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RADIOGRAPHIC ASSESSMENT OF COMPUTER GUIDED MODIFIED RIDGE SPLITTING TECHNIQUE VERSUS CONVENTIONAL FREE HAND TECHNIQUE IN MANAGEMENT OF HORIZONTAL DEFICIENCY IN POSTERIOR MANDIBLE: A RANDOMIZED CONTROL CLINICAL TRIAL

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ABSTRACT

Purpose: The aim of this study was radiographic assessment of computer guided modified ridge splitting technique versus conventional free hand technique in management of horizontal deficiency in posterior mandible.

Methodology: Eighteen patients with horizontally deficient posterior mandibular ridges were equally and randomly allocated into two groups; in the study group (group A), patients underwent augmentation using guided modified ridge splitting grafting procedure, on the other hand, in the control group (group B) , they underwent augmentation using conventional free hand modified ridge splitting grafting technique. Each patient was assessed radiographically using cone beam computed tomography (CBCT) in the following intervals pre-operatively, immediately post-operatively and four months post-operatively for assessment of horizontal bone gain.

Results: The postoperative recovery and healing phase were uneventful in all patients. In the study group, the mean horizontal bone gain after four months was **(4.93±0.64) mm**, whereas in the other group was (**4.46±0.67**) mm and the difference was statistically significant (p=0.038).

Conclusion: Using a 3D-printed, patient-specific guide for harvesting and fixation of the modified cortical shell offered superior and better horizontal bone gain compared to the freehand harvesting and fixation technique.

KEYWORDS: Alveolar ridge deficiency, horizontal augmentation, modified ridge splitting, computer-guided bone augmentation, accuracy.

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INTRODUCTION

Management of horizontally deficient posterior mandibular alveolar ridge represents a great challenge regarding anatomical variations and selection of the appropriate treatment modalities with subsequent necessity for continuous search for different treatment modalities. Among these treatment options are autogenous bone grafting, ridge splitting, guided bone regeneration using bone &collagen membrane, titanium or peak meshes and sub-periosteal implants. [1, 2, 3]

Autogenous bone grafts remain the gold standard for bone augmentation for several reasons including their higher survival rates, non-immunogenic nature and osteo-inductive properties. When it comes to donor site; extra-oral & intra-oral sites are used and the latter one has many advantages such as easier accessibility, proximity to the recipient site, reduced morbidity, shorter operative times, lower costs and improved quality of regenerated bone when compared to extra-oral donor sites. Even though, several attempts were made to overcome the disadvantages of autogenous bone grafts which include: (a) donor site morbidity, (b) potential for volumetric instability, (c) limited bone availability and (d) increased surgical time. Accordingly, other bone graft substitutes (xenografts, allografts & alloplasts) were introduced to overcome these limitations; nevertheless, they act as scaffolds with no osteo-inductive properties. [4, 5, 6]

Moreover, ridge splitting is introduced as a treatment option for augmentation of horizontally deficient posterior mandibular alveolar ridge, although this technique has its own limitations regarding lateral bone gain and significant bone resorption, additionally, it is technically demanding with a steep learning curve that can result in complications such as loosening, fracture, or incomplete separation of the buccal plate with subsequent negative impact on the success of bone grafts and implant placement. [7]

Furthermore, an alternative approach utilizing remote cortical shell grafts harvested from the outer cortical retro molar mandibular plates was established in order to reinforce deficient alveolar ridges and cover the cancellous bone. [8]

One of the major challenges in rehabilitating patients with mandibular and maxillary deficiencies is planning the necessary bone augmentation to support the final prosthesis. Additionally, the results of bone augmentation and implant restoration are often unpredictable, as traditional free-hand bone block grafting depends on the surgeon's experience and does not always align with the shape required for prosthetically guided tissue augmentation. A poor fit between the recipient site and the graft can lead to connective tissue formation, which can prevent proper graft integration. [9,10]

Accordingly, this study utilized computer guided surgical guide which offered the following advantages; accurate placement of the pre-planned cuts & the cortical shell dimensions, anatomical considerations by avoiding mal-split of the block or harming the nerve , prevention of mal-positioning or inclination of the cortical shell and accurate pre-planned horizontal bone gain with subsequent ability to fully leverage pre-surgical planning based on CBCT and use a stereolithographic template. [4 , 5]

Consequently, this study aimed at radiographic assessment of computer guided modified ridge splitting technique versus conventional free hand technique in management of horizontal deficiency in posterior mandible.

PATIENTS AND METHODS

Study design:

Eighteen patients with posterior horizontally deficient mandibular ridges were included in this randomized study. The first participant was enrolled on December 20, 2023, and the last participant was recruited on July 20, 2024. Participants were selected from the outpatient clinics of Oral and Maxillofacial

Surgery department, Faculty of Dentistry, Cairo University. This study was approved by the research ethics committee of Faculty of Dentistry, Cairo University, with the reference number (12124) and was registered on clinicaltrials.gov by the ID: NCT06195761.

Randomization and allocation:

Each patient in this study was randomly assigned equally into two groups (9 patients per group) without bias. Sequence generation was performed using computer software www.random.org. Allocation was concealed from the patients and the clinicians.

In the study group, augmentation was performed using guided modified ridge splitting grafting procedure, on the other hand, in the control group, patients' undergone augmentation using conventional free hand modified ridge splitting grafting technique. Patients were selected according to the following inclusion criteria: (1) patients with horizontally deficient posterior mandibular alveolar ridge ranged from 2 to 4 mm, (2) patients with age range from 25 to 55 years, (3) male and female patients and (4) patients with good oral hygiene. Meanwhile, patients with prior surgeries in the study area and those with systemic diseases that might impede normal bone and wound healing were excluded.

Intervention:

Preoperative preparations:

A detailed and comprehensive history (medical, dental & history of chief complain) were obtained from each patient. Furthermore, intra-oral examination was conducted accurately to evaluate interarch space, mucosal tissue biotype, opposing dentition status, and maxillomandibular relationship. Moreover, preoperative CBCT scans were obtained using a Planmeca ProMax 3D (Helsinki, Finland) to evaluate the vertical dimension of the deficient alveolar ridges and confirm study eligibility based on deficiency criteria. Patients completed consent forms after being thoroughly informed about the procedure.

Virtual planning and guides fabrication:

The DICOM data from the CBCT scans of the study group's patients were imported into the planning software (Mimics21, Materialise, Leuven, Belgium). During the Segmentation phase of the virtual planning process, a 3D model of the bony skeleton was created to isolate the mandible. The surgical guides were then designed using the exported model in the software (3-Matic, Materialise, Leuven, Belgium).

In order to precisely harvest the cortical bone shell with patient-specific dimensions preplanned so as to place the osteotomy lines the crestal cut, the two vertical cuts and the inferior cut at least 5 mm from the inferior border of the mandible, away from the inferior alveolar nerve, and the mental nerve, The initial step in the virtual planning process involved the digital design of the cutting guide. Following this, a second guide was virtually created to ensure accurate intraoperative placement and secure attachment of the cortical bone shell to the recipient site **(Figure 1).**

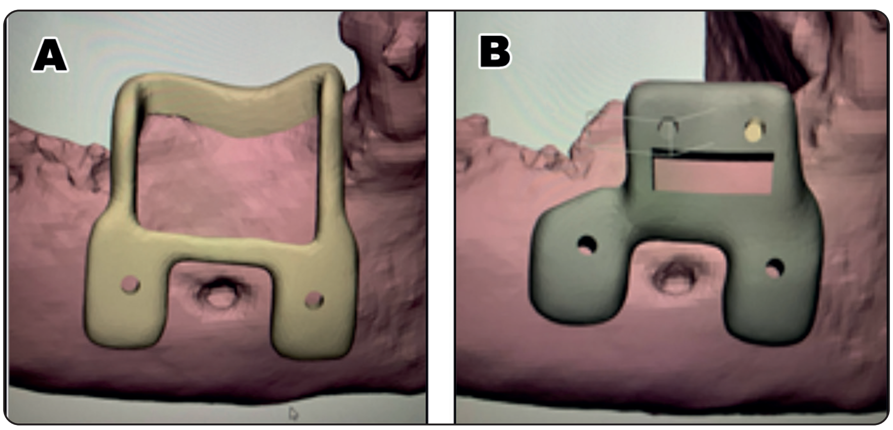

Fig. (1) Virtual planning of the A: cutting guide, B: fixing guide.

Finally, each guide was 3D printed from resin using additive manufacturing technology. Prior to surgery, the guides were submerged in CIDEX Solution, which contains chelating agents, buffers, and a corrosion inhibitor (ASP International GmbH, Switzerland), for 12 hours and then rinsed with saline.

Surgical Intervention:

Intra-operative procedures: (in both groups)

All the patients underwent treatment in aseptic conditions under local anesthesia with the following sequence; all patients received an intramuscular injection of sulbactam 250 mg + ampicillin 500 mg (Unictam 750 mg, Medical Union Pharmaceuticals, Ismailia, Egypt) one hour prior to surgery and rinsed with chlorhexidine Gluconate mouthwash 0.1% (Antiseptol, kahira pharmaceutical, Egypt) for one minute immediately before we started, a local anesthetic containing a vasoconstrictor (ARTINIBSA 40 mg/ml + 0.01 mg/ml, Inibsa Dental S.L.U, Barcelona, Spain) was infiltrated into the mandibular vestibule, ensuring the inferior alveolar nerve was not blocked, allowing for minimal patient sensation that would alert the surgeon to the proximity of the nerve during the osteotomies, a crestal incision was made starting at the retro molar area, passing over the deficient premolar–molar region and extending into the gingival sulci of two anterior teeth. This was followed by a mesial oblique incision, then a complete trapezoidal mucoperiosteal flap was reflected to expose the entire lower posterior region, then a piezoelectric surgical handpiece was used to perform the osteotomy outlines one crestal superior cut, one inferior cut and two vertical cuts guided by the fixed surgical stent under copious saline irrigation (this step was done through the harvesting guide in the study group , and free hand in the control group) & then razor sharp straight bone chisels were used to connect the four osteotomy lines bilaterally and the corticocancellous bone block was tapped out using angled chisels and was stored in cold saline solution. The lingual cortex left intact to avoid alterations to vital structures in the floor of the mouth and the inherent risk of bleeding.

Intra-operative procedures – continued in the study Group:

The harvesting guide accurately was adapted on the exposed area as planned on the three-dimensional model and was fixated in place using titanium osteosynthesis mini screws, through which the four cuts are done by the saw disk. The harvesting guide then removed after the four cuts finished by the piezo then the split was initiated by placing a spatula chisel and was marked with a length reference, through the crestal cut, followed by the insertion of a second spatula chisel on the lingual side. Finally, a third bi-beveled chisel (Triple Chisel Technique) was gently malleted between the two spatulas until the outer cortex was separated as shown in **(Figure 2)**. Then the cortical shell was harvested after chiseling & fixated to the fixation guide using two micro screws as designed on the three-dimensional model with the guide covering a part of the cortical shell only. Then the guide with the fixated block was fixated on the ridge using two mini screws in the pre-drilled screw holes as shown in (**Figure 3**). Moreover, two more micro screws were drilled in the exposed part of the block that was not covered by the guide's hardware buccally to fixate it to the underlying ridge. The block accurately was placed on the ridge as planned on the three dimensional model. The two superior & the inferior mini screws were removed followed by removal of the guide. Finally, ACM bur was used to drill out some autogenous bone particulate from the body of the mandible from the same site and was inserted between the ridge and the grafted bone block.

Intra-operative procedures – continued in the control Group:

The harvested free hand bone block was fixed free hand on the ridge buccally using 3 micro screws as shown in **(Figure 4)** . Then ACM bur was used to drill out some autogenous bone particulate from the body of the mandible from the same site. And finally, the autogenous bone particulate was packed between the mobilized bone segment and the grafted bone block. Periosteal scoring was done first to allow tension-free interrupted closure. Recipient sites were closed with simple interrupted and horizontal mattress sutures.

Postoperative medication regimen included Augmentin tablets1 gm (GlaxoSmithKline, Cairo, Egypt) every 12 hours for 7 days, Ibuprofen 600 mg (Brufen, Abbott Int., Cairo, Egypt) every eight hours for 7 days. Additionally, long acting corticosteroids; Methylprednisolone Acetate (Depo Medrol 80 mg/ml, Pharmacia, USA) was prescribed as a single dose immediately postoperatively. Moreover, patients were received post-operative instructions with great emphasize on the importance to follow strict oral hygiene regimen and they recalled for observation after 3 days and weekly thereafter for the first month and then once monthly for clinical assessment.

Furthermore, radiographic assessment was achieved by CBCT scan immediately and 4 months postoperatively to evaluate bone regeneration and final horizontal bone height. A total of three scans will be taken for each patient.

Radiographic assessment

Horizontal bone gain was measured radiographically using CBCT four months postoperatively. The augmentation was measured by superimposing planned preoperative and immediate postoperative CBCT scans along with the virtual plan using the "Image registration" function in Mimics 21.0 (Materialise, Leuven, Belgium). To perform this process, data from the preoperative CBCT were extracted and integrated with the immediate postoperative CBCT, along with a colored STL surface **(Figure 5)**. A point scale approach was used for all reference points, with the condyles, coronoid processes, mental foramen, and inferior border of the mandible serving as anatomical markers for alignment.

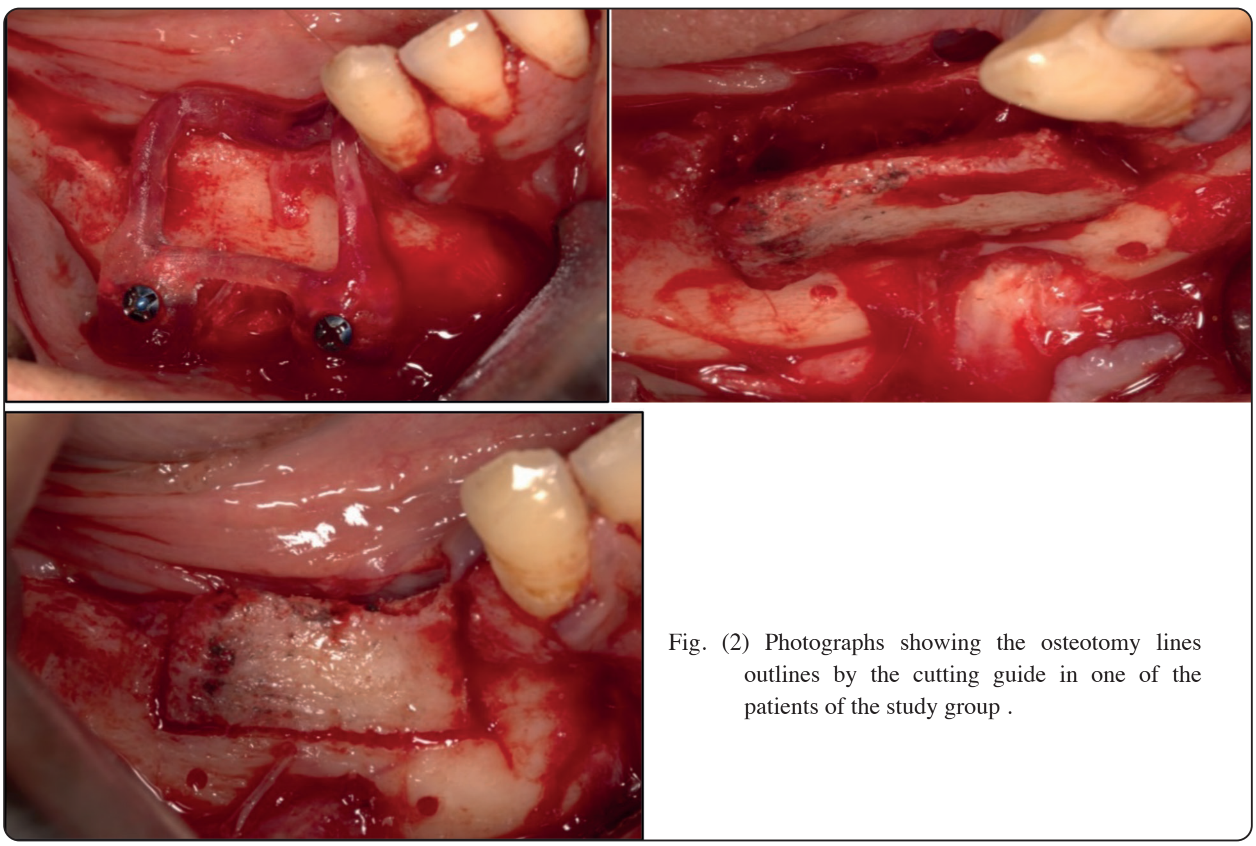

Fig. (2) Photographs showing the osteotomy lines outlines by the cutting guide in one of the patients of the study group .

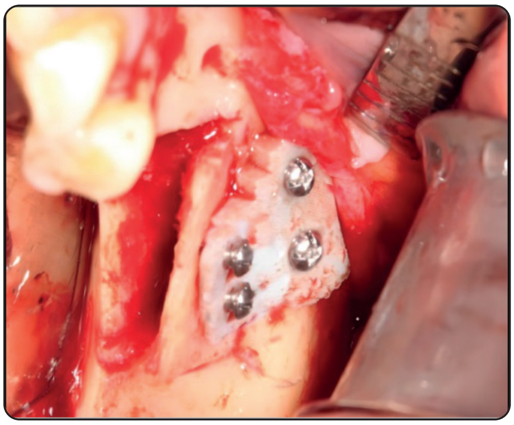

Fig. (3) Photograph showing the cortical shell bone graft fixed to the ridge by the fixing guide in one of the patients of the study group.

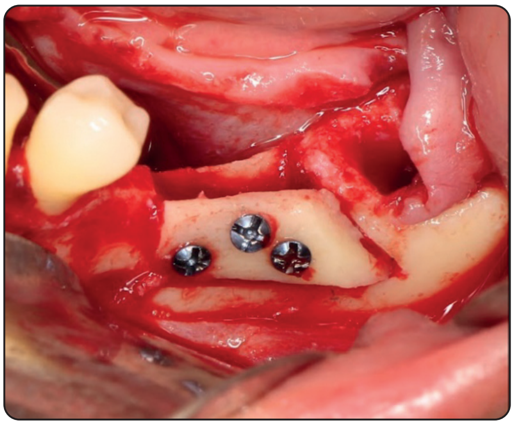

Fig. (4) Photograph showing the cortical shell bone graft fixed to the ridge freehand in one of the patients of the control group.

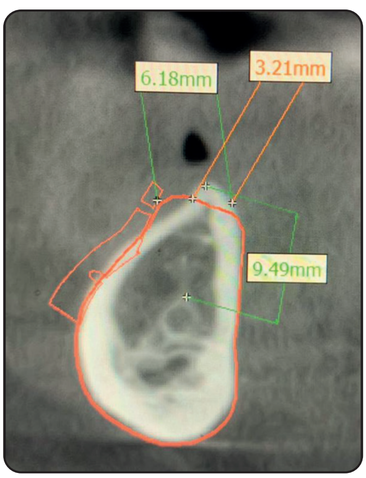

Fig. (5) Coronal view showing superimposition of preoperative CBCT scan and the planned guide on top of the immediate postoperative CBCT scan (pink outline) in one patient in the study group.

Statistical analysis

Data were coded and entered using the statistical package SPSS version 22. Data were summarized using mean and standard deviation. Data were explored for normality using Kolmogrov-S mirnov test. Comparisons of different outcomes for normally distributed data were done using independent t test, accuracy was evaluated by comparison between planned and actual bone gain by paired t test. . Categorical data was expressed as frequency and analyzed by chi2 test. P value less than or equal to 0.05 was considered statistically significant. **Chan Y. (2003):** Biostatistics102: Quantitative Data – Parametric & Non-parametric Tests. Singapore Med. J.; 44: 391-396

RESULTS

Demographic data

Eighteen cases were equally and randomly allocated in each group (9 cases per group). The study group included 6 female and 3 male patients with a mean age of the cases was 35.89±7.99, whereas, in the control group, 5 male and 4 female patients were included with a mean age of 32.22±6.33 as shown in (**Table 1**).

TABLE (1) Demographic data.

	Study group	Control group	P value
Age	35.89±7.99	32.22±6.33	0.2
Sex			
Male	3 (33.3%)	5(55.5%)	0.9
Female	6(66.7%)	4(45.5%)	

Clinical results:

In this study, patients reported little to no pain at the surgical site, with no discomfort or functional limitations. Soft tissue healing progressed uneventfully in most cases except in patient number 2 and number 8 in the control group who developed soft tissue dehiscence after one month post-

TABLE (2) Mean and standard deviation (SD) values between the study and control group of the horizontal bone gain.

Group	Minimum	Maximum	Mean	SD	Mean difference	t value	P value
Study	**3.81**	**5.9**	**4.93**	**0.64**	**0.47**	**2.16**	**0.038**
Control	**3.1**	**5.97**	**4.46**	**0.67**			

Significant level p≤0.05, ns=non-significant

operatively and treated by irrigation and wound care. In contrast, in the study group, there were no signs of soft tissue dehiscence with good soft tissue quality throughout the observation period.

Radiographic results:

In the study group, the mean horizontal bone gain four months post-operatively was **(4.93±0.64) mm**, whereas in the other group was (**4.46±0.67**) mm and the difference was statistically significant (p=0.038) **(Table 2).**

DISCUSSION

Alveolar bone resorption as a sequela following teeth extraction still remains a persistent challenge for clinicians in choosing the most suitable augmentation technique for each case. Several factors influence this decision, including (1) location of the defect, (2) remaining bone dimensions, (3) bone quality and (4) inter-arch space. Consequently, managing a horizontally deficient posterior mandibular alveolar ridge is a significant challenge that requires an ongoing exploration of various treatment options. [11]

In line with the literature, autogenous bone augmentation, such as the cortical shell technique is regarded as one of the most effective methods for reconstructing severely deficient bone. While this technique has proven reliable, it is technique-sensitive and requires advanced surgical skills, a lengthy learning curve, and carries the risk of damaging surrounding vital structures due to the lack of anatomical guidance during harvesting. Additionally, there is the potential for grafts to be misplaced or rotated, or for an insufficient gap to be left between the graft and the defective site due to the absence of guidance when creating the bone shell. Accordingly, this study aimed at radiographic assessment of computer guided modified ridge splitting technique versus conventional free hand technique in management of horizontal deficiency in posterior mandible. [12]

The freehand approach remains unpredictable regarding critical anatomical features. When transferring the location of these structures from the CBCT to the patient during surgery, the operator has limited reference points, which increases the risk of damaging critical structures, the absence of anatomical guidance during fixation, a particularly difficult step for less experienced surgeons—and the potential for incorrect bone block angulation, which could lead to insufficient augmentation or excessive enhancement of the ridge contour. As a result, the success of the procedure heavily relies on the surgeon's skill. Additionally, concerns about the long-term survival rates of implants in full-arch onlay grafting persist . The positioning and stabilization of a grafted bone block are crucial for achieving high accuracy, and any imprecision in graft adaptation can hinder its integration, potentially resulting in graft failure. [13, 14]

This study therefore concentrated on the use of 3D-printed surgical guides for the cutting and positioning of the cortical bone shell as computer-guided implant surgery offered greater precision than traditional freehand drilling, due to the controlled working direction provided by the surgical guide. (15)

In the study group, the surgical guide offered accurate placement of the pre-planned cuts &the cortical shell dimensions, anatomical considerations by avoiding mal-split of the block or harming the nerve, prevention of mal-positioning or inclination of the cortical shell, allow accurate pre-planned horizontal bone gain, guiding the insertion of internal fixations such as screws and determining the extent of osteotomy. With the use of these guide templates, the surgeon can precisely control the depth, direction and angle of the osteotomy, as well as the screw trajectory, improving the accuracy and consistency of the procedure resulting in outcomes that were less dependent on the surgeon's skill and more predictable than with a freehand approach with subsequent reduction of intra-operative time. These methods are particularly beneficial in mandibular reconstruction for cranial and maxillofacial surgery. (4)

The findings of the current study were in accordance with a study conducted by ***Zhu et al., (2022)*** who studied the accuracy of a complete digital workflow in comparison to the freehand technique and concluded that the surgical guides for intraoral block (bone harvesting, cutting and fixation) utilizing a fully computerized workflow provided more precise and predictable outcomes. (9)

With regard of the amount of horizontal bone gain, the mean horizontal bone gain after four months was (4.93±0.64) mm in the study group, whereas in the other group was (4.46±0.67) mm which was in agreement with the studies conducted by **Dan J Holtzclaw et al.** who revealed a comparable amount of horizontal bone gain (4.03 ± 0.67) mm.(1)

In the current study, none of the patients in the study experienced postoperative paresthesia or wound site infection at the donor site which was attributed to the high accuracy of the cutting and harvesting procedure provided by the cutting surgical guide which was in accordance with the studies conducted by ***(De Stavola et al., 2015; Osman & Atef, 2018; Zhu et al., 2022).*** However, in patient number 2 and number 8 in the control group, soft tissue dehiscence was noted after one month post-operatively and treated by irrigation and wound care which was attributed to poor oral hygiene & lack of patient's. (9,15,16)

With regard to the limitations came across this study, there were anatomical limitations such as proximity to the inferior alveolar nerve and thin cortical bone plates, mechanical and functional limitations and consequently more studies are advised to overcome these limitations.

CONCLUSION

In this study, using a 3D-printed, patient-specific guide for harvesting and fixation of the modified cortical shell offered superior and better horizontal bone gain compared to the freehand harvesting and fixation technique.

Competing interests

No conflict of interest

Ethical approval

The Ethics and research committee, Faculty of Dentistry, Cairo University approved the study and patients' consent was obtained.

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