height changes in implant-retained mandibular overdentures and patient satisfaction.

II. MATERIALS AND METHODS

The Faculty of Dentistry at October 6 University discussed the research and follow-up procedures with patients for the written agreement by the ethical committee's rules. The ethics committee gave its approval to the study's design. Each subject received instructions on the study procedure prior to participating, had the chance to ask questions about it, and was given the option to accept or refuse taking part in the study. Informed consent was obtained from all participants. Sample size calculation was performed using G*Power version 3.1.9.7[15]. Based on the results of a previous study [16]. A power analysis was designed to have adequate power to apply a two-sided statistical test to reject the null hypothesis that there is no difference between groups. By adopting an alpha level of (0.05) and a beta of (0.2), i.e. power = 80% and an effect size (d) of (1.70) calculated based on the results of a previous study. The predicted sample size (n) was (14), i.e., 7 samples per group. To detect for different measurements between groups.

A total of fourteen male patients aged 50 to 65 years were chosen to participate in this study. To be considered, all patients had to meet the following criteria: maxillary and mandibular arches that are completely devoid of teeth; enough bone volume in the anterior mandible to support two implants; good oral hygiene; enough inter-arch space; and an angle Class-I maxillo-mandibular relationship; Exclusion criteria included: having a systemic condition that is uncontrolled and could endanger implant surgery, such as diabetes, hypertension, or cardiovascular disease (hemoglobin A1c > 7.0%); having had head-and-neck chemotherapy or radiography in the past; using bisphosphonates in the past; smoking heavily (more than 20 cigarettes per day); having an infectious disease present at the same time; and having any temporomandibular joint disorders.

a. *Prosthetic procedures:*

The same technique was used to create complete dentures for all 14 patients before implant placement. Alginate (Alginmax, Major Prodotti, Dentari SPA, Moncalieri, Italy) was used to make upper and lower primary impressions in stock trays for each patient, and medium-body rubber base (Swiss TEC, Coltene, Whaledent, Altstatten, Switzerland) were used to make upper and bottom secondary impressions. Construction of the occlusion blocks was done using the poured master casts. The centric-occluding relation was recorded using the traditional wax wafer method.

The lower casts were placed using a wax wafer-centric occluding record. In contrast, on a semi-adjustable articulator, the top casts were mounted using a Dentatus face bow record

(Dentatus face bow, Dentatus, Stockholm, Sweden). The artificial teeth (Acrostone, Egypt) were developed using lingualized occlusion. Before it was flasked and transformed into high-impact heat-cure acrylic resin (Lucitone 199, Dentsply, York, PA, USA), the patient tried a waxed-up denture in their mouth. Laboratory remounting and occlusal inconsistencies were fixed before the denture was finished.

After making any required changes to remove occlusal interference, the denture was given to the patient. After twenty-four and seventy-two hours, it was examined to see if any revisions were required and whether the patient was happy with the denture's appearance, stability, and retention. After the mandibular denture was put in place and the patient had gotten used to it, a copy of it was made in clear acrylic resin (Vertex Rapid Simplified; Vertex-Dental BV, Zeist, The Netherlands), and virtual denture designing was done using dental CAD software called Exocad to create a surgical guide for implant surgery.

b. *Surgical procedure*:

Two implants (Neobiotech Dental Implant, Korea, 3.5 mm in diameter and 10 mm in length) were placed in the inter-foraminal region of each participant using a flapless surgical technique with the aid of a surgical guide (Figure 1). The primary stability was evaluated using the Osstell ISQ (Osstell Mentor Device) system as soon as the implant was in place to ensure it was suitable for the immediate loading procedure.

c. *Patient grouping:*

Depending on the type of attachment utilized, the patients were randomly divided into two groups: Group I received OT equator therapy with a smart box attachment (Rhein 83, Bologna, Italy); the equator attachment has two parts, the male part being as follows: consisting of titanium abutments with a 2 mm height and OT equator titanium. Female component: Made up of a pink soft retaining cap on top of an

anodized smart box housing. Ball and socket attachments were also used to rehabilitate Group II at the same time. Consists of a single straight implant ball abutment for the male. Metal housing with a pink silicone retentive cover on the female part.

Figure (1): Implant placement with the surgical guide

d. Loading protocol:

Following the manufacturer's instructions, the attachment abutments were screwed into the implants as soon as they had been placed. For patients in Group I, the OT equator abutments had to be secured with a torque of at least 30 N cm (figure 2). Using a hex tool, the ball abutment was screwed into the implant (Group II) (Figure 3).

It was demonstrated by radiography of the implant-abutment interface that the abutments were securely seated on the respective implants. The metallic housings and nylon caps were intra-orally incorporated using auto-polymerizing acrylic resin (Acrostone, Acrylic Resin, Egypt) into the fitting surface of the denture after the denture base was adjusted to create place for the newly inserted attachments. The participants were told not to remove their dentures throughout the first week. (figure4a,b and figure 5)

Figure (2): Implants with OT equator

Figure (3): Implants with ball and socket attachment

(a) **(b)**

Figure (4:a,b) Pickup of OT equator housing

Figure (5): Pickup of Ball and socket housing

e. Crestal bone height evaluation:

The evaluation was planned for three, six, nine, and twelve months after the placement of the dentures. Patients visit again at these intervals for a standard satisfaction and functional evaluation of the implant and prosthesis. The digital intraoral radiographs were acquired using the GXS-700 intraoral sensor. The capture was performed using a specially designed jig and the long cone paralleling technique. Customized biting blocks were created utilizing a condensation silicon impression substance that had the consistency of putty.

Serial, standardized periapical radiographs were taken and gathered on the day of loading and at each appointment after that. The bone height was mesial, and distal to each implant abutment was measured using the software ruler's linear measurement method. The GXS-700 was used to conjure a specially created positioning device XCP that is included with the system to obtain digital intraoral radiographic images that are simple to reproduce and well aligned with the x-ray beam. Two horizontal lines were drawn at the implant apex and the alveolar bone crest; the program automatically shows the distances in millimetres between the two lines on the screen. Next, the difference in bone height was calculated using subtraction.

The means of the distal and mesial readings were computed. The software automatically shows the measurements in millimetres on the screen between the two lines. The importance of linear measures was recorded in the patient's chart at each subsequent consultation. This data was used to calculate the mean value of the change in bone height.

f. Patient satisfaction:

Patient satisfaction was measured using a visual analog scale-based questionnaire (VAS). Patients received questionnaires to gauge their satisfaction with their recovery. The questionnaires were given to the patients at each follow-up consultation, scheduled six and twelve months after the denture was placed. The following cut points for the patient satisfaction VAS have been proposed:

The questionnaire was given to the patients in Arabic. The six questions were: 1) How do you generally feel about your prosthesis? 2) How well can you communicate when using a prosthesis? 3) Are you content with your ability to bite or chew? 4) Are you content with the solace and the absence of discomfort when eating? 5) Are you pleased with the way your prosthesis looks? Six factors were rated on a scale of 1 to 5 about hygiene maintenance (very satisfied = 5, satisfied = 4, fair = 3, dissatisfied = 2, and highly dissatisfied = 1.(Participants rated their general satisfaction, speaking, chewing, comfort, retention, and oral hygiene with their dentures using a 100-mm VAS anchored at the extremes left and right with the words "highly dissatisfied" and "highly satisfied," respectively.

g. Statistical analysis:

Two tables with the statistical analysis results were produced using Windows Excel, GraphPad Prism, and SPSS 16® (Statistical Package for Scientific Studies).

Shapiro-Wilk and Kolmogorov-Smirnov tests for normality were used to investigate the provided data, and it was found that all of the data came from a normal distribution (parametric data) that resembled a normal Bell curve.

As a result, for changeable comparisons involving qualitative data, Tukey's post hoc test followed an independent t-test for comparisons between groups and a one-way ANOVA test for comparisons between intervals. The chi-square test was used for all comparisons.

III. Results

3.1. Bone height changes: Within each group:

• Effect of time (Comparison between different intervals):

Table (1): Comparison between the Mean difference and standard deviation of both groups at different intervals in mesial, distal sides, and overall

Side	Interval	N	OT Equator Group		Ball and Socket Group		P value	95% CI	
			MD	SD	MD	SD		L	U
Mesial	**1st 6 months**	9	0.13	0.06	0.58	0.06	<0.0001*	0.39	0.51
	2nd 6 months	9	0.39	0.09	0.45	0.01	0.06	-0.003	0.12
	1st 12 months	9	0.52	0.2	1.03	0.07	<0.0001*	0.36	0.65
Distal	**1st 6 months**	9	0.15	0.03	0.58	0.04	<0.0001*	0.39	0.94
	2nd 6 months	9	0.38	0.19	0.57	0.07	0.01*	0.04	0.33
	1st 12 months	9	0.53	0.19	1.15	0.11	<0.0001*	0.46	0.77
Overall	**1st 6 months**	9	0.14	0.045	0.58	0.05	<0.0001*	0.39	0.48
	2nd 6 months	9	0.385	0.14	0.51	0.06	0.02*	0.01	0.23
	1st 12 months	9	0.525	0.195	1.09	0.11	<0.0001*	0.61	0.72

MD: mean difference
SD: standard deviation
Means with the same superscript letters were insignificantly different as P>0.05
Means with different superscript letters were significantly different as P<0.05

*Significant difference as P< 0.05

The first 6 months were significantly the lowest, while the second 6 months and the first 12 months were significantly the highest in mesial, distal, and overall, as shown in Table (1). In the OT Equator group, there was a significant increase in bone height changes (P< 0.05) using the one-way ANOVA test, followed by Tukey's post hoc test. Tukey's post hoc analysis revealed that the 1st 12 months were significantly the highest on the mesial side and the distal side, and overall, the 1st and 2nd 6 months were significantly the lowest, with an insignificant difference between them. In the ball and socket group, there was a significant increase in bone height changes (P< 0.05) using the one-way ANOVA test, followed by Tukey's post hoc analysis.

3.2. Patient`s satisfaction:

After 6 months, a comparison between both groups revealed an insignificant difference regarding all satisfaction parameters as P>0.05 by using the Chi-square test, while after 12 months, Group I revealed better satisfaction regarding general satisfaction, chewing, and retention as P>0.05, as presented in table (2).

Table (2): Frequency and percentages of different answers regarding patient satisfaction in both groups after 6 months and after 12 months

		After 6 months				After 12 months				
		Group I OT Equator attachment		Group II ball attachment		Group I OT Equator attachment		Group II ball attachment		P value
		N	%	N	%	N	%	N	%	
General satisfaction	High dissatisfied	0	0	0	0	0	0	0	0	------
	Dissatisfied	0	0	2	22.2	0	0	3	33.3	0.06
	Fair	1	11.2	1	11.2	0	0	2	22.2	0.16
	Satisfied	3	33.3	3	33.3	3	33.4	4	44.5	0.64
	High satisfied	5	55.5	3	33.3	6	66.6	0	0	0.003*
Speech	High dissatisfied	0	0	0	0	0	0	0	0	------
	Dissatisfied	0	0	0	0	0	0	0	0	------
	Fair	1	11.2	1	11.2	1	11.1	1	11.1	1.00
	Satisfied	2	22.2	2	22.2	1	11.1	1	11.1	1.00
	High satisfied	6	66.6	6	66.6	7	77.8	7	77.8	1.00
Chewing	High dissatisfied	0	0	0	0	0	0	0	0	------
	Dissatisfied	0	0	2	22.2	0	0	3	33.33	0.06
	Fair	0	0	2	22.2	0	0	3	33.33	0.06
	Satisfied	2	22.2	2	22.2	3	33.3	3	33.33	1.00
	High satisfied	7	77.8	3	33.3	6	66.7	0	0	0.003*
Comfort	High dissatisfied	0	0	0	0	0	0	0	0	------
	Dissatisfied	0	0	0	0	0	0	0	0	------
	Fair	0	0	2	22.2	0	0	3	33.3	0.06
	Satisfied	4	44.5	4	44.5	5	55.5	4	44.3	0.65
	High satisfied	5	55.5	3	33.3	4	44.5	2	22.2	0.33
Retention	High dissatisfied	0	0	0	0	0	0	0	0	------
	dissatisfied	0	0	0	0	0	0	0	0	------
	Fair	0	0	0	0	0	0	6	66.7	0.004*
	Satisfied	4	44.5	4	44.5	5	55.5	3	33.3	0.36
	High satisfied	5	55.5	5	55.5	4	44.5	0	0	0.02*
Oral hygiene	High dissatisfied	0	0	0	0	0	0	0	0	------
	dissatisfied	1	11.2	1	11.2	0	0	0	0	------
	Fair	2	22.2	2	22.2	3	33.33	3	33.33	1.00
	Satisfied	2	22.2	2	22.2	3	33.33	3	33.33	1.00
	High satisfied	4	44.4	4	44.4	3	33.33	3	33.33	1.00

-Means with different superscript letters were significantly different as P<0.05

-Means with the same superscript letters were insignificantly different

IV. DISCUSSION

The current study contrasts the OT® Equator with Smart Box Attachment with the most popular classical attachment, the ball attachment, regarding the changes in bone height around the nonparallel implant and patient satisfaction. There is certain to be 1.2 mm of bone loss around dental implants in the first year following loading, which is well accepted and tolerated. This procedure, considered typical (17, 18), has no impact on the implant's success.

The careful consideration given to biomechanical, surgical, and prosthetic considerations to reduce any elements that might cause excessive bone loss may help to explain this. The variations in bone height seen in the current investigation were clinically acceptable. This study focuses on careful patient selection to prevent implant overload due to unusual circumstances like bruxism or aberrant ridge connections.

Participants with diseases that might have impacted bone remodeling were also excluded from the study. The opposing dentition was another important factor that helped keep the bone loss around the implants within the permissible, acceptable range. This complete denture allowed less stress transfer on the opposing arch than natural teeth or fixed restorations. A mouth-mounted overdenture is subjected to various forces applied in different directions (19).

The lingualized occlusion concept was chosen to be used in this study because it allows for freedom of movement in centric relation and even contact during lateral and protrusive movements when conventional maxillary dentures are placed in opposition to 2 implant mandibular overdentures (20,21).

When forces are applied vertically, the bone can tolerate them better. Axial implants have forces applied vertically along their longitudinal axis, which should increase their effectiveness because the load is distributed evenly throughout the implant (22). This explains why implants placed axially only experience crestal bone loss of 0-0.2 mm/year and have a high survival or success rate (23).

Angular implants present a unique set of challenges. Larger forces act on the implant-bone contact during axial loading due to the angles at which the angled implants direct the pressures. It makes sense that the disturbance of the implant-bone interface would result in bone resorption. The angled implant had considerably more marginal bone loss than the straight implant at the prosthesis and six months after loading. However, if you wish to avoid transplant procedures, they can still be an excellent alternative to vertical implants (24).

The stability of the guide, the patient's compliance, the morphology of the bone, and the clinician's skill may all impact the implant’s final position. Some doctors use an angled abutment or a bar to account for implant angulation when the stud attachment is incorrect because the implant is not parallel. However, this has limitations in terms of cost, manufacture, and prosthesis maintenance. Due to the off-axial occlusal load, the denture rotates around the attachment on resorbed alveolar ridges (25).

Group OT Equator had less crestal bone loss at the end of the year than Group Ball and Socket, which may have resulted from the latter's low-profile design, which had a beneficial effect (26).

Ball attachments' primary drawback is that they gradually lose retention and must be replaced regularly. Ball attachments are flexible, but when the ball is positioned so that it is not parallel to the occlusal plane, the attachment loses its flexibility and becomes nonresilient (27, 28).

Rhein 83 presented the Equator smart box solution in 2007. The OT equator stands out for having a low profile (vertical profile of 2.1 mm, diameter of 4.4 mm). According to Rhien, the overdenture may correct for misalignments between dental implants of up to 50° using Smart Box Metal Housing technology.

Regarding comfort and usefulness in implant-retained overdenture treatments, its internal mechanical structure allows passive denture implantation while preserving superior elastic component performance [29,

The Smart Box® is an abutment container that, thanks to a tilting mechanism with a rotation fulcrum, permits passive insertion even in high divergences of up to 50°. The Smart Box® is inserted at diverging angles due to this characteristic, which enables force passivation and enhances the predictability of our therapy. Other retentive techniques, including ball and socket attachment, do not allow divergence angles up to 50° so that residual forces may form in our prosthesis, the structure, or the placement of the dental implants [31].

The study's findings, showing the crestal bone height change with the Ball group was greater than that with the OT® equator group, are supported by the possibility that residual stresses could damage mechanical components or cause biological damage, both of which contributed to an increase in the frequency of bone alterations around implants. Regarding patient satisfaction, patients expressed greater happiness with the OT equator than with ball attachments over the follow-up period. This was consistent with the in vitro investigation and did not influence retention or increase wear.

V. CONCLUSION

With the study's limitations in consideration, the following conclusions can be drawn:

The bone alterations brought about by the Equator and ball and socket implant attachments did not exceed the crestal bone's acceptable range. When implants are not parallel (10-degree divergence between two mandibular implants), the OT equator with the smart box attachment loses less crestal bone than the ball attachment.

Regarding patient satisfaction, the positive effects of the implant therapy, as measured by satisfaction with the mandibular denture, were present despite the form of attachment used. However, compared to the ball attachment, the OT Equator with smart box showed greater general, chewing, and retention satisfaction levels.

Conflict of Interest:

The authors declare no conflict of interest.

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Ethics:
This study protocol was approved by the ethical committee of the faculty of dentistry-October 6 University on 1/12/2021, approval number: (RECO6U/16-2021)

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