ORIGINAL RESEARCH

Effect of Ridge Splitting of Mandibular Knife Edge Ridges with Two-implant Retained Overdenture with Locator Attachments on Peri-implant Bone Level and Posterior Ridge Resorption: A One-year Preliminary Study

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Abstract

Aim: This study was conducted to evaluate peri-implant bone height changes and posterior ridge resorption by using two-implant retained polyetheretherketone (PEEK) overdentures with locator attachments following expansion of mandibular knife edge ridges by ridge splitting.

Materials and methods: Eighteen patients were selected for ridge splitting followed by expansion, implant placement, and bone graft application. Six months later, the fabrication of PEEK overdentures retained by locator attachments was accomplished. Friedman test, Wilcoxon signed-rank test, and Spearman correlation were used to evaluate the changes over time.

Results: Peri-implant bone height loss increased significantly with the advance of time between 6 and 12 months following denture insertion. Posterior area index changes were significant over time when measured at the time of denture insertion and twelve months following denture insertion.

Conclusion: The effect of using PEEK as overdenture base material retained with two locator attachments allowed sharing the load between the peri-implant bone anteriorly and residual ridge posteriorly in cases with ridge splitting technique.

Clinical significance: Using PEEK as an overdenture base material is a successful means of bone preservation.

Keywords: Knife edge ridge, Locator, Polyetheretherketone, Ridge splitting.

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Introduction

Using two implants to support an overdenture is the minimum requirement for an implant-supported prosthesis, although more than two implants can be placed and are desirable.[1] They are documented to be less invasive and more economical than fixed implant prostheses as they improve biting force, chewing efficiency, speech, and other psychological benefits.[2]

Inadequate alveolar ridge width is a common obstacle to conventional implant placement as the rate of bone loss after dental extraction decreases by 3.1–5.9 mm (approximately 50% of the original bone width) four to twelve months after tooth removal.[3]

Various procedures are performed by clinicians to increase the horizontal width such as block bone grafting, distraction osteogenesis (DO), guided bone regeneration (GBR), alveolar ridge splitting, and expansion.[4–6]

Block bone grafting as the autogenous bone graft is considered the golden standard in bone augmentation procedure due to its osteoconductive, osteogenic, and osteoinductive characteristics. Moreover, autogenous bone graft has no risk of immunological rejection or possible disease transmission.[7,8] However, using it is associated with the risk of donor site morbidity, unpredictable resorption of the grafting material, and prolonged patient treatment time due to its extra healing period.[9]

Distraction osteogenesis is a surgical technique that induces bone regeneration by the gradual distraction of surgically separated bone segments. Ilizarov pioneered the law of tension stress, which defines the mechanism of new bone and soft tissue regeneration under the stimulation of tension stress.[10] This procedure is composed of three sequential phases including latency, distraction, and consolidation. It usually takes half to one year or longer to accomplish.[11]

Guided bone regeneration (GBR) is an established technique for horizontal and vertical augmentation with long-term stability.[12] However, the use of this approach may be limited by difficulties in handling the titanium mesh during placement or the second-stage removal and the incidence of mesh exposures because of early or late dehiscence of the overlying soft tissues.[13,14]

To overcome the drawbacks of these augmentation techniques, the alveolar ridge-splitting/expansion technique (ARST) allows

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clinicians to perform one-step surgical procedures and shorten the treatment time.[15]

The alveolar ridge splitting and expansion technique is a 4-wall defect with a cortical envelope that simulates an extraction socket. Vertical osteotomy was avoided to preserve the vascularity of the ridge. An internal coagulum that forms with the placement of interposition grafting helps in healing and early woven bone formation. This technique provides excellent protection to the graft from exposure and displacement, while providing vascularization from both the cortices and basal bone by internal perfusion throughout the whole healing process.[16] However, due to the higher bone density and thicker cortical buccal plate, the mandibular ridges are more difficult to treat than maxillary ridges and the risk of buccal plate fracture always exists.[17–19]

Piezo surgery (PS) is performed by a device that uses microvibration at a frequency capable of cutting bone. Due to its selective cutting property, it is safe to use near important soft tissue. Also, the operative field remains almost free of blood during the cutting procedure. It also possesses the advantage of micrometric cutting which is achieved by micro vibrations with limited amplitude.[20,21]

The locator attachment is a universally resilient non-splinted attachment system that is self-aligning. It is indicated for use with implant-supported overdentures especially for those patients who suffer from rapid wear of the ball components, in cases of limited interarch space.[22] It also offers the smallest attachment dimensions with a low risk of denture base fracture. Furthermore, locator attachments have gained great popularity as an alternative treatment option because of their excellent dual retention, quick and easy repair when needed in addition to their component durability.[23] It is compatible with many implant systems and has become widely used.[24]

Polyetheretherketone (PEEK) is a high-temperature thermoplastic, semi-crystalline material with a high melting temperature. Documented evidence suggests the physical properties such as the Young's elastic modulus of PEEK is 3.6 GPa which allows displaying a mechanical behavior more closely related to bone and shock-absorbing properties drive the rising enthusiasm, enabling a uniform transfer of stress to the underlying bone and reducing the potential deleterious effects of active stress points in the mouth.[25]

Polyetheretherketone exhibits good impact strength, low vapor pressure, very good thermal stability, chemical resistance, and excellent creep behavior. The isothermal creep resistance (at room temperature) of PEEK is exceptional for both short and long-term applications. However, creep compliance of PEEK increases by a large factor as temperature passes beyond the glass transition temperature (143°C).[26,27]

Change in bone height represents the difference in bone levels at the same site at separate timepoints. The initial reference bone level value is subtracted from each of the later values, usually but not always, resulting in a negative measurement representing a loss of crestal bone. The initial reference is often recorded either right after implant placement (postoperative value) or once the implant becomes functionally loaded (prosthetic loading). These calculations compare the vertical distance between the crestal bone level at the implant contact and a reference point on the implant (implant platform for example).[28]

Posterior mandibular area measurement in terms of area indices is a more reliable method for assisting posterior mandibular residual ridge (PMRR) than absolute values as it decreases the problems associated with magnification and distortion inherent in panoramic radiographs. Proportional measurement on panoramic radiographs is very accurate in determining mandibular bone resorption as it measures the whole area of the posterior mandibular ridge, while cephalometric radiographs evaluate PMRR at four selected points only. Greater PMRR could be expected in the chewing center (area of the first molar), where maximum occlusal forces are exerted due to maximum contraction of the elevator muscles.[29]

This study was employed to study the effect of PEEK overdenture with two locator attachments following ridge splitting and simultaneous implant placement on peri-implant bone height changes and on posterior ridge resorption.

Materials and Methods

Sample Size Calculation

Considering ELsyad et al.[30] a sample size of 13 to be increased to 17 subjects (20% drop-out rate) achieves 95% power to detect a mean of paired differences of 0.1 for vertical bone loss (VBL) with a known standard deviation of differences of 0.1 and with a significance level (alpha) of 0.05 using a two-sided paired *z*-test. PASS 15.0.5.

Study Design

A preliminary study was executed on 18 completely edentulous patients with maladaptive experiences of wearing conventional mandibular dentures. Cases were consecutively recruited from April 2019 to December 2021 and treated with ridge expansion in the Faculty of Dentistry, Mansoura University, Egypt. The study was approved by the Local Ethics Committee, number 01100918, and ClinicalTrials.gov Identifier NCT05837078. After being briefed about the study protocols, each patient signed an informed consent form.

Patients' Criteria

Inclusion Criteria

Patients were completely edentulous with an anterior knife edge mandibular residual ridge (2.5–3 mm of bone width and a minimum of 13 mm of bone height) to accommodate implant placement which was determined by Cone beam computed tomography (Cone Beam CT), additionally, they had class I maxillomandibular relation.

Exclusion Criteria

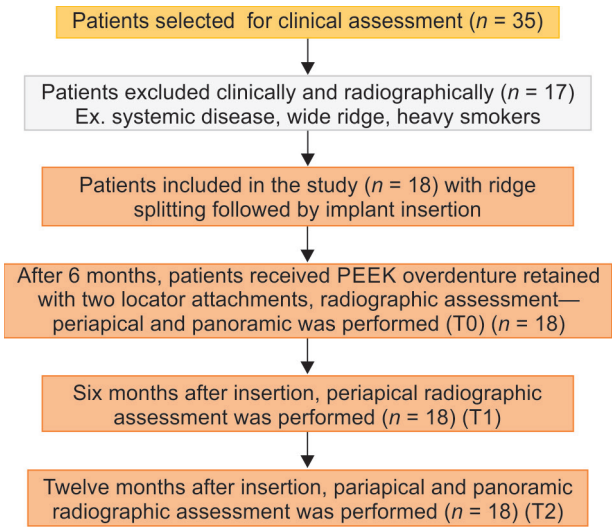
Patients with cancer, a history of head and neck radiotherapy, or autoimmune disease, diabetic patients, patients with parafunctional habits, heavy smokers, and those who had thick cortical bone but had no cancellous bone inside or with bone defects were excluded from the study.

Patients' Examination

To meet the aforementioned criteria, patients' medical and dental histories as well as clinical and radiographic evaluations were accomplished. Patients received ridge splitting followed by implant insertion and 6 months later they received a PEEK overdenture with locator attachments as explained in the Flowchart 1.

Each patient received a conventional complete denture constructed with a balanced lingualized occlusion. Mandibular dentures were duplicated into clear, heat-cured Poly-methylmethacrylate (PMMA) resin dentures in order to fabricate surgical stents with two holes drilled at the corresponding implant location.

Flowchart 1: Overall study design flowchart



Surgical Technique

The mid-crestal incision was made at the crest of the mandibular alveolar ridge from the premolar area of one side to the other side followed by 2 vertical releasing incisions followed by retraction of the full thickness mucoperiosteal flap.

A bone trimer was used with a speed of 1200 rpm to flatten and smoothen the narrow crestal bone followed by an initial drill of 1.5 mm which was used to mark the implant position with the aid of the surgical stent.

A piezoelectric device (Piezotome cube, SATELEC) with a maximum power of 30 KHz and abundant irrigation was used to make a crystal bone cut extending mesiodistally followed by two longitudinal cuts at both ends of the crestal incision (Fig. 1A).

A set of color-coded expanders with increasing diameters was used (Implant Microdent System, Microdent) with a speed of 25–35 rpm for sequential expansion of the labial cortical plates. Motorized expansions were used first followed by manual expansion.

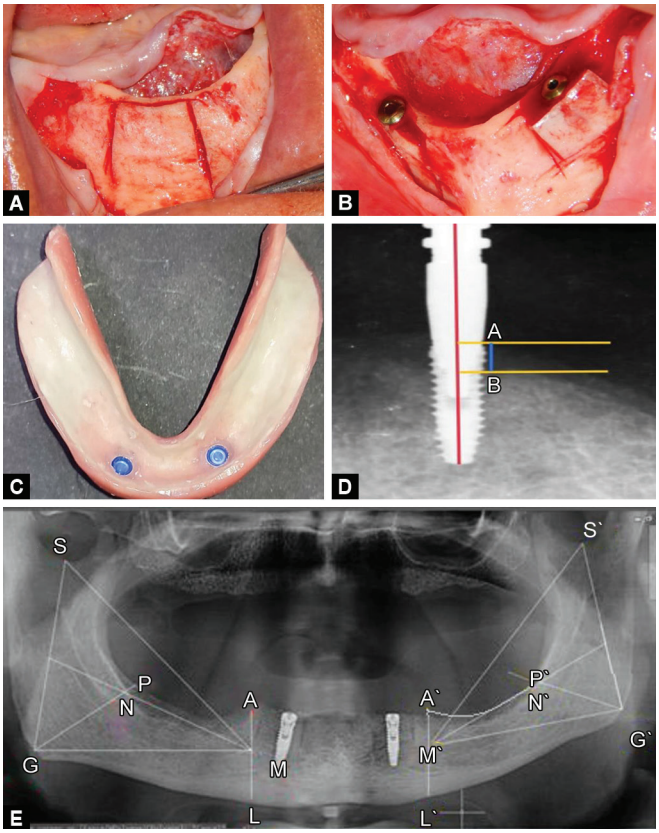
The implant beds were prepared with a minimum drilling. An implant of 11 mm length and 3.5 mm width (IS-II active Fixture, Neobiotech Co., Ltd) was inserted at the prepared surgical site followed by cover screw application (Fig. 1B). Xenograft bone material (OneXeno Graft) was utilized to fill the defect around each implant followed by the application of a resorbable collagen membrane (Colla-D, MedPark). Then suturing of the mucoperiosteal flap was completed with silk suturing material.

Postoperative medications were prescribed for patients including antibiotics and analgesics. The sutures were removed two weeks post-surgery. The existing mandibular dentures were relived and followed by soft relining material application (Promedica Dental Material, Germany) 2 weeks after surgery.

Definitive Prosthesis

After 6 months of surgery, the patients were recalled for the construction of definitive mandibular PEEK overdentures. The second stage of surgery was performed by removing the mucosa overlying the implant sites. Healing abutments were screwed to the implant fixtures for 2 weeks to allow for healing.

Transfer copies were screwed to the implant fixtures after unscrewing the healing abutments. The mandibular final



Figs 1A to E: (A) Longitudinal and horizontal incisions; (B) Implant insertion; (C) Polyetheretherketone overdenture; (D) Periapical radiograph; (E) Posterior area index measurement

impression was recorded using the open tray implant level impression technique. Border tracing was accomplished utilizing green compound followed by zinc oxide impression material, then the transfer copies were recorded using light body additional silicone (DETAX, GmbH and Co., KG). After impression recording, the implant analogs (ISLA Lab analog, Neobiotech Co., Ltd) were screwed to the impression posts and the impression was then poured to obtain the final cast. Upon the final cast, the locator abutments (HGLCA, LOCATOR Abutment, HIOSSEN) were screwed to the implant analog, and the metal housing with its black processing inserts was snapped over the locator abutments.

The cast was scanned using an extraoral scanner. The scanned data was stored as an Stereolithography (STL) file. The design of the PEEK overdenture base was established using the designing software (Exo-cad, Intel Core-i7 9700k/AMD Ryzen 7 2700X). A resin template (Mammoth, PLA Pro resin) of the overdenture base was created using 3D printing and tried in the patient's mouth. Small holes were made as a mechanical means of retention corresponding to the locator cap. Using the subtractive technique, a computer numerical control (CNC) machine was used to mill the PEEK disk (Coritec350i_PRO) into the PEEK overdenture base. The base was tried in the patient's mouth. Maxillomandibular relationships were recorded followed by the setting of the artificial teeth, processing, laboratory remount and finally finishing and polishing.

A block-out spacer and metal housings with their black processing caps were inserted over each locator abutment. The metal housings of the attachments were picked up into fitting

surface of the denture using auto-polymerizing acrylic resin (Repair Material, Dentsply) while the patients were gently guided into centric occlusion. The black processing caps were replaced with a blue extra light retention cap (Fig. 1C).

Patients' Evaluation

Anterior bone height level changes were evaluated by periapical X-ray at the time of insertion (T0), 6 months following insertion (T1), and 12 months after insertion (T2).

A periapical standardized radiograph was made for each implant using the long cone paralleling technique. A hole was drilled precisely above the implant hex in the film holder to standardize the film-implant distance and the cone-implant distance during film exposures. The holder was fastened to the long-serrated impression coping.

On the radiograph, the distance AB was measured from the implant neck (point A) to the most coronal part where the bone seems to be in contact with the implant (point B) parallel to the long axis of the implant. Radiographic VBL was calculated by subtracting the distance AB around the implant at (T1) and (T2) from the AB distance at (T0). Measurements were done from the mesial and distal surface of each implant and the average was calculated (Fig. 1D).

Actual VBL was calculated to avoid the magnification error by multiplying the actual implant length by the radiographic VBL and dividing the result by the radiographic length of the implant.[31]

The posterior area index was evaluated by proportional measurement of a posterior mandibular area like the method described by Wright and Watson.[32] Two panoramic radiographs were taken, one at the time of insertion (T0) and the second one at 12 months following the insertion (T2). The reference points and lines were traced using AutoCAD 2018 software (Fig. 1E).

The posterior mandibular area was outlined by joining points at the gonion (G/G′) to the lower border of the mental foramen (M/M′) and the sigmoid notch (S/S′). (N/N′) represents the center of the triangle joining the three points M-S-G/M′-S′-G′. The reference area is presented by a line joining M-G-N/M′-G′-N′. The experimental area was determined A-P-G-M/A′-P′-G′-M′ where A-L/A′-L′ represents the crest of the mandibular ridge to the lower border of the mandible and is perpendicular to the M-G/M′G′ line. The area difference which represents the bone resorption was calculated by the equation (X/Y+X′/Y′)/2 where X/X′ represents the experimental area and Y/Y′ represents the reference area.[29]

Statistical Analysis

The data was analyzed using the Statistical Package for the Social Sciences (SPSS) software version 25 (SPSS Inc.). The Shapiro–Wilk test was used to determine the normal distribution. The data were non-parametric. Data was described as a median (minimum–maximum). The Friedman test and Wilcoxon signed ranks test for testing the change over time in the studied patients. Spearman correlation was conducted to correlate the change in the posterior area index with time. The *p*-values < 0.05 were considered significant.

Results

Anterior Bone Height Level Changes

Descriptive statistics (median; minimum; maximum) of radiographic peri-implant vertical bone height loss at different times are shown in Table 1 where peri-implant VBL significantly increased with the advance of time (Freidman test *p*-value was < 0.001). On studying the changes between T0 and T1 (Wilcoxon signed-rank test *p*-value < 0.001) and between T1 and T2 (Wilcoxon signed-rank test *p*-value < 0.001) (Table 1).

Table 1: Comparison peri-implant vertical bone height loss at different observation times

	(T0)	*(T1)*	*(T2)*	*Freidman test (p-value)*
Median (mm)	0.00	0.25	0.60	< 0.001*
Min (mm)	0.00	0.10	0.40	
Max (mm)	0.00	0.55	0.90	
Wilcoxon signed-rank test *z* value	–3.737 < 0.001*			
p-value	–3.737 < 0.001*			

**p*-value is significant if < 0.05. X, mean; SD, standard deviation; Min, minimum; Max, maximum; T0, time of insertion; T1, 6th month after insertion; T2, 12th month after insertion

Table 2: Comparison of posterior area index at observation times

	(T0)	*(T2)*	*Wilcoxon signed-rank test z-value p-value*
Median	1.5000	1.1700	
Min	1.20	1.00	–3.736 < 0.001*
Max	1.72	1.51	

**p*-value is significant if < 0.05. X, mean; SD, standard deviation; Min, minimum; Max, maximum; T0, time of insertion; T2, 12th month after insertion

Posterior Area Index

Descriptive statistics (median; minimum; maximum) of the posterior area index at (T0) and (T2) are shown in Table 2. Posterior area index changes significantly decreased over time (Wilcoxon signed-rank test *p*-value < 0.001) (Table 2). On correlating the change over time using Spearman correlation, a moderate negative correlation was estimated ($r = -0.618$, *p*-value < 0.001).

According to these results, PEEK overdenture base material showed a share of load anteriorly and posteriorly allowing less amount of bone resorption posteriorly.

Discussion

This study was conducted to manage the knife edge ridge surgically and prosthetically by using the ridge expansion technique with simultaneous implant placement followed by PEEK overdenture construction to evaluate the effect on bone resorption anteriorly around the implants and posteriorly under the denture base.

Vertical bone loss was significantly increased after 1 year of overdenture insertion. These bone loss values were considered acceptable as the generally accepted standards for implant-induced bone loss which have been less than 1.5 mm one year following implant loading and less than 0.2 mm for each following year. Other researchers demonstrated similar results in terms of bone loss within the normally accepted range.[30,33,34] These studies recorded higher values than those in the current study. One explanation could be the PEEK material used to make the overdenture bases. Other researchers evidenced that PEEK transmits lesser stresses to implants thanks to its lower modulus of elasticity and shock absorption when compared to cobalt chromium framework reinforcements.[35,36] This is supported by studies comparing the

effects of PEEK and metal frameworks on marginal bone resorption, which showed that PEEK framework had lower marginal bone resorption than metallic framework.[37]

Our study showed a moderately significant change in the posterior area index over time as shown by the spearman correlation test. Lower values in the posterior ridge resorption study may be attributed to the flexible properties of PEEK material and the resiliency of locator attachment. This agreed with a study conducted to compare the stresses on the residual ridges exerted by different denture base materials which reported that PEEK material was preferred to reduce the stresses and strains generated on bone tissues.[38]

In this issue, Chen et al.[39] stated that the PEEK framework had a more even dispersion of masticatory force compared with conventional metallic materials. Another study confirmed the previous results and owed them to the low modulus of elasticity.[40]

Moreover, Badr and Hassan[41] have measured the changes over the posterior area index using a metallic framework implant-supported overdenture and revealed that the posterior ridge resorption rate was between 0.15 and 2.63% per year. These results were consistent with Raedel et al.[42] who showed that the mean loss of bone height per year was approximately 0.15 mm which ranges from 0.02 to 0.48 mm.

Our results could be explained by the ability of locator attachment to provide an equitable load on the implants and tissue-bearing area during function as shown by a former study.[43] The study explained that the locator attachment allows a resilient connection between abutment and overdenture with a limit of 1.2 mm in the vertical direction and 8° in all directions, hence, the overdenture considered totally mucosal supported.[43] Locator attachment was used to retain the overdenture to decrease the load on the implants. The resilience of the locator attachment allows anteroposterior, lateral, and intrusive movements, eventually lowering the resultant stresses on the implants and the peri-implant bone.[44] The lower the locator attachment profile, the more freedom of rotation and the lesser stress on the peri-implant bone.[45] A previous study elaborated that Locator attachments may be beneficial to preserving peri-implant bone.[46]

After discussing the result of this study, PEEK overdenture was justified as a material for mandibular knife edge ridges treated by ridge splitting as it may decrease the forces on the underlying implants and minimize the posterior ridge resorption. Further studies are needed to study the effect of PEEK as a denture base material.

Limitations of Study

This study is limited by the small sample size and very brief follow-up. Additionally, the PEEK overdenture denture base material was not compared to a conventional one when related to ridge resorption and force distribution. Hence, future randomized controlled clinical trials with a sizable sample size and an extended follow-up period are necessary to assess the impact of the mandibular PEEK overdenture following ridge splitting on the peri-implant bone height changes and posterior ridge resorption compared.

Conclusion

The effect of using PEEK as overdenture base material retained with two locator attachments allowed sharing the load between the peri-implant bone anteriorly and residual ridge posteriorly in cases with ridge splitting technique.

Clinical Significance

The use of PEEK as a denture base material provides better outcomes for bone resorption as it allows a decrease of the stresses transmitted to the underlying bone due to its intrinsic physical properties, especially when we it is applied to a surgically split ridge.

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