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Assessment of vertical ridge augmentation in anterior aesthetic zone using onlay xenografts with titanium mesh versus the inlay bone grafting technique: A randomized clinical trial☆

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Abstract. The aim of this study was to evaluate the final vertical gain at the deficient anterior maxillary alveolar ridges using onlay bone grafts with titanium mesh versus inlay bone grafting. This was a single institutional randomized comparative clinical trial. The study population included 16 patients, with edentulous anterior maxillary alveolar ridges (40 implant sites) who were presented and treated at the Faculty of Oral and Dental Medicine in Cairo University from September 2013 to August 2015. Selected patients were randomly divided into two equal groups. The control group received onlay particulate xenograft together with titanium mesh as a space-maintaining device while the study group received inlay block xenograft (sandwich osteotomy) fixed with mini-plates. Assessment using cone beam computed tomography (CBCT) included the mean percentage of vertical gain at the proposed implant sites after 6 months taken from cross-sectional cuts. A total of 40 delayed implant placements were done. Results showed that there was no

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statistical significance between the two groups ($P = 0.2$); the mean percentage of 6 months postoperative vertical bone gain in the control group was 20.7% and that in the study group was 31.6%.

Key words: onlay; inlay; bone grafts; titanium mesh; anterior maxilla.

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The problem of inadequate alveolar ridge height is a major limitation for successful placement of dental implants, where the routine techniques of implant placement are not possible because of the discrepancy between the available height of the ridge and that of the implant. For situations where the ridge height is marginal (i.e. < 10 mm or so), it is often possible to manage complications in osteotomy preparation such as bone fenestrations or dehiscence with various graft and barrier materials.

In more extreme cases, however it becomes necessary to prepare the deficient ridge with some form of ridge augmentation procedure, using, for example, either guided bone regeneration, vertical block grafting with autogenous bone, vertical distraction osteogenesis, and vertical reconstruction using titanium mesh with autogenous particulate bone grafts. These ridge augmentation procedures can increase the ridge vertical dimension but they will add extra expense, time, and morbidity of the donor. As an alternative to these approaches, some clinicians have proposed a variety of alveolar ridge vertical reconstruction techniques for treatment of vertical ridge deficiencies.

Inlay bone grafting and ridge reconstruction using titanium mesh have received growing acceptance and success as a vertical augmentation technique for maxillary bone. The resiliency and softness of the maxillary bone renders it possible for accepting the bone graft using titanium mesh and also mobilization in an occlusal direction during the inlay bone grafting procedure. Vertical bone gain remains the main challenge and restriction for the application of these techniques in the anterior aesthetic zone; thus, the aim of this study was to evaluate which technique will be more beneficial to the patient in terms of vertical bone gain.

Materials and methods

The investigators designed and implemented a single institutional double-blind randomized comparative clinical study. Patients suffering missing multiple maxillary anterior teeth were selected with deficient vertical bone height. After approval of the Ethics and Research Committee all patients were informed and consented to the procedures to be followed throughout the study (Fig. 3).

To be included in the study sample, patients had to follow the following inclusion criteria: all patients were free from any systemic disease that may affect bone healing, no local pathosis that may interfere with bone healing, no history of any grafting procedure at the designated edentulous ridge.

Criteria of the edentulous ridge

The anterior maxillary vertical dimension was less than 10 mm, measured from the alveolar crest to the basal bone of the maxilla (i.e. the ridge had vertical inadequacy); the minimum number of missing teeth in the anterior maxillary alveolar ridges was two anterior teeth; the maximum was all six anteriors. There was increased interarch space compared with the adjacent teeth and the horizontal alveolar dimension was normal.

Patient grouping

The patients were randomly divided into two equal (8 patients each) groups that underwent vertical ridge augmentation using either a particulate xenograft together with titanium mesh (control group) an inlay block xenograft fixed with miniplates (study group). Randomization was carried out using appropriate computer software.

Preoperative preparation

Clinical evaluation

A thorough medical and dental history followed by clinical examination was carried out for all patients. Clinical measurements were taken to ensure patient adherence to our initial inclusion criteria prior to further investigations. Impressions were taken and a radio-opaque denture was fabricated to be used as a radiographic guide for standardizing the calculation of the final vertical ridge gain. The denture was fabricated using a radio-opaque material (barium sulphate mixed with acrylic in an 8:2 ratio), the radio-opaque teeth were used as a fixed reference to ensure that the measurements were done at the same area of interest: pre-, immediate, and 6 months postoperatively

Periapical radiographs were taken for primary investigation in order to exclude the presence of any lesion at the area of interest. A cone beam computed tomography (CBCT) scan was done as a final investigation for the assessment of the vertical dimension of the edentulous alveolar ridges. This vertical dimension of each implant site could be measured accurately in the reformatted cross sectional images (Fig. 1).

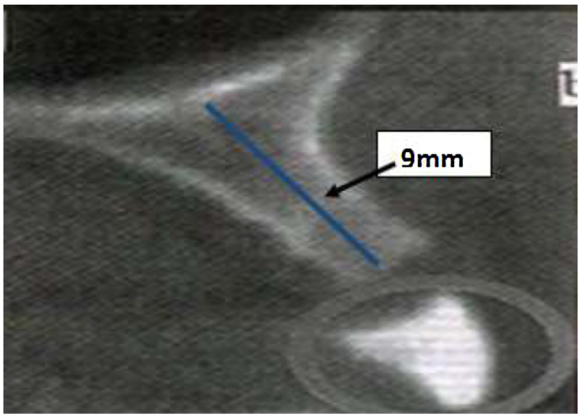

Fig. 1. CBCT showing vertical ridge deficiency preoperatively.

Intraoperative surgical procedures: (both groups)

The local anaesthesia used was Scandonest 2% (each 1.8-ml cartridge contained 36 mg of mepivicaine hydrochloride with 18 mg of adrenaline (Septodent, Saint-Maur-des-Fossés, France)) for haemostasis.

Scrubbing and draping of the patient was carried out in a standard fashion using bitadine surgical scrub. A three-incision-line pyramidal flap was done by placing a crestal incision more to the palatal aspect of the crest of the ridge where the incision was cut between the two teeth that bounds the edentulous area. Two oblique releasing incisions were then cut at the distal ends of the crestal incision.

Control group

A full-thickness reflection of labial and palatal mucoperiosteal flap was performed. Reflection was extended to expose the whole length of the facial cortical plate of the alveolar ridge. In this group, bleeding points (decortication) were done using a rounded burr to expose the underlying marrow for easier graft consolidation, followed by application of the titanium mesh and the gap between it and the native bone was filled with particulate xenograft bone material (Tutogen, Neunkirchen am Brand, Germany; particle size 0.25–0.5 nm). Finally, the titanium mesh was fixed in place using three or four micro screws. Scouring was done to allow tension free closure using resorbable suturing material (vicryl 3-0) (Figs. 2 and 3).

Study group

Only the labial flap was reflected leaving the palatal tissues without elevation as the mobilized bony segment will be pedicled on it (Fig. 4). Three full-thickness cuts were performed. Two vertical stop cuts were made using a tungsten carbide disc at the distal ends of the midcrestal bony cut on the facial surface of alveolar ridge; the vertical cuts were 3 mm from the neighbouring teeth.

The above-described cuts were revised using ridge-splitting osteotomes (fine chisels) of sequential width (2 mm, 3 mm) and a lightweight mallet. The rectangular bony segment (transport segment) was finally mobilized occlusally and pedicled on the palatal mucoperiosteum (Fig. 5). A block xenograft was snugly fitted between the mobilized segment and the basal bone, and finally the segment was fixed using mini-plates and mini-screws (Fig. 6). Scoring was done to allow tension-free closure using resorbable suturing material (vicryl 3-0).

Fig. 2. Vertical ridge deficiency preoperatively (clinically).

Fig. 3. Application of the titanium mesh and particulate xenograft.

Fig. 4. The vertically deficient alveolar ridge preoperatively (study group).

Data analysis and randomization

Patients were randomly divided into two equal groups using computer software; numbers were concealed by closed envelopes. Neither the patient nor the assessor was aware of the type of surgery done.

Study variables and measuring the final vertical gain for both groups (standardization of calculations)

The nasal floor was used as a fixed reference by adjusting the cross-sectional long axis in the centre of the area of interest and bisecting it (showing the buccolingual dimension). All the patients had worn the radiographic dentures with radio-opa-

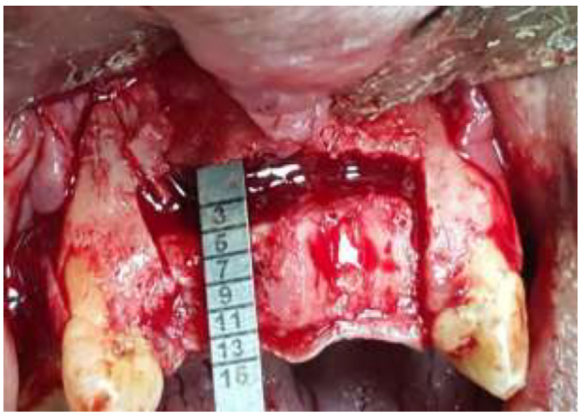

Fig. 5. Mobilization of the transport segment 6 mm in an occlusal direction. Pedicled on the palatal mucosa.

Fig. 6. Fixation of the graft and the transport segment using two miniplates.

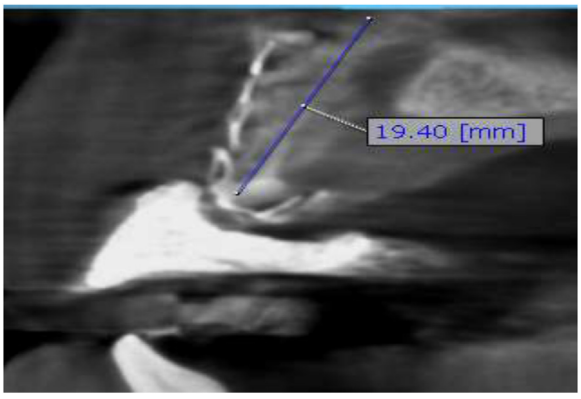

Fig. 7. Measurement of the postoperative height from the nasal floor as a fixed reference to the crest with the radio-opaque denture (control group).

que material (barium sulphate mixed with acrylic powder) filling the teeth at the area of interest, to ensure that the calculations were taken at the same region.

On the cross-sectional view of CBCT and at each proposed implant site, a line was drawn starting from the crest of the ridge till the apical level. The height was estimated preoperatively, immediately (1 week) and 6 months postoperatively (Figs. 7 and 8). Now, the difference between them in millimetres was recorded. As it was not possible to standardize the amount of immediate height gain (it is a case dependent) so, the percentage of height gain for each group was calculated and compared with those of the other group.

The obtained data were subjected to statistical analysis.

Statistical analysis

Statistical analysis was performed using SPSS (Statistical package for the social sciences) version 20 (IBM Corp., Armonk, NY, USA).

Data were represented as mean ± standard deviation. A paired Student's *t*-test was used to compare two variables within the studied group of patients. An independent sample *t*-test was used to compare variables between the two studied groups. In all tests, the result was considered statistically significant if $P < 0.05$.

Results

Vertical anterior maxillary alveolar ridge augmentation was performed in 16 patients (10 males and 6 females) with an average age 39 years (range 25–53 years).

Forty implant sites were included in this study and were classified randomly into two groups.

The two groups underwent vertical alveolar ridge augmentation utilizing either titanium mesh with particulate xenograft (group 1; control group), or the inlay bone grafting technique with block interpositional xenograft (group 2; study group).

Clinical results

Wound healing was uneventful in all patients without any signs of infection or wound dehiscence, except in patients in the control group who showed flap dehiscence and titanium mesh exposure 10 days postoperatively. These patients were treated with daily irrigation using normal saline and finally healed with secondary intention.

Radiographic results

All patients were included for statistical analyses. There was no statistical significance between the two studied groups regarding patients' age and gender distribution, but there was **no** statistical significance between the pre-, immediate and 6 months postoperative height at each separate group ($P = 0.001$**)**. On the other hand, the difference between the percentages for 6 months of postoperative gain between the both groups was not statistically significant ($P = 0.2$) (Figs. 9 and 10) (Table 1). In this study the mean percentage of 6 months postoperative vertical bone gain of the control group was 20.7% and that of the study group was 31.6% (Figs. 11–13).

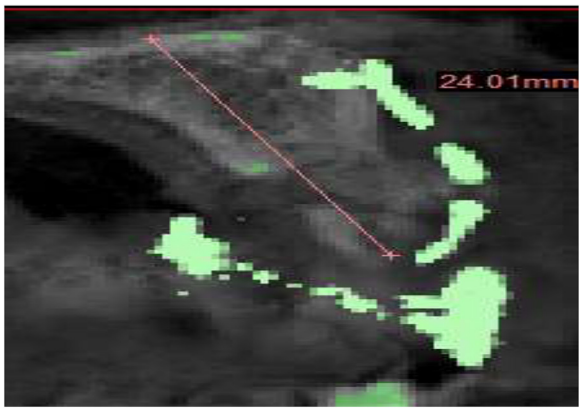

Fig. 8. Measurement of the postoperative height from the nasal floor as a fixed reference to the crest with the radio-opaque denture (study group).

Discussion

The choice of the appropriate reconstructive technique to fit every situation is sometimes a matter of debate. This depends on the position of the edentulous span, dimensions of the remaining bone, proximity to vital structures, amount of the available soft tissue coverage, systemic condition of the patient and of course the operator skills and preferences.

The aim of the current study was to evaluate the final vertical gain in the anterior aesthetic zone using customized titanium mesh containing particulate xenograft versus the inlay bone grafting technique with block xenograft.

In the literature, the use of titanium mesh is considered to be reliable containment system in anterior maxillary alveolar reconstruction, it showed evidence of vascular ingrowth into the graft and new bone formation. Von Arx[1] recommended the use of titanium mesh that was shown to

Table 1. Percentage of net vertical gain between both groups 6 months postoperatively.

	Mean %	SD	*P*
Control	20.7%	13.3	0.2
Study	31.6%	22.5	

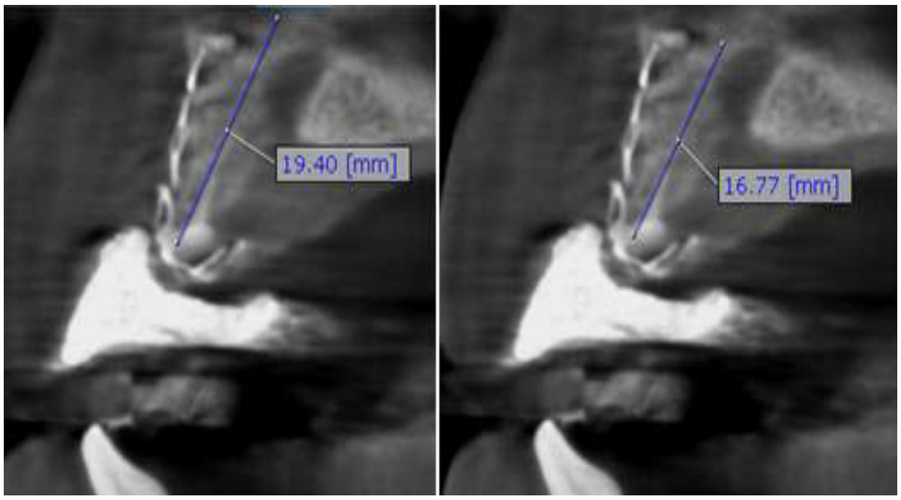

Fig. 9. Cross sectional CBCT image of control group showing the bone height immediate postoperative (left image) and 6 months postoperative (right image).

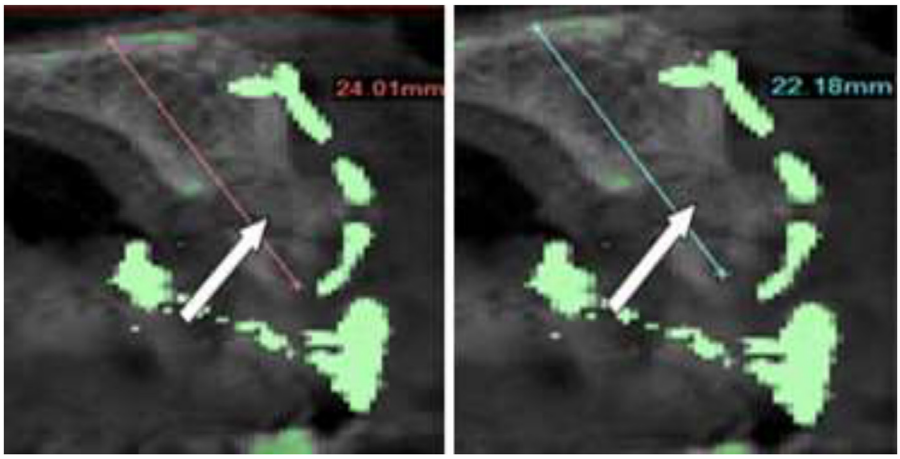

Fig. 10. Cross sectional CBCT image of study group showing immediate postop. Height (left image) and 6 months postoperatively height (right image). White arrow shows the interpositional graft.

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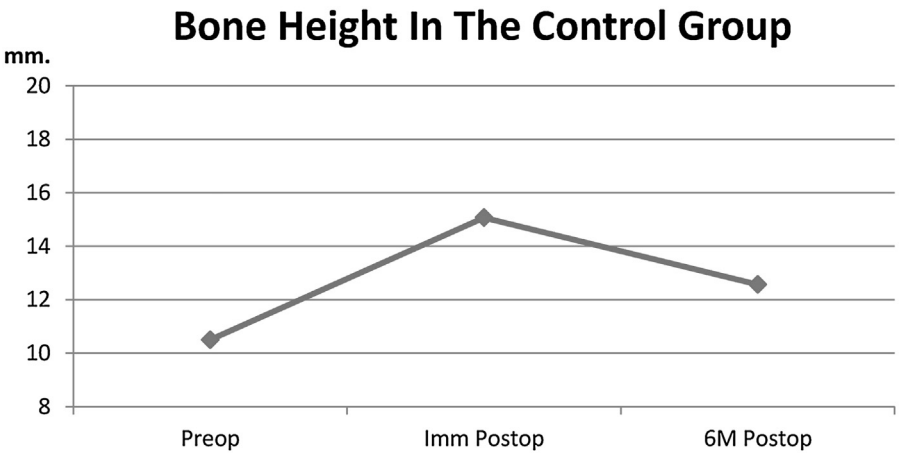

Fig. 11. Graph representing bone height in the control group.

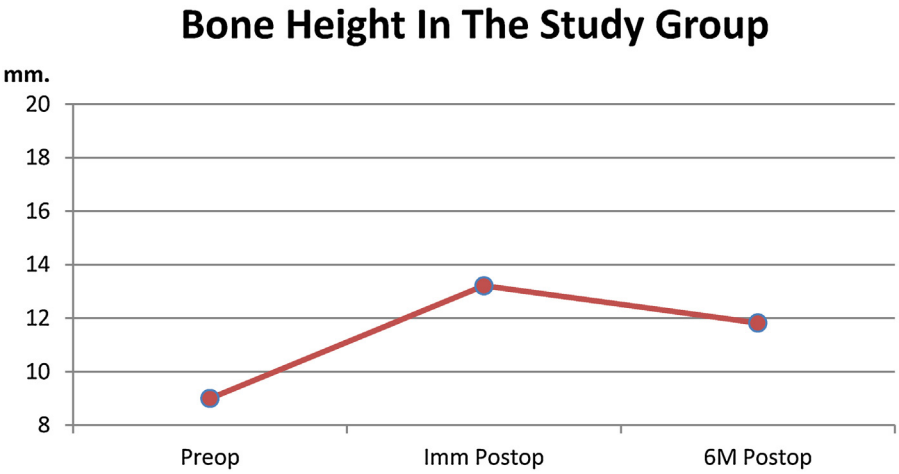

Fig. 12. Graph representing bone height in the control group.

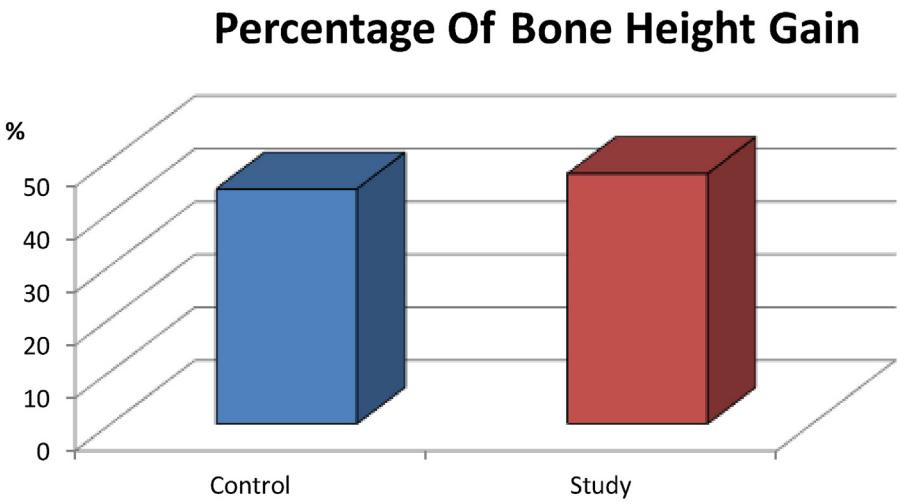

Fig. 13. Bar chart representing percentage of net vertical gain between both groups 6 months postoperatively.

be rigid enough to prevent soft tissue collapse, thus maintaining a space for grafted bone.

Wound healing was uneventful in all patients in the control group without any signs of infection or wound dehiscence, except for one patient who showed flap dehiscence and titanium mesh exposure 10 days postoperatively. This patient was

treated with daily irrigation with normal saline that finally healed with secondary intention; this clinical result was better than Her et al.[2], who reported exposure of titanium mesh in seven (26%) of the 27 surgical sites evaluated. They finally concluded that substantial bone augmentation can be achieved using titanium mesh in conjunction with bone grafting. Furthermore, exposure of titanium mesh during healing does not necessarily compromise the final treatment outcome.

The concept of the interpositional or sandwich grafting technique used in the study group is based on the theory that the bone graft is placed between two pieces of pedicled bone with internal cancellous bone, which is thought to undergo a rapid and complete graft incorporation. The inlay bone grafting technique (sandwich technique) carries many advantages over other reconstructive techniques. As the available vasculature of the bone graft to maintaining its viability. Moreover, Jensen et al.[3] claimed that the placement of the incision paracrestally allows blood supply to be maintained to the transport segment and decrease the probability of dehiscence. Another advantage of this technique is the ability to increase the height of the ridge by as much as 8 mm as reported by Bormann et al.[4].

During mucoperiosteal flap elevation, crestal and lingual tissues were not reflected. This was aiming at preserving the blood supply to the transport segment, which in turn reduces crestal bone resorption following the first stage of surgery. This was first adopted by Frame et al.[5], who carried out an experimental study to prove the ability of the lingual pedicle to maintain the viability of the coronal bone segment, allowing rapid remodelling of the interpositional autogenous bone graft.

Autogenous bone grafting remains the gold standard in alveolar reconstructive techniques; however, we selected a xenograft block graft in our study group to eliminate the complications associated with harvesting the autogenous bone graft such as donor site morbidity and patient discomfort. Fixation of the graft using a plate and screws aimed at eliminating micromotion at the graft–recipient interphase, which might increase rate of graft resorption. This was emphasized by Tamimi et al.[6].

Also, it aimed at preventing the graft tipping out of the recipient bed with subsequent failure. In contrast, a study by Scarano et al.[7] that the use of miniplates and screws as they were the cause of fracture of the osteotomized segments. The study used 56 blocks of collagenated equine bone and concluded that the rigidity of the equine collagenated blocks eliminated the use of miniscrews and miniplates and simplified the technique.

The radiographic calculation of the final vertical gain in each group of this research was very similar to Mounir et al.[8], who depended on linear measurements taken from CBCT preoperatively, immediately, and 6 months postoperatively to assess the percentage of marginal bone loss in the ridge-splitting technique with immediate implant placement in the deficient anterior maxillary alveolar ridges.

In our research, the nasal floor was used as a fixed reference by adjusting the cross-sectional long axis in the centre of the area of interest and bisecting it (showing the buccolingual dimension. On the cross-sectional CBCT view and at each proposed implant site, a line was drawn starting from the crest of the ridge till the apical level. The height was recorded preoperatively, immediately (1 week), and 6 months postoperatively, and the difference between them was recorded in millimetres. As it was not possible to standardize the preoperative ridge height and immediate height gain (it is a case dependent), the percentage of resorption for each group was calculated and compared with those of the other group.

The radiographic results of the control group showed a mean increase in the final vertical gain by 20.7%, which is better than that of Louis et al.[9] and Ciocca et al.[10] of 13% and 18% respectively. The radiographic results of the study group have revealed a mean increase in the final vertical bone gain by 31.6%, and a 100% success in implant installation was achieved, where all the elevated segments received dental implants (10 and 12 mm long). The study group results were less than the study reported by Scarano et al.[7], who stated a median vertical bone gain of 40.4% after the 4-month postoperative period in the lower 7 position and a median of 30.4% bone gain in the lower 5 position.

The control group showed greater resorption than that of the study group. Schettler and Hotter Mann[11] believed that less bone resorption occurred with interpositional grafts because the graft is surrounded by bone and periosteum on all sides, thus facilitating rapid vascular connection with the surrounding tissues. Also, Scarano et al.[7] stated that interpositional grafting offers the advantage of guaranteeing a greater vascular supply to the graft and allows optimal use of the basal bone which is less prone to resorption.

Funding

None.

Ethical approval

Approved by the ethics committee of Cairo University.

Competing interests

None.

Patient consent

All patients were consented.

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