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Original Article

Radiographic Assessment Of The Accuracy Of Vertical Ridge Augmentation For Posterior Mandible Using Computer Guided Onlay Versus Free Hand Onlay Grafting Procedure: A Randomized Clinical Split Mouth Trial

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Abstract

Aim: The aim of this study is the radiographic evaluation of the guided onlay bone grafting approach versus the freehand onlay grafting approach in the vertical augmentation of posterior mandibular ridges using bone blocks harvested from the chin by patient specific cutting guide.
Subjects and methods: In this split mouth, controlled clinical trial, 10 patients with bilateral vertically deficient posterior mandibular ridges were enrolled into the study. For each patient, one side was augmented using guided onlay grafting procedure, and the other side using freehand onlay bone grafting technique. The bone blocks in both groups were both harvested from the chin using patient specific surgical cutting guide. This was followed by the radiographic superimposition of the preoperative CBCT scan with the immediate postoperative CBCT scan for each patient to the test for the accuracy of each technique.
Results: The accuracy was estimated by calculating the mean value of planned vertical bone gain of the guided group **(4.24 ±1.78) mm** compared to the mean value of the actual immediate postoperative bone gain **(4.5±1.5) mm**, and the difference was not statistically significant (p=0.75). while in the control group the planned vertical bone gain of the guided group **(3.17 ±1.26) mm** compared to the mean value of the actual immediate postoperative bone gain **(4.5±1.5) mm**, and the difference was statistically significant (p=0.014).
Conclusion: The use of patient specific surgical guide for the harvesting and fixation of onlay bone block in the vertically deficient posterior mandible yields more accurate results than the freehand onlay technique.

Keywords: Alveolar ridge deficiency, vertical augmentation, onlay bone graft, computer-guided bone augmentation, accuracy.

Introduction

Dental implant surgeries may be hindered by alveolar bone resorption resulting from tooth loss ***(Raghoebar et al., 2001).*** Bone augmentation techniques play a critical role in the functional and aesthetic success of prosthodontic restorations in the context of alveolar crest atrophy. These procedures allow for the proper positioning of implants ***(Cristoforetti et al., 2019)***.

Because autologous bone grafting delivers a greater bone survival rate and implant success due to the augmentation material's non-immunogenic, osteo-inductive, and osteoconductive qualities, it is now regarded as the "gold standard" among bone restoration procedures ***(Cristoforetti et al., 2019).***

Compared to other surgical approches, the onlay bone grafting technique using autogenous bone is considered the best option. Onlay grafts have been shown to have a high success rate in vertical augmentation of alveolar ridges and may be utilised for both immediate and delayed implant insertion ***(Felice et al., 2009).***

When compared to extraoral bone harvesting, intraoral donor sites are more favourable in terms of accessibility, closeness to recipient sites, morbidity, operating time, expenses, and the improved quality of the regenerated bone ***(Cristoforetti et al., 2019; Zhu et al., 2022).***

A good donor location for membranous mono-corticocancellous bone grafts with sufficient volume that can fill up space defects up to three teeth wide is the symphysis area. When compared to other donor locations, the inter-foraminal distance provides a somewhat safe area, with the exception of nourishing vascular systems and incisive canals ***(Osman and Atef, 2018).***

Planning the amount of bone augmentation required for the final prosthesis, however, is one of the main challenges in the rehabilitation of patients with mandibular and maxillary deficiency ***(Ciocca et al., 2015).*** Furthermore, the results of bone augmentation and implant restoration are not satisfactorily predictable because traditional free-hand bone block grafting relies only on the surgeon's experience and lacks orientation with the final prosthesis and prosthetically driven tissue augmentation target shape. Furthermore, poor fit between the recipient region and the block graft may cause connective tissues to develop between them, impeding the effectiveness of graft integration. ***(Zhu et al., 2022).***

The use of CAD/CAM technology in dentistry has made it possible for the surgeon to do procedures with less risks. When considering freehand techniques, computer-designed stereolithographic surgical guidance could be more advantageous if the surgeon is aware of the degree of accuracy achievable by this method ***(Cristoforetti et al., 2019).*** By employing this innovative method, the surgeon may fully benefit from pre-procedural surgical planning based on CBCT and use a stereolithographic template ***(De Stavola et al., 2017; Cristoforetti et al., 2019).***

Drawing from this technology, the aim of this study is to evaluate the accuracy of using patient specific surgical guides for the fixation of onlay bone block in the vertically deficient posterior mandible versus the freehand onlay technique.

Subjects and Methods

I. Study design:

This is a randomized clinical trial, with a split-mouth design, that included ten patients with bilateral posterior vertically deficient mandibular ridges. Patient specific surgical guide was used to fix onlay bone block to one side while the free hand onlay bone grafting technique was used to fix the bone block to the other side in each patient. Both bone blocks were harvested fronm the chin using 3d printed surgical guide. Each surgical approach was administered to arches (10 patients).

II. Setting and locations:

The outpatient clinics of Cairo University's Department of Oral and Maxillofacial Surgery, Faculty of Oral and Dental Medicine, were used to select participants for this split-mouth randomised clinical study. December 20, 2021 marked the enrollment of the first participant, and June 20, 2022 marked the recruitment of the last participant.

III. Study registration:

The Ethics Committee of Cairo University's Faculty of Dentistry gave its approval to the project. (**NCT05512078**) is the registration number for the clinical study on www.clinicaltrials.gov.com. The study adhered to the Helsinki Declaration's ethical guidelines for using human participants in medical research. Prior to participation, each participant gave written, informed consent. The deidentified participant data for each individual can be made available upon request to the corresponding author.

IV. Eligibility criteria and selection method:

The study’s inclusion criteria were: both patients’ posterior mandibular ridges had to be atrophic with alveolar ridge height of less than 7 mm measured from the crest of the ridge to the inferior alveolar canal; Patients also had to have good oral hygiene, no prior surgeries in the study area, and ; patients' ages ranged from 25 to 55 years; patients with a history of alveolar surgical interventions and those with systemic diseases that might impede normal bone and wound healing were excluded.

V. Randomization:

Each patient's right and left posterior mandibular sides received randomized treatment approach in this split mouth trial. Using opaque sealed envelopes with the group assignment for each side inside, allocation concealment was accomplished. Bias was eliminated through the sequence generating and envelope preparation steps. Following patient registration, a randomly selected envelope was opened to show the allocation of the right and left side groups. The group assignment was hidden from the statistical analyst, but because of the nature of the surgical interventions involved, the assessors, participants, and surgeons were not blinded.

VI. Preoperative preparations:

Each patient provided a complete medical and dental history, including information on their chief complaint, dental health, medical history, oral hygiene, interarch space, mucosal tissue biotype, opposing dentition status, and maxillomandibular relationship. Palpation was used in the clinical examination to check for soreness, undercuts, and edoema. Planmeca ProMax 3D (Helsinki, Finland) was used to obtain preoperative CBCT scans for each patient in order to assess the vertical dimension of the deficient alveolar ridges and verify study eligibility according to deficiency criteria. Patients completed consent forms after being fully briefed about the procedure's nature.

VII. Virtual planning and guides fabrication:

The study group's patients' CBCT scans' DICOM data were imported into the planning programme (Mimics21, Materialise, Leuven, Belgium). The mandible was separated using a 3D model of the bony skeleton that was produced during the Segmentation phase of the virtual planning process. The programme (3-Matic, Materialise, Leuven, Belgium) used to design the surgical guides from the exported model.

In order to precisely harvest two symphyseal bone blocks with patient-specific dimensions preplanned so as to place the osteotomy lines at least 5 mm away from the inferior border of the mandible, the bilateral mental foramen, and the root apices of the anterior teeth, the first step in the virtual planning process was the digital design of the cutting guide. Subsequently, a second guide was virtually designed to guarantee precise intraoperative placement and attachment of the onlay bone block to the recipient area **(Figure 1).**

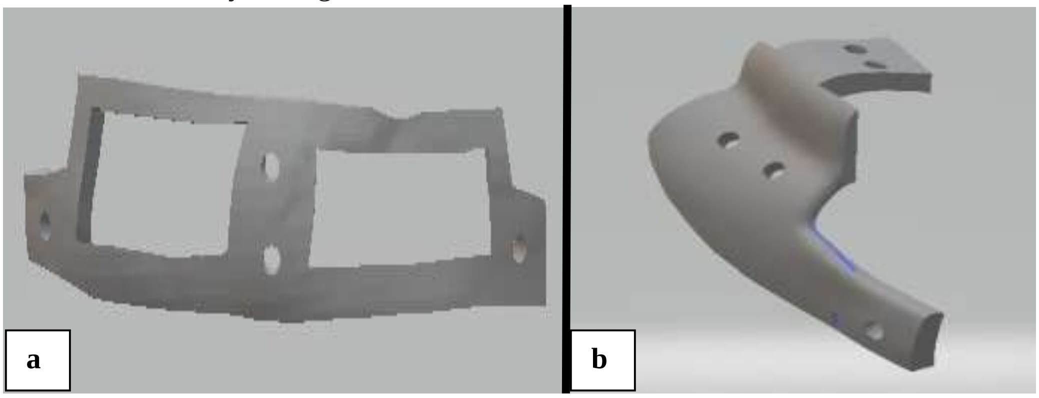

Figure 1: Virtual planning of the a: cutting guide, b: fixing guide.

Finally, each of the guides were 3D manufactured from resin utilising additive manufacturing technology. Before surgery, they were immersed in CIDEX Solution, which contains chelating agents, buffers, and a corrosion inhibitor (ASP International GmbH, Switzerland), for a length of 12 hours then cleansed with saline.

VIII. Surgical Intervention:

All ten patients had surgery while under general anaesthesia in addition to localised infiltration for hemostasis and pain management. Using a vestibular incision made away from the mucogingival junction, the chin area was surgically exposed. First, the mentalis muscle was exposed by making a 45-degree incision, and then the flap was extended 90 degrees down to the bone. Two releasing cuts were made to extend the flap to the recipient sites' midcrestal flaps, and then the entire mucoperiosteal flap was reflected to expose the entire symphysis region. The bilateral visualisation and exposure of the mental nerve resulted from its skeletonization.

For the study group patients, two titanium osteosynthesis mini-screws were used to seat and secure the cutting guide in the pre-planned position, then, using a disc that was bevelled in order to accomplish four osteotomy outlines guided by the fixed surgical stent **(Figure 2)**, the two bilateral bone blocks were outlined. The cutting guide was then removed and both bone blocks were then harvested by elevation that began from the medial cut and moved towards the midline. This was done to shield the mental neurovascular bundle from needless damage. The two corticocancellous bone blocks were tapped out using angled chisels and kept in cold saline solution after the blocks were separated using razor-sharp straight bone chisels to link the four osteotomy lines bilaterally. on order to prevent bleeding and changes to important tissues on the floor of the mouth, the lingual cortex was kept intact. Spongy bone particles were extracted from the symphysis using an auto chip maker bur (ACM), and combined 1:1 with xenogenic bone transplant.

Figure 2: The osteotomy lines outlined by the cutting guide.

Subsequently, the excised bone block was fastened to the positioning guide's fitting surface outside the patient's mouth using mono cortical micro screws.

A 2 mm diameter tissue bur was used to decoraticate the recipient location in order to improve the grafted block's blood supply. After positioning the onlay guide on the study group's designated inadequate ridge, the 3D model's two inferior screw holes were drilled in accordance with the plan, and the guide was taken out. After that, the harvested block was secured to the positioning guide, which only covered a portion of the onlay block, using two tiny screws supracrestally, as pre-designed on the 3D model. Next, two mini screws were used to secure the block fixed to the guide to the ridge, inserting them into pre-drilled screw holes **(Figure 3).** To secure the block to the underlying ridge, two more mini screws were driven into the exposed portion of the block that was not covered by the guide. The guide was removed when the two inferior micro screws holding it to the block were removed. Finally the space between the grafted block and the ridge was filled with a mixture of pre-made autogenous and xenograft bone particles.

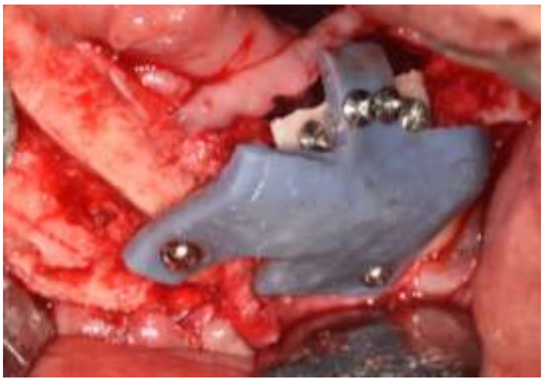

Figure 3: The onlay bone graft fixed to the ridge by the fixing guide.

On the other hand, the patients in the control group had the harvested onlay bone block secured with micro screws conventionally, and the space between the grafted block and the ridge was filled with a mixture of pre-made autogenous and xenograft bone particles.

The rough bony borders of all the repaired alveolar ridges in both groups were detected and smoothed, and a collagen sponge (SURGISPON® Aegis Lifesciences PVT.Ltd., India) was used to fill the donor site. The suturing material employed was polyproline 4-0, Assucryl®, Assut sutures, Switzerland, which is non-resorbable monofilament.

IX. Accuracy assessment radiographically

The technique of superimposing preoperative and immediate postoperative CBCT scans and the virtual plan using the "Image registration" function in mimics 21.0 (Materialise, Leuven, Belgium) was used to measure the augmentation accuracy. In order to perform this process, data had to be extracted from the preoperative CBCT and integrated into the immediate postoperative CBCT together with a coloured STL surface **(Figures 4 &5).** Using a point scale approach for all reference points, the condyles, coronoid processes, mental foramen, and inferior border of the mandible served as anatomical markers for alignment

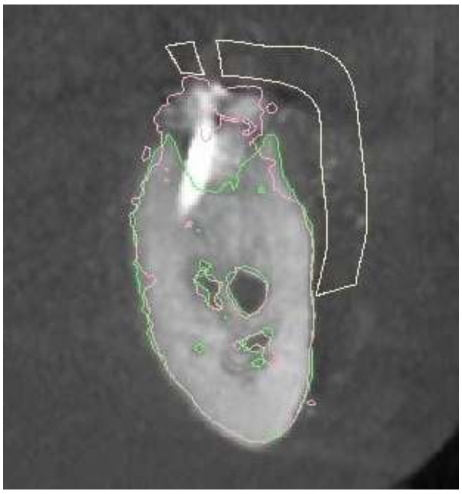

Figure 4: Coronal view showing superimposition of preoperative CBCT scan (green outline) and the planned guide (white outline) on top of the immediate postoperative CBCT scan (pink outline) of the same patient in the study side.

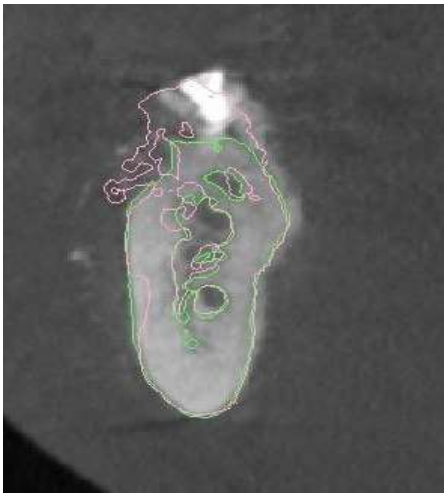

Figure 5: Coronal view showing superimposition of preoperative CBCT scan (green outline) on top of the immediate postoperative CBCT scan (pink outline) of the same patient in the control side.

Statistical analysis

All Data were collected, tabulated, and subjected to statistical analysis. Statistical analysis was performed by SPSS (Statistical package for the social sciences- IBM Corp., Armonk, NY), while Microsoft Office Excel was used for data handling and graphical presentation. Quantitative variables were described by the Mean + Standard Deviation (SD) or median and range. Qualitative categorical variables were described by frequencies and Percentages. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests for further choice of appropriate parametric and non-parametric tests.

All the variables were found normally distributed, thus allowing the use of parametric tests. Independent samples t test was applied to compare the means of the two groups. Significance level is considered at $P < 0.05$ (S) Two Tailed tests are assumed throughout the analysis for all statistical tests.

Results

I. Demographic data

The mean age of this split-mouth study participants was (43.2±6.86) years. The patients of this study consisted of 3 males (30%) and 7 females (70%).

II. Clinical results:

At the postoperative follow up sessions, patients were assessed for wound healing, suture breakdown, dehiscence, pain, swelling, infection, hematoma and bleeding or graft exposure. Most patients reported no or minimal pain at the site, along with no discomfort or functional limitations.

The soft tissue healing demonstrated overall uneventful progress in most cases. However, in one patient who had a poor oral hygiene, soft tissue dehiscence was observed after 1 month. Interestingly, the dehiscence occurred specifically on the control side. After a follow-up period of 6 months and strict adherence to oral hygiene measures, the soft tissue dehiscence became more pronounced on the control side. In contrast, the study side exhibited no signs of soft tissue dehiscence and maintained good soft tissue quality throughout the observation period.

III. Radiographic results

The accuracy of the procedure was estimated by calculating the mean value of planned vertical bone gain of the guided group (**4.5±1.5**) mm which was comparable to the mean value of the actual immediate postoperative vertical bone gain (**4.24±1.78**) mm, and the difference was not statistically significant (p=0.75) showing a high degree of accuracy (**Table 1**). In contrast, the mean value of planned vertical bone gain of the control group (**3.57±1.26**) mm which when compared to the mean value of the actual immediate postoperative vertical bone gain (**4.5±1.5**) mm, the difference was statistically significant (p=0.014) (**Table 2**).

Table 1: Mean and standard deviation (SD) values between the planned and actual immediate postoperative vertical bone gain in the guided group in mm

Group	Mean	SD	Mean difference	*t* value	*p*-value
Planned gain	**4.5**	**1.5**	**0.26**	**0.1**	**0.75 ns**
Actual Gain	**4.24**	**1.78**			

Significant level p≤0.05, ns=non-significant

Table 2: Mean and standard deviation (SD) values between the planned and actual immediate postoperative vertical bone gain in the control group in mm

Group	Mean	SD	Mean difference	*t* value	*p*-value
Planned gain	**4.5**	**1.5**	**1.33**	**0.1**	**0.014 s**
Actual Gain	**3.17**	**1.26**			

Significant level p≤0.05, ns=non-significant

Discussion

Onlay bone grafting operations have improved from the initial reported 50% failure rate, but issues still arise at the donor site. These issues include the risk of damaging important structures, the lack of anatomical guidance during fixation—a challenging step that can be particularly so for novice surgeons—and the possibility of incorrect bone block angulation, which can result in inadequate augmentation or over-enhancement of the ridge contour. As such, the success of this procedure depends on the skill of the operator. Moreover, worries over full-arch onlay grafting implant survival rates continue ***(Sheikh et al., 2017).*** The positioning and stabilization of a grafted bone block are key factors in achieving high accuracy, and imprecise graft adaptation may affect graft integration, eventually leading to its loss ***(Zhu et al., 2023).***

No equipment or processes now described or used for bone cutting can prevent danger of anatomical structural damage since the freehand approach is unpredictable with respect to the anatomical important structures. When transferring the location of these anatomical features from the CBCT to the patient intraoperatively, the operator has relatively few points of reference, which increases risk. It has been discovered that computer-guided implant surgery is more precise than traditional freehand drilling operations because of the working direction enforced by the surgical guide ***(Westendorff et al., 2005; De Stavola, Fincato and Albiero, 2015; Osman and Atef, 2018).*** This is why this study focused on the use of 3D printed surgical guides for the cutting and positioning of onlay bone block.

The devices known as 3D printed surgical guides are employed to assist in the realignment of the bone, direct the insertion of internal fixations such as screws, and determine the extent of osteotomy. With the use of guide templates, the surgeon may choose the depth, direction, and osteotomy angle as well as the screw route, enhancing the accuracy, safety, and consistency of the operation. They may also completely translate the treatment plan to the execution stage, producing results that are less reliant on the skill of the surgeon and more predictable than with a freehand approach, and they may even shorten operating room durations. These methods are useful for mandibular reconstruction in cranial and maxillofacial surgery ***(Chen et al., 2016; Papagelopoulos et al., 2018; Cristoforetti et al., 2019).***

Using a surgical guide made from a stereolithographic model to harvest bones provides the surgeon with the chance to introduce information on the superficial position of the osteotomy lines—that is, the shape of the harvestable bone block on the surface of the bone—into the operating room. The osteotomy can be tailored to the precise location of anatomical components using a computer-guided bone harvesting technique, reducing or eliminating the chance of injury ***(De Stavola et al., 2017)***

Recipient sites of both study and control groups undergone decortication prior to bone block fixation in our study. This was based on the theory that decortication, which encourages bleeding and makes it easier for progenitor cells and blood vessels to reach a bone-grafted location, is done allegedly to speed up the healing process. Decortication may also strengthen the physical connection between grafted bone and the recipient site ***(Greenstein et al., 2009)***.

By superimposing the preoperative plan with the post-operative CBCT scan, the total procedure's precision in this inquiry was assessed. The average planned vertical bone gain in the guided group (4.24 ± 1.78 mm) was found to be comparable to the mean value of the actual immediate postoperative bone gain (4.5 ± 1.5 mm) using the condyles, coronoid processes, mental foramen and inferior border of the mandible as fixed anatomical reference points during registration of pre and post operative models This difference wasn't determined to be statistically significant ($p=0.75$). Meanwhile, the difference in control group between the planned vertical gain (3.57±1.26 mm) and the actual vertical gain (4.5 ± 1.5 mm) was statistically significant ($p=0.014$). This means that surgical fixation guides can be used to accurately place and fix the harvested onlay bone block to the recipient site according to the preplanned position, thus increasing the accuracy of the procedure and the success rate of implant surgeries.

The findings of our study are in accordance with a study by ***Zhu et al., (2022)*** who also studies the accuracy of a complete digital workflow in comparison to the freehand technique and concluded that Compared to a free-hand procedure, the surgical guides for intraoral block bone harvesting, cutting, and fixation utilising a fully computerised workflow may provide surgical outcomes that are more precise and predictable.

It is noteworthy that none of the ten cases reported postoperative parasthesia or wound site infection at the donor site which could be attributed to the high accuracy of the cutting and harvesting procedure that was provided by the cutting surgical guide which is in accordance with the studies made by ***(De Stavola et al., 2015; Osman & Atef, 2018; Zhu et al., 2022).***

Conclusion

Using 3D printed patient specific guide for the fixation of onlay bone block is superior to the freehand fixation technique in terms of accuracy and adherence to the pre-operative virtual plan.

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- Cairo university on 27/7/221, approval number:10721

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