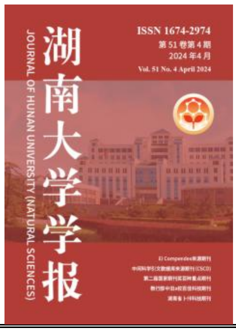

湖南大学学报（自然科学版）
Journal of Hunan University (Natural Sciences)

第 51 卷 第 4 期
2 0 2 4 年 4 月

Available online at http://jonuns.com/index.php/journal/index

Vol. 51 No. 4
April 2024

Open Access Article

https://doi.org/10.55463/issn.1674-2974.51.4.5

Evaluation of Computer-Guided Surgical Stents for Ridge Splitting with Simultaneous Implant Placement versus the Freehand Technique in Narrow Maxillary Alveolar Ridges

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Received: January 17, 2024 / Revised: February 10, 2024 / Accepted: March 8, 2024 / Published: April 30, 2024

Abstract: We present a modified technique of bone splitting based on precise patient-individualized preoperative planning by means of three-dimensional diagnostics and the use of surgical guide templates to enable reliable and minimally invasive bone splitting and spreading. The objective of this study was to assess the effectiveness of ridge splitting assisted by a surgical guide with simultaneous implant insertion compared to the freehand technique. The clinical study involved 20 patients with partially edentulous narrow anterior maxillary alveolar ridges who were candidates for dental implant placement. The patients were divided into two groups: study group (ridge splitting was performed using patient-specific surgical guides (PSGs)) and control group (ridge splitting was performed using the freehand technique). The radiographic assessment involved measuring linear changes in the vertical dimensions of the labial and palatal bone plates on cross-sectional cone beam computed tomography (CBCT) cuts, bone density, and ridge width. The data were collected and statistically analyzed using IBM® SPSS* Statistics Version 23 for Windows 10. The study group showed lower bone loss and complications than the control group, with a statistically significant difference. There was a statistically non-significant difference between the two groups in implant stability and bone density. PSGs decrease the occurrence of crestal ridge resorption, enable accurate cutting, and maintain the integrity of alveolar bone.
Keywords: computer-guided ridge splitting, freehand technique, surgical stent, crestal bone loss.

计算机引导手术支架在窄上颌牙槽嵴中同步种植体植入与徒手技术的评估

摘要：我们提出了一种基于精确的患者个体化术前计划的改良骨劈裂技术，通过三维诊断和使用手术导板模板来实现可靠且微创的骨劈裂和扩散。本研究的目的是评估与徒手技术相比，手术导板辅助同时植入种植体劈裂牙槽嵴的有效性。该临床研究涉及20名部分无牙颌上颌前牙槽嵴狭窄且适合种植牙的患者。将患者分为两组：研究组（使用患者专用手术导板（巴黎圣日耳曼）进行脊劈裂）和对照组（使用徒手技术进行脊劈裂）。射线照相评估包括测量横截面锥形束计算机断层扫描(CBCT)切口上唇骨和腭骨板垂直尺寸的线性变化、骨密度

和牙槽嵴宽度。使用适用于视窗10的IBM® SPSS*统计版本23收集数据并进行统计分析。研究组的骨丢失和并发症低于对照组，具有统计学显着性差异。两组种植体稳定性和骨密度之间无统计学差异。巴黎圣日耳曼可减少牙槽嵴吸收的发生，实现精确切割并保持牙槽骨的完整性。

关键词：计算机引导劈脊、徒手技术、手术支架、牙槽嵴骨质流失。

1. Introduction

Treatment of patients with atrophic ridges who require prosthetic rehabilitation is a common problem in oral and maxillofacial surgery. Following tooth loss, the alveolar ridge undergoes bone resorption in the vertical, transversal, and sagittal planes, and there is a greater reduction in bone thickness than in height [1].

The alveolar ridge splitting technique was a successful bone grafting technique for augmenting the horizontally deficient alveolar ridge with immediate implant placement, avoiding donor site morbidity, and shortening the overall treatment time. The main drawback of the conventional ridge splitting technique is the significant risk of experiencing poor splits, fractures, or even fenestrations of the buccal cortical plate of bone during separation, leading to substantial crestal bone loss around the implants [2].

Therefore, numerous clinical trials have been implemented to address complications through minimally invasive protocols. Examples include flap modification, the utilization of piezoelectric surgery, and the use of surgical templates [3].

Several studies have shown that guided surgery is more accurate, resulting in less technical sensitivity than the conventional freehand method [4].

This study was designed to introduce a minimally invasive computer-guided protocol for ridge splitting using patient-specific surgical guides (PSGs) for osteotomy preparation and compare it with the conventional freehand approach.

2. Patients and Methods

2.1. Study Setting and Population

The clinical study involved 20 patients, with 50 implants placed. Thirteen females and seven males participated in the study, all of whom had partial edentulous narrow anterior maxillary alveolar ridges that required dental implant placement. The patients were selected from an outpatient clinic of the Oral and Maxillofacial Surgery Department, Faculty of Dental Medicine, Al-Azhar University, Assiut Branch. The age ranged from 24 to 42 years. All patients were informed about the study and signed a consent form. Ethical approval was obtained from the Faculty of Dental Medicine, Al-Azhar University (Assiut Branch) ethical committee. This study followed the Declaration of Helsinki on medical protocol and ethics.

2.2. Inclusion Criteria

This study included patients with a deficient horizontal alveolar ridge in the anterior region of the maxilla (3-5 mm) that prevents standard dental implant placement, a vertical length of more than 8 mm, bone density of D3-D4, good oral hygiene, free from any systemic diseases, and over 18 years old of both genders.

2.3. Exclusion Criteria

Patients with inadequate ridge width or insufficient vertical height (less than 8 mm), a history of alcohol or drug abuse, heavy smoking, previous radiotherapy or chemotherapy, parafunctional habits, uncontrolled systemic diseases, a perforated or lost labial bony plate, or obvious undercuts on the labial cortical plate were excluded from the study.

2.4. Grouping and Intervention

The patients selected for this study were classified into two equal groups using online randomization software:

Study Group (Group A): Ridge splitting with simultaneous implant placement was performed using PSGs, including 10 patients (7 females and 3 males).

Control Group (Group B): Ridge splitting with simultaneous implant placement was performed using the freehand technique and included 10 patients (6 females and 4 males).

2.5. Preoperative Evaluation

Past and present dental histories were obtained through thorough clinical examinations and radiographic evaluations of all patients included in the study.

2.6. Ethical Considerations and Patient Consent

• The research protocol was approved by the ethical committee of the Faculty of Dental Medicine, Al-Azhar University, Assuit Branch (N: AUAREC202100009-14).

• All patients were provided with comprehensive information regarding the surgical procedure, postoperative follow-up, research procedures, and associated risks of study procedures.

• All patients agreed to participate in the study and signed the appropriate informed consent form from Al-Azhar University.

2.7. Surgical Procedure

Before undergoing surgery, patients were directed to rinse their mouths for about 1 minute with a 0.12% chlorhexidine gluconate mouthwash. This was followed by scrubbing around the mouth with gauze soaked in a 10% povidone-iodine solution. Local anesthesia was administered using Artinibsa (Inibsa, Barcelona, Spain), a combination of articaine hydrochloride and epinephrine (adrenaline) at a ratio of 1:100,000.

2.7.1. Surgical Flap Exposure

A full-thickness trapezoidal flap was created using a paracrestal incision, along with two oblique releasing incisions at its distal and mesial ends. This technique allowed the elevation of the flap, providing visibility of the entire length of the facial cortical bone. The palatal mucoperiosteum was also reflected to improve exposure of the crest of the alveolar ridge and facilitate the free placement of surgical guides in the study group.

2.7.2. Ridge Split and Expansion Technique

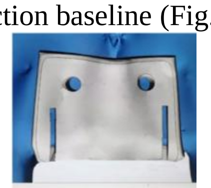
Study Group

The PSG was securely positioned and anchored using monocortical osteosynthesis screws (mini-screws measuring 2 mm × 5 mm) at the predetermined locations on the labial cortical plate of the bone.

A midcrestal incision was made on the facial aspect of the alveolar ridge, followed by two vertical stop cuts at the distal and mesial ends of the midcrestal bony cut. These cuts extended 5 mm apically from the crest of the ridge.

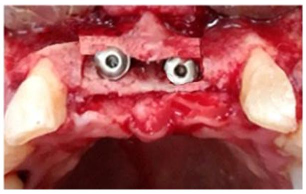
The incisions were made along the guide slits using a piezoelectric surgery device (Piezotome® Solo, Acteon, Satelec, France) equipped with graduated ridge splitting tips of varying widths (CS 1, CS 2, CS 3, and CS 4 tips). In certain instances, additional tips such as CS 5 and CS 6 were utilized to further manipulate and expand the alveolar bone plate. Subsequently, the guides were removed.

The buccal plate was meticulously examined for any perforations, fractures, or accidental vertical fractures using visual inspection and blunt periodontal probes. This thorough assessment ensured the integrity of the apical distraction baseline (Fig. 1A and B).



A

B



C

D

Fig. 1 A - preoperative planning for PSGs involving crestal and vertical cuts; B - midcrestal cut performed using Piezotome ridge splitting tips, guided by a guide slit; C - implant inserted into the osteotomy sites; D - flap repositioning and closure (The authors)

Control Group

The control group underwent the detailed protocol utilizing the standard freehand approach. This involved making a midcrestal cut, followed by two vertical stop cuts at the distal and mesial ends of the midcrestal bony cut on the facial aspect of the alveolar ridge. These cuts extended 5 mm apically from the crest of the ridge. Graduated ridge splitting tips from a piezoelectric surgery device (Piezotome® Solo, Acteon, Satelec, France) were used to widen the cuts, gradually lateralizing and expanding the alveolar plate of bone.

2.7.3. Implant Installation

The implant osteotomy sites were prepared using a series of graduated bone drills of increasing diameters. Finally, Neobiotech®Co, Ltd implants from Korea were inserted into the osteotomy sites using a torque wrench in a self-tapping manner, ensuring optimal engagement with the palatal and basal bone for primary stability (Fig. 1C).

2.7.4. Flap Repositioning and Closure

The flap was repositioned in its position. The soft tissue was closed over the implant using a 3-0 suture with a 3/8 circle reverse cutting technique (Fig. 1D).

2.8. Postoperative Care and Instructions

It is crucial for patients to follow postoperative instructions immediately after surgery to reduce contact with the implants. Patients are advised to consume softer foods and chew away from the implant site. Additionally, patients should thoroughly clean their mouths after each meal starting the day after surgery, using a soft bristle toothbrush and toothpaste. Patients should refrain from rinsing their mouths on the day of surgery.

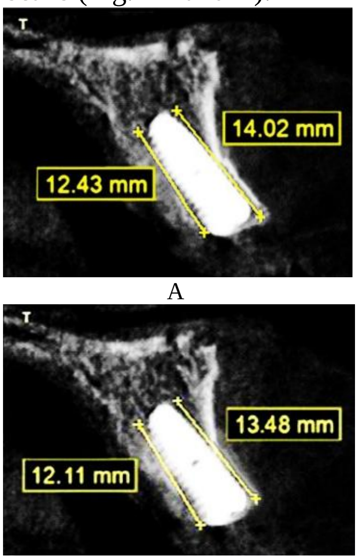
2.9. Postoperative Evaluation

2.9.1. Clinical Evaluation

The duration of each surgical procedure was documented and recorded in minutes, from the incision to suturing. Following the surgery, clinical follow-up assessments were conducted immediately post-operatively and again at the 6-month mark to evaluate stability, identify complications, measure probing depth, assess bleeding index, and monitor for signs of swelling or infection. Additionally, initial stability was assessed using the Osstell device immediately after implant insertion, with a second evaluation of secondary stability using the same device at the 6-month postoperative mark during the second-stage surgery.

2.9.2. Radiographic Evaluation

1) Labial and palatal bone height: Cone beam computed tomography (CBCT) radiographs were performed for each patient both immediately following the procedure and again at the 6-month postoperative mark. The height of the labial and palatal bone was measured from the crest to the apical area at both time points. The labial and palatal crestal bone loss was determined by calculating the difference between these two measurements. Finally, the percentage of bone loss was calculated by comparing the labial and palatal crestal bone loss to the baseline height. Radiographic measurements were taken from the cross-sectional cuts of the CBCT scans (Fig. 2A and B).



A

B

Fig. 2 A - height of the labial and palatal bones of the alveolar ridge immediately following the right implant surgery; B - labial and palatal bone height of the alveolar ridge at 6 months post-surgery in the right implant (The authors)

2) Labiopalatal ridge width: Preoperative and postoperative ridge widths were measured using CBCT. The analysis of dental CBCT scan images was conducted using the Blue Sky Plan 4.ink imaging software. Upon importing data as DICOM files into the software, a series of steps were followed to ensure consistency in views across all patient scans. Reference points and lines were utilized; two points were identified at the outer surface of the labial and palatal cortical plates, positioned apically 3 mm to the crest of the alveolar bone. A tangential line was drawn through these points, and the distance between them was measured in millimeters on the day of implant placement and during the 6-month follow-up visit.

3) Bone density: Utilizing the BlueSky Plan 4.ink software, we calculated the change in bone density surrounding the implant in grayscale. Measurement sites were positioned at the top, middle, and apical regions of the implant on the labial, palatal, mesial, and distal aspects. The areas of interest remained consistent throughout all examinations. Mean values of bone density along each side of the implant were recorded, and the average density was determined. This process was conducted immediately post-operation and at the 6-month mark.

2.10. Statistical Analysis

The data were collected, tabulated, and inputted into the computer for statistical analysis using IBM® SPSS Statistics Version 23 for Windows. The analysis included calculating the range (minimum and maximum), mean, and standard deviation. Additionally, Student's t-test was conducted to compare the two groups under study, with a significance level set at a P value of ≤ 0.05.

3. Results

3.1. Labial and Palatal Crestal Bone Loss

The mean ± SD for labial and palatal crestal bone loss in the study group after 6 months was 0.861 ± 0.15, compared to 1.437 ± 0.09 in the control group. The study group exhibited a statistically significant lower crestal bone loss of 0.861 mm, as opposed to the control group's 1.437 mm (P value ≤ 0.05).

3.2. Alveolar Ridge Width

The study group demonstrated a significantly greater increase in bone gain than the control group.

3.3. Implant Stability Quotient (ISQ)

The study revealed an improvement in implant stability at 6-month intervals, with a statistically significant difference between primary and secondary implant stability. However, there was no statistically significant difference between the two groups.

3.4. Bone Density

There was a statistically non-significant difference between the two groups after 6 months (p value ≥ 0.05).

Table 1 Statistical analysis (The authors)

		Study group	Control group	P Value
Palatal and labial bone height	Initial	13.385 ± 0.95	12.889 ± 1.07	0.000**
	After 6 months	12.524 ± 1.10	11.452 ± 1.16	0.000**
	Bone loss	0.861 ± 0.15	1.437 ± 0.09	0.000**
Bone density	Immediate postoperative	437 ± 52.9	439.2 ± 54.1	0.389*
	6 months postoperatively	644 ± 54.4	643 ± 55.6	0.662*
Alveolar ridge width	Preoperative	4.21 ± 0.62	4.032 ± 0.40	0.000**
	Immediate postoperative	7.373 ± 0.70	7.502 ± 0.35	0.000**
	6 months postoperatively	6.99 ± 0.68	6.49 ± 0.42	0.000**
ISQ reading	Initial	53.8 ± 6.069	53.6 ± 5.719	0.934*
	After 6 months	78 ± 7.483	76.1 ± 7.549	0.424*

* Statistically nonsignificant; ** statistically significant at $p \leq 0.05$
P value: for comparison between the two study groups

4. Discussion

Several approved techniques have been developed to address the issue of narrow ridge width: onlay/inlay bone grafts, horizontal guided bone regeneration, distraction osteogenesis, alveolar ridge expansion, and edentulous alveolar ridge splitting [5]. One of the main drawbacks of onlay bone grafts is their invasiveness as they require bone harvesting from intraoral or extraoral sites. This increases the risk of morbidity and bone graft resorption [6].

One of the challenges associated with normal guided bone regeneration is the potential for membrane exposure, infection, and an unpredictable rate of bone resorption following reconstructive and regenerative procedures and implant placement [7]. Also, the alveolar ridge expansion technique provides a gradual increase of the ridge width and allows simultaneous positioning of implants, thus significantly reducing treatment time. However, it is recommended only for soft bone quality (D3 and D4) [8].

The objective of this study was to present a minimally invasive, fully guided protocol for ridge splitting utilizing a PSG to direct the osteotomy preparation process and compare it with the conventional approach.

This study explores the technique of ridge splitting in conjunction with immediate implant placement, as first reported by Summers [9]. This method takes advantage of the viscoelastic nature of bone, allowing compression and manipulation. Simion et al. [10] concurred that this technique yields the same survival rates as the two-step split ridge expansion method, while reducing the overall treatment duration and eliminating the morbidity associated with a second surgical procedure.

In our study, the width of the ridge measured 3-5 mm. This finding aligns with Scipioni et al. [11], who noted that a buccolingual bone width of 3 mm or more but less than 6 mm may require augmentation of the alveolar ridge to facilitate implant placement. Effective options for achieving this are ridge splitting and bone expansion techniques.

This study observed a notable increase in bone width as a result of alveolar bone splitting and expansion, indicating a successful treatment outcome. This finding aligns with previous studies by Simion et al. [10] and Scipioni et al. [11], which also reported alveolar width gains of 1-4 mm following the split-crest procedure and successful immediate implant placement.

The study group in this research revealed a lower amount of labial and palatal crestal bone loss (1.071 ± 0.4 mm) than the control group (1.895 ± 0.14). The study group exhibited superior outcomes in terms of labial and palatal crestal bone resorption. This is in contrast to the results reported by Jensen et al. [12], who measured labial crestal bone resorption in the context of ridge splitting technique with simultaneous implant placement. Their clinical measurements, taken using a periodontal probe at 6 months post-implant placement, indicated a range of 1.5-3.5 mm of crestal bone loss at the labial plate. These results are consistent with the findings of Hamzah et al. [13], who observed labial bone loss ranging from 1.38 to 2.42 mm after 4 months.

The findings of this study indicate a significant increase in implant stability after 6 months, aligning with the research by Kreissel [14], which focused on assessing implant stability in expanded ridges and found that the use of bone spreaders led to a notable increase in ISQ values.

Digholkar et al. [15] emphasized the significance of ISQ in dental implant procedures. Studies, conducted with RFA, have identified an optimal stability range of 55-85 ISQ, with an average ISQ level of 70. In this study, the mean ISQ value after a healing period of 6 months was 78 ± 7.438 for the study group and 76.1 ± 7.549 for the control group.

The findings of this study indicate that utilizing a comprehensive digital protocol with patient-specific CAD-CAM surgical guides is a superior option compared to the freehand technique. Our research demonstrates that PSGs reduce intraoperative complications and minimize crestal ridge resorption.

5. Conclusions

1. One of the primary benefits provided by the PSG is its ability to reduce intraoperative and postoperative complications and minimize crestal ridge resorption compared to the freehand technique.

2. The findings on the study group on labial and palatal crestal bone resorption in this study surpass those reported by Jensen et al. and are consistent with the research by Hamzah et al.

3. The use of PSGs is a minimally invasive technique that enables precise cutting, preserves alveolar bone, and reduces operative time.

5.1. Recommendations for Future Research

- Further clinical research with a larger sample size should be conducted to thoroughly evaluate the effectiveness of PSGs.

- It is imperative to explore various sites beyond the anterior maxilla to elucidate the impact of PSGs as a method for splitting and expanding narrow alveolar ridges.

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