EVALUATION OF ONE-STAGE INVERTED U-SHAPED RIDGE SPLITTING AND CONCURRENT IMPLANT PLACEMENT IN ANTERIOR MAXILLARY UNDERCUT DEFECT (A CLINICAL TRIAL)

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ABSTRACT

INTRODUCTION: The alveolar ridge splitting method is a surgical technique for horizontal ridge augmentation of narrow ridges in order to insert implants for prosthetic treatment.
Objective: To evaluate one stage ridge splitting technique using piezotome with immediate implant placement for treatment of maxillary anterior undercut areas.
MATERIALS AND METHODS: Seven individuals with anterior maxillary undercut defect were chosen based on a set of inclusion and exclusion criteria. In the same procedure, the individuals underwent inverted U-shaped maxillary ridge splitting with a piezotome and immediate implant insertion. The assessment comprised cone beam computed tomography analysis of bone gain at the undercut defect and bone density labial to implants in each participant.
RESULTS: There was a significant bone width increase at the undercut area after four months of the splitting procedure and implant placement. The bone density labial to the implant also was found to be significantly higher than the initial measurements. All cases showed normal healing, except two cases showed soft tissue inflammation which were managed conservatively.
CONCLUSION: This study showed favorable outcomes of one-stage ridge splitting and implant placement in the treatment of undercut defect at the maxillary ridge. In addition, the one-stage technique is suggested to be safer and less time consuming with no need for a second surgery.
KEYWORDS: Narrow maxillary anterior ridge, Horizontal ridge augmentation, Ridge splitting, Piezosurgery, Undercut defect.
RUNNING TITLE: One-stage U-shaped ridge splitting technique

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INTRODUCTION

After tooth extraction, great changes occur to the alveolar ridge dimensions. It has been found that, severe resorption in the alveolar width occurs that could reach up to 50% in the first year. This loss, which is equal to 5-7 mm, occurs mainly in the first 3 months after extraction. The more the reduction of alveolar process, the more complications will be associated with implants placement and treatment with fixed or removable prosthesis (1).
For dental implants placement, at least 1-1.5 mm of buccal and palatal bone should surround the implant (2). Thus, different techniques are being used for ridge augmentation including: Guided Bone Regeneration (GBR) using membranes in combination with different bone materials (3), autogenous bone blocks harvested intra or extra orally (4), or distraction osteogenesis (5). All of the previous treatment modalities have risks of dehiscence, infection and long treatment time (4).
To overcome the drawbacks of these augmentation techniques, Tatum introduced a new approach for narrow ridge augmentation, which is alveolar ridge expansion using manual osteotomes with different sizes (6), which was later on modified by Summers (7). Another approach called Alveolar Ridge

Splitting, introduced by Simion includes longitudinal dividing of the alveolar ridge into two parts using small chisels (8).

The corticotomies can be done by either microsaw devices (9), or piezoelectric devices (10). The piezoelectric devices have the advantage of precise cutting of the hard alveolar bone, and thus avoiding malfracture of the osteomized segment. (11, 12)

Moreover, their use prevents soft tissue injury for example nerves, blood vessels or the schneiderian membrane, and thus allow for better visualization of the surgical field and less postoperative complications (13).

Ridge splitting technique with immediate placement of implant is an alternative method of augmentation in anterior region of maxilla with advantages of using less bone substitute and simultaneous placement of implant (12, 13), especially in maxillary undercut areas where fenestration may happen during implant placement (14).

The four-cut alveolar ridge splitting technique may cause labial bone fracture during implant loading, Therefore, maintaining the top of the crest in case of horizontal bone augmentation may be recommended when the bone thickness is decreased away from this point (14).

To overcome this problem an inverted U-shaped splitting technique (IUST) using piezotome for horizontal bone augmentation in undercut area with simultaneous implant placement was introduced (14).

Therefore, the aim of this study focused on evaluating one stage ridge splitting technique using piezotome with implant placement immediately for treatment of maxillary anterior undercut areas

MATERIAL AND METHODS

Study sample

Seven patients with presence of labial undercut defect in anterior maxillary ridge were chosen from the outpatient clinics of the faculty of dentistry Alexandria University's department of oral and maxillofacial surgery. The patients' ages ranged from 18 to 45 years old, with a mean of 30±6, and there were four men and three females. Before the procedure, all patients signed an informed consent form.

Inclusion criteria

Adult patients (18-45) with no sex preference, at least one missing tooth in the anterior maxilla, and a labial undercut greater than 2 mm in thickness (14), the presence of sufficient bone width at the coronal section of alveolar crest- a minimum of 4.5 mm, the absence of vertical bone defect, and a minimum bone height of 10 mm.

Exclusion criteria

Any systemic disease that would preclude surgery, such as diabetes, pregnancy or lactation, long-term amino-bisphosphonate therapy, daily smoking of more than ten cigarettes, alcohol or drug abuse, uncontrolled periodontal disease, active infection, insufficient inter-incisal space, and bruxism or clenching.

Materials

1- Piezotome (Manufactured by Acteon CO, France)
2- Crestal Split tip (CS1) that was used with thickness of 0.5 mm and length of 8 mm
3- Bone expanders(S-Wide Kit: manufactured by NEOBIOTECH IMPLANT CO, KOREA) with the 3 diameters of 2.4, 3.2 and 3.6 mm
4- Implant system (IS implant system: manufactured by NEOBIOTECH IMPLANT CO, KOREA) tapered implant design with conical hex connection with diameter of 3.5 mm and length of 8 mm.

Methods

Pre-surgical assessment:

1- **History:**

a) **Personal history:**

Full personal data in-detail including name, age and gender were obtained.

b) **Past medical history:**

Health history form (questionnaire) was given to the participants for collecting the medical history

c) **Past dental history:**

Including: cause and time of extraction.

2- **Clinical examination:**

Intra oral examination was done including: quality of the mucosa and contour of the underlying bone, occlusal status, existing restorations, and oral hygiene assessment.

3- ***Radiographic examination:***

A cone beam computed tomography (CBCT) was taken to evaluate the morphology of the residual alveolar ridge at baseline before any surgical procedures.

I. **Surgical phase** ***(Figure 1)***

Before surgery, every patient in this group went for scaling and root planning to obtain proper periodontal health and patients were told to rinse their mouths with mouthwash containing 0.12 percent chlorhexidine. Local anesthesia by infiltration technique was injected using 4% articaine (1:100000 epinephrine). A crestal incision (slightly palatal to the mid-crest) followed by two vertical releasing incisions were performed using a number 15 blade for good visualization of undercut defect. Using a sharp periosteal elevator, a full muco-periosteal flap was elevated to reveal the bone crestally and buccally. Fig (1-A)

In the undercut area, a piezoelectric device (Piezotome Cube by ACTEON, FRANCE) was used to make an inverted U-shaped bone cut with working-tip CS1(11,12) down to the cancellous bone by 4 mm depth. Fig (1-B) The two vertical bone cuts were spaced at least one millimeter apart from the adjacent roots and went beyond the undercut area. A periotome was used to minimally mobilize the bone segment

Using a low-speed drilling process at speed of 800 rpm and torque of 25 Ncm, all implants were put with the implant shoulder flush with the bone level. The implant site was drilled first using a lance drill to determine the osteotomy position and then

continued using the screw-expanders in the sequence recommended by the manufacturer to expand the bone segment at the area of undercut and to make enough space for the implant to be placed. Fig (1-D) Using the final drill, the final drilling was done according to the diameter of the implant to be inserted and a cover screw is secured to the implant. Fig (1-E) The wound was closed using 3/0 silk sutures. Fig (1-F)

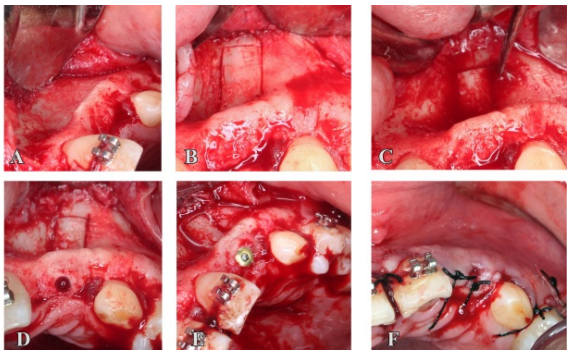

Figure (1): One stage inverted U-shaped ridge splitting technique. (A) A full muco-periosteal flap. (B) An inverted U-shaped bone cut. (C) Elevation of released bone end. (D) Preparation of implant site. (E) Implant placement at its site. (F) Wound closure.

II. Post-surgical phase

A. Post-operative care

Patients were instructed to apply cold fomentation extraorally at the day of surgery, followed by hot fomentation for the next 24 hours to avoid ecchymosis and tissue discoloration(15), Antibiotic was given every 12 hours for 7 days (Amoxicillin + Clavulanic acid 1 gm). (Emoxclav: Amoxicillin 875 mg + Clavulanic acid 125 mg: EPICO, Egypt) and Non-steroidal Anti-inflammatory drug was given every 8 hours for 4 days (Diclofenac potassium 50 mg). (Cataflam: Diclofenac Potassium 50mg: Novartis-Switzerland) 0.12% chlorhexidine mouthwash two times daily for 2 weeks. (Hexitol: Chlorhexidine 125mg/100ml, concentration 0.125%: Arabic drug company, ADCO).

B. Post-operative follow up

The sutured wound was examined for any signs and symptoms of infection including inflammation, redness, hotness, swelling and pus discharge at the second day after the surgery for each participant. Seven to ten days after surgery, the sutures were removed.

Radiographic evaluation

CBCT-investigation was performed before surgery to measure the bone width (BW0). Another CBCT was taken after 4 months postoperatively to measure the amount of bone that has increased (BW2). The amount of final bone expansion was calculated (BW2 – BW0). Bone density (BD) was measured preoperatively and 4 months post operatively based on CBCT-data.

Radiographic examination was performed by using cone beam 3D imaging system (Morita 3DX; J Morita., Kyoto, Japan), and CBCT analyzing software (OnDemand 3D version 1.0, Win 32 edition), Firstly, we standardized the settings of the CBCT device (preoperative, and 4 months postoperative), the scan was done with field of view (FOV) W 100mm x H 50mm with 0.160mm isometric voxel size. The tube voltage was 90KV (kilovoltage), 8 mA (Milliampere), and the exposure time was 20 seconds.

All CBCT scans were taken at the same radiology center and with the same device to minimize error-bias.

C. Prosthetic treatment

After 4 months, healing abutments were placed to gain proper emergence profile. Impressions were taken and prosthesis was delivered two weeks later.

D. Statistical analysis

All collected data were statistically analyzed and presented in the form of tables, graphs and charts. IBM Statistical Package for the Social Sciences (SPSS) software version 22.0 is used.

RESULTS

Seven individuals were included in the trial, four men and three females and treated at Alexandria University's Faculty of Dentistry's Department of Oral and Maxillofacial Surgery. The age of the patients varied from 18 to 45 years, with a mean of 30±6.

Intra-surgical results

No accidental iatrogenic fracture of the distracted bone-plate was observed in the all 7 cases this is because the minimal mobilization only was done using the periotome and the using of sequential bone expanders aid in more elevation of the distracted plate in addition to starting the two vertical cuts away 3 mm from the alveolar crest

Postoperative results

Clinical data

I- Postoperative follow up

A. Soft tissue healing

Regarding the soft tissue healing, all cases showed normal healing, except two cases showed soft tissue inflammation. The two cases were managed conservatively by taking chlorhexidine mouthwash 3 times daily and administration of anti-inflammatory drugs. (**Figure 2**)

B. Bone width (**Figure 3**)

In measuring the bone width preoperatively (**Figure 3A**), a palatal line was drawn from the alveolar crest upward facing the most concave labial undercut defect and was measured. A horizontal line from the outer labial surface to the outer palatal surface of the ridge was also drawn connecting a constant crestal line at angle of 90 degree. Subsequently, same measurements were used for post-operative CBCT after 4 months. (**Figure 3B**). The bone width results showed an increase of 26.66%±9.28 between the two studied periods which was significantly different (P <0.05).

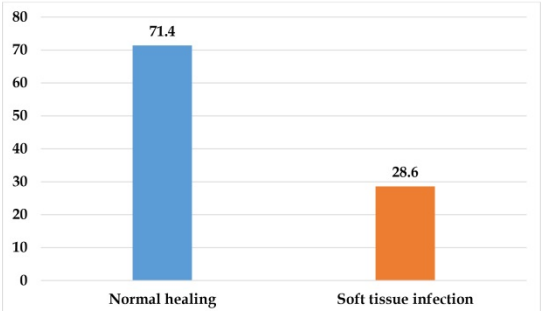

Figure (2): Distribution of the studied cases according to soft tissue healing (n = 7).

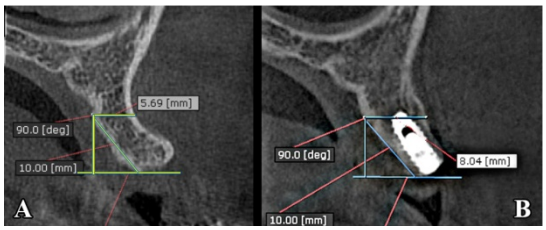

Figure (3): Bone width measurements preoperatively and after 4 months.

C. Bone density

The bone density was measured preoperatively and 4 months after implant placement. By using OnDemand 3D software, we selected a virtual implant that matches the same dimensions and position of the actual implant to be placed at the planned implant site, then the mean of the peri-implant bone density value was calculated automatically (pre-operatively) (**Figure 4A**) from outside the implant by 2 mm. After 4 months -by using OnDemand 3D software- we selected the same virtual implant that mimics the placed implant, then superimposed it over the placed actual implant, the mean of the peri-implant bone density value was measured automatically also from the outside of the implant to avoid the any artifacts caused by the metal stray beam of the actual implant,(**Figure 4B**) we compared between (pre-operative) and (post-operative) of their effect on the peri-implant bone density.

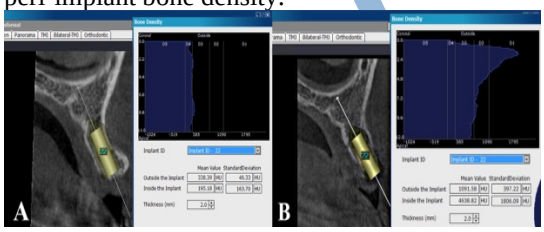

Figure (4): Bone density measurements preoperatively and after 4 months.

The bone density was increased at 4 months by approximately 13.81%±7.32 the initial measurements which was significantly different ($P < 0.05$).(Table 2)

Table 1: Evaluation of the bone width at the undercut area immediately and after 4 months (n=7)

	Participants (n=7)
	Mean (SD)
Immediately	6.02 (1.49)
After 4 months	7.53 (1.39)
Test **P value**	Paired t=14.584 <0.0001*
Percent increase	26.66 (9.28)

Table 2: Evaluation of the bone density immediately and after 4 months (n=7)

	Participants (n=7)
	Mean (SD)
Preoperative	533.65 (70.41)
Bone Density after 4 months	607.45 (89.37)
Test **P value**	Paired t=4.672 0.003
Percent increase	13.81 (7.32)

DISCUSSION

Survival and success rates of implants placed in the expanded ridges are consistent with those of implants in non-reconstructed native bone

The survival and success rates of implants placed in expanded ridges are comparable to those of implants inserted in non-reconstructed, natural bone. Spontaneous ossification, similar to that seen in fractures and tooth extraction sites and new bone production, enables fusion of the alveolus's oral and buccal bone plates (16, 17).

Alveolar ridge splitting with a piezotome is a well-documented procedure for restoring alveolar ridge thickness prior to implant insertion, in agreement with Pénzes et al. (18) and is documented as preferrable alternative to autologous bone-block-grafting(19).

Studies showed that alveolar ridge splitting technique (ARST) fulfill all requirements for best bone healing/regeneration of bony defects, such as minimum bone loss, the preservation of bony walls, a closed healing environment, provision of space and mechanical wound stability (11,12,20).

In the current study, bone density around implant measured by OnDemand system automatically showed statically significant difference between preoperative and postoperative results. These results correlated with the studies conducted by Fanuscu et al.,(21) where expansion technique using bone expanders resulted in increase in bone density compared with drilling technique which aid in better primary stability of the implant. Another study conducted by Guillemant et al.,(22) who described the screw expanders action on 2 clinical cases suffering from maxillary horizontal ridge atrophy revealed its efficacy in increasing

cancellous bone density in case of horizontal ridge atrophy. Another corresponding study by Ahmed A Abd Elhalim et al.,(23) who did ARST and the osteotomy was done by the use of bone expanders in 11 patients showed a significant bone density increase after six months

In addition to Mustafa MN et al.,(24) who discussed the benefits of using screw expanders together with alveolar ridge splitting in condensing and expansion of bone with maintaining bone density and increasing fixation

On the other hand Gnanasegaran et al.,(25), discussed the artefacts caused by metallic objects that can affect the bone mineral density results of the spine and hip which may biased the bone density measurements results at the post-operative evaluation from the CBCT scans.

Aslo ZT Mahmoud et al.,(19) discussed the flapless piezotome crest splitting technique as an alternative less traumatic method with no interruption of the vascularization of the splitted bone segment that might lead to bone resorption

B. Wadhwa et al., (26) also discussed the flapless technique in implant placement and its benefits in maintaining blood supply to alveolar bone and decreasing the post-operative discomfort since large flaps causing much time needed for revascularization, increasing the healing time and bone deposition thus affecting the net results of bone density and width gained.

According to bone width, it was found that there was a highly significant increase in bone width (P= <0.0001) after 4 months' assessment which was compatible with Wu et al. (12) who reported the mean changes in bone width at the different levels preoperatively, immediately, and 1 year after surgery, as there was a significant increase in ridge width (RW) at all levels revealed an overall mean RW gain of 2.56 ± 1.92 mm after apical U-shaped splitting technique.

Similarly, Hamdan et al.,(27) and Mahmoud, et al.,(19) showed that one stage alveolar ridge splitting technique is more effective and predictable in gaining bone width compared to traditional two-stage horizontal grafting technique using autologous bone blocks due to less traumatic effect of avoiding donor site morbidity and avoiding the interruption of oxygenation of the bone segment that results in creating a better bone scaffold for better healing and that short term and long-term survival rates are higher for implants placed in both the maxilla and the mandible when following this technique.

According to Starch-Jensen & Becktor (2019) (28) who did a systematic review comparing the ARST with autologous lateral ridge augmentation, an average gain in alveolar ridge width varying between 3.3 to 3.5 mm after maxillary alveolar ridge expansion with the split-crest technique was noticed after 4 months which comes in agreement with our results.

Another study conducted on 10 patients received 22 implants- by Vinh et al., (29) divided into 2 groups; the test group received ARST with simultaneous implant placement and the control group received conventional rotary drilling method. The results of the test group showed that the net gain in bone width after the ARST was significant.

In contrast, Guo et al., (30) conducted a research on 56 healthy patients who had undergone split-crest technique (SCT) to increase the width of the alveolar ridge. After SCT, the average alveolar bone width was reported to have increased. This width decreased somewhat three months later (P< 0.05) but still there is a significant increase between the baseline width and after 3 months compared to our study which didn't face this decrease in bone width after 4 months .This is might be related to different used methods of splitting as we didn't use onlay grafting material in addition to the splitting geometry was different and the different nature of the bone between maxilla and mandible. Overall compared to Guo et al the bone width increased and not only did the alveolar ridge become thicker, but the keratinized mucosa also became wider 3 months after the SCT procedure.

Similar study was evaluated by Wu et al., (14) who investigated a unique apical U-shape splitting method for horizontal bone expansion in undercut areas that was revealed to result in a large increase in bone width at the undercut area of (2.561.92mm) after ridge splitting.

Various related studies were also done by Hamdan et al., (27) Abou Hamdan et al., (31) and Agarwal et al., (32) who demonstrated that ridge splitting with implant placement immediately appears to be a less invasive therapeutic option for horizontal alveolar ridge augmentation.

The one-stage splitting technique is less time consuming because of no need for second surgery to insert the implant which agreed with Abou Hamdan et al., (31) who found a decrease in healing period in maxilla by three months, with less surgical complications than in the two-stage technique such as detachment of the splitted segment ,possibility of infection due to re-entry and more safe due to direct visualization of splitted segment during the implant insertion.

In conclusion, this study showed favorable outcomes of one-stage ridge splitting and implant placement in the treatment of undercut defect at the maxillary ridge. In addition, the one-stage technique was believed to be safer and less time consuming with no need for a second surgery.

Recommendations

Further long-term studies with larger sample size are recommended in order to validate the attained outcomes.

Limitations

Availability of patients with maxillary anterior undercut indicated for dental implantation.

Availability of piezotome surgical tip.

Conflict of Interest

The authors state that they are not involved in any conflict of interest.

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