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Research Article

Novel Technique for Alveolar Ridge Expansion: A Comparative Clinical Study

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Abstract

Background: Piezosurgery improved the split approach by making it safer, easier, and less prone to complications when treating extremely atrophic crests. Densah drills, with their unique design, expand the ridge by densifying bone in a reverse, non-cutting mode. ***Objective***: To assess the effectiveness of sagittal piezosurgery, which involves cutting bone to the full implant depth and then expanding it using osseodensification drills. We use this technique to expand narrow alveolar bones and simultaneously place dental implants in the maxillary and mandibular arches. ***Methods***: Fourteen patients received 31 dental implants. The maxillary arch received 19, and the mandible received 12 dental implants. This study will include patients who have narrow alveolar bone ridges (2.5–4 mm). After marking the implant sites with a pilot drill, we used a piezoelectric surgery tip to cut the alveolar crest to the depth of the planned dental implant. We then sequentially used Versah Drills, accompanied by extensive irrigation using cooled, sterile normal saline, and finally inserted the implant into the subcrestal level. ***Results***: This study revealed a significant difference in alveolar ridge width immediately after the procedure, and the significant change in the mandible was slightly higher than that in the maxillary arch. However, all implants in both jaws achieved successful osseointegration. ***Conclusions***: The alveolar ridge width changed a lot more in the mandible than in the maxillary arch after the procedure. These two strategies work well together to properly and simply expand severely atrophied alveolar ridges without affecting bone healing or the osseointegration process.

Keywords: Alveolar ridge splitting, Dental implant, Osseodensification, Piezosurgery.

تقنية جديدة لتوسيع الحافة السنخية: دراسة سريرية مقارنة

الخلاصة

الخلفية: حسنت جراحة بيزو طريقة التقسيم لتصبح أكثر أمانًا وسهولة وأقل عرضة للمضاعفات عند علاج القمم الضامرة الشديدة. تساعد مثاقب دينساه، وهي نوع معين من المثاقب المستخدمة في تكثيف العظام، في تكثيف العظام أثناء عملية تحضير قطع العظم. **الهدف**: مقارنة فعالية قطع العظام السنخية المعدلة بجراحة بيزو مع مثاقب تكثيف العظام في توسيع العظام السنخية الضيقة بين القوس العلوي والسفلي. **الطرق**: تلقى أربعة عشر مريضًا مشمولين في هذه الدراسة السريرية 31 غرسة أسنان. تلقى القوس العلوي 19 غرسة وتلقى الفك السفلي 12 غرسة أسنان. ستشمل هذه الدراسة المرضى الذين لديهم حواف عظمية سنخية ضيقة (2.5-4 مم) في العرض. من خلال استخدام وحدة جراحة بيزو كهربائية ، تم تقطيع قمة العظم أفقيًا. وصل عمق القطع إلى نفس مستوى آخر غرسة أسنان كان من الضروري وضعها. بعد ذلك، سيتم استخدام سلسلة من مثاقب Versah، يليها ري مكثف بمحلول ملحي طبيعي معقم ومبرد، وفي النهاية، وضع غرسة ratchet. **النتائج**: أظهرت نتائج هذه الدراسة أن هناك اختلافًا كبيرًا في عرض الحافة السنخية مباشرة بعد العملية والتغيير الكبير في الفك السفلي أعلى قليلاً من التغيير في القوس العلوي. **الاستنتاجات**: عظم الفك السفلي أكثر قشرية وأكثر كثافة من الفك العلوي. غالبًا ما يكون عظم الفك العلوي أقل سمكًا وأكثر قدرة على تحمل مكاسب توسع أكبر دون التضحية بالسلامة البنيوية. لذا فإن التغيير الكبير في عرض الحافة السنخية مباشرة بعد العملية في الفك السفلي أعلى قليلاً من التغيير في القوس العلوي.

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INTRODUCTION

Dimensional bone changes are an inevitable process after dental extraction. Despite the different techniques used to overcome these, severe bone remodeling may complicate prosthetic rehabilitation [1,2]. In the vertical, transversal, and sagittal planes, the alveolar ridge experiences bone resorption after tooth loss [3]**.** The lower jaw suffers more severe effects than the upper jaw [4]. The posterior mandibular and maxillary segments exhibit more extensive atrophic phenomena [5]. Tatum first presented the ridge-splitting technique in 1986, but Scipioni et al. brought it back in 1990. Scipioni et al. called it the "edentulous ridge expansion (ERE) technique [6]. The sagittal osteotomy, with two vertical bony cuts created by the ridge-splitting technique [7], allows for the insertion of dental implants by splitting the buccal and lingual bone plates. Horizontal distraction osteogenesis and guided bone regeneration with onlay bone grafts are alternatives to the alveolar ridge split technique [8]. The main drawbacks of onlay bone grafts include their invasiveness, the constant resorption of grafted bone at the selected donor site, and the need for bone harvesting at an additional donor site [9]. In the past, surgeons used a chisel and a hand mallet for ridge expansion. These days, people use osteotomes in conjunction with an electrical or magnetic mallet. The osteotome attaches to the handpiece (mallet), which transfers shock waves to the instrument's tip, causing longitudinal movements on the bone's surface [10,11]. On the other hand, Vercellotti et al. first used piezosurgery to treat atrophic jaws in 2000 [12]. The piezosurgery technique reduces the risk of bone fracture and increases bone elasticity, which minimizes complications [13] with ultrasonic intermediate vibration following osteotomy. The cavitation effect makes the surgical process easier because it creates a clear, clean operative field with good sight [14, 15]. Densah burs, a type of burse used in osseodensification, are specifically made to assist in densifying soft bone while preparing an osteotomy site, which was introduced by Huwais (2013) [16]. During the preparation of an osteotomy, the Densah burs help to preserve bone and compact autografts, which increases the density of the bone around the implant and makes it more stable [17]. However, a hard, compacted, and atrophied alveolar ridge prevents the Densah drills from achieving ridge expansion, resulting in heat generation and bone resorption, as well as an increased risk of implant failure. Simultaneously, relying solely on a piezoelectric device to split narrow ridges with sagittal and two coronal cortical buccal bone cuts may result in poor splitting, thereby compromising the primary stability of the implant and heightening the risk of buccal bone plate resorption leading to dental implant failure [18]. This study aims to evaluate the efficacy of sagittal piezosurgery bone cutting to the full implant depth, followed by subsequent expansion using osseodensification drills, in expanding narrow alveolar bone while simultaneously placing dental implants in the maxillary and mandibular arches.

METHODS

Study design and setting

This study was designed as a prospective comparative clinical study. The protocol of this study (reference number: 691, in November 2022) has been approved by the ethical institution committee of the University of Baghdad, Faculty of Dentistry, according to the Declaration of Helsinki in 1964. The trial is registered at https://clinicaltrials.gov with a trial identifier of NCT06294171. This clinical study was conducted from November 2022 to November 2023. The patients who underwent implant placement with a narrow dental arch (the ridge width measured at the crest of the alveolar ridge on CBCT, and the ridge width was 2.5–4 mm) at the Dental Teaching Hospital, College of Dentistry, University of Baghdad, Dental Implant Unit. All patients included signed an informed consent form after the full details of the nature of the study were explained to them. The sample size of the study was calculated using G-Power software, and the calculation data were obtained from a study by Arakji *et al*. [16]. A total of 70 implant sites in 43 individuals were evaluated for eligibility. Out of these, 34 implant sites were eliminated for various reasons. The study flow chart (Figure 1) illustrates that the remaining 36 implant sites in 16 patients were included in the study.

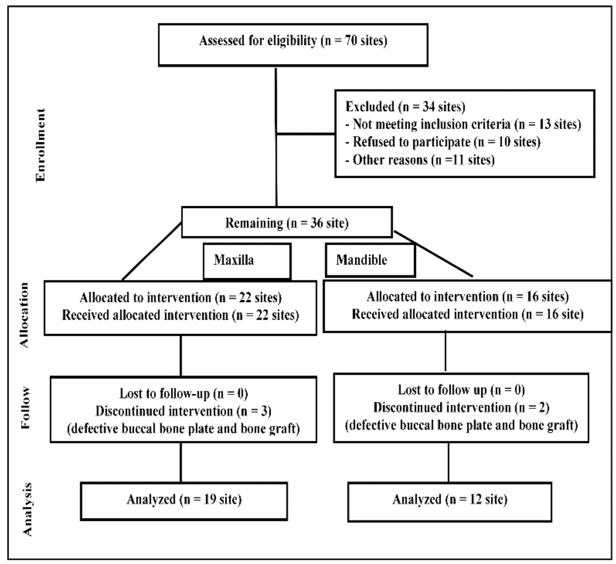

Figure 1: The CONSORT flow chart of the study.

Inclusion criteria

Eighteen-year-old patients of both genders with edentulous areas must have healed for at least six months following extraction. The alveolar ridge width (crestal level) was measured using CBCT with at least 12 mm height and 4-2.5 mm width. The patient must not have a history of any systemic diseases or local conditions that could compromise bone healing.

Surgical procedure

A pre-operative cone beam computed tomography (CBCT) was obtained for all patients assessed for eligibility for possible inclusion in the study. The bone's density, width, and height at the chosen implantation site were assessed. The width was measured at two levels. The first level is the tip of the crest of the alveolar ridge, to assess the eligibility of the patient to be included in the study. The second level was 2 mm subcrestally to correlate this radiological measurement with the direct clinical measurement at the implant site. The eligibility of all patients for potential inclusion in the study was evaluated by obtaining a preoperative cone beam computed tomography (CBCT). The density, width, and height of the bone at the selected implantation site were evaluated. The width was measured at two distinct altitudes. The initial level is the point of the crest of the alveolar ridge, which is used to evaluate the patient's eligibility for inclusion in the study. As illustrated in Figure 2, the second level was 2 mm subcrestally to establish a correlation between the direct clinical measurement at the implant site and the radiological measurement.

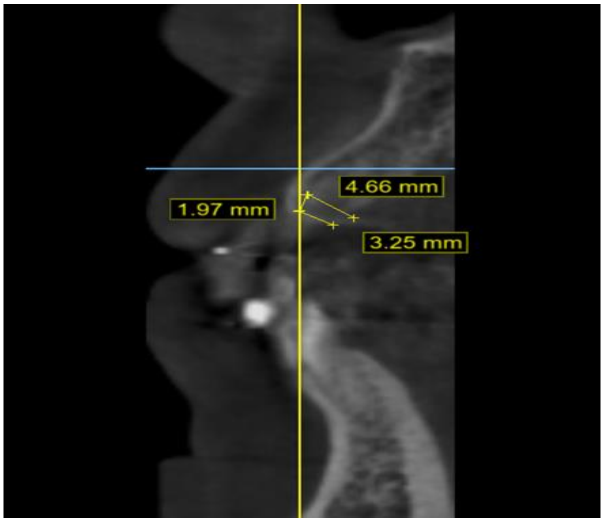

Figure 2: width measured crestally and 2mm sub-crestally.

The patient's blood pressure was recorded and monitored prior to surgery. In order to mitigate the risk of additional oral contamination, the patient was draped in sterile surgical drapes. The patients were instructed to clean their mouths with a 0.2% chlorhexidine solution. Local anesthetic (Lidocaine 2%) was used while the full-thickness flap was elevated. The design of the envelope mucoperiosteal membrane was determined by the location of the implantation. A pilot drill was mounted into the implant engine handpiece to mark the site of the implant bed preparation in the alveolar bone after flap reflection. Subsequently, a 2 mm subcrestal marking was made at the pilot drill hole, where the pre-expansion clinical measurement of the ridge width was assessed using the digital Vernia, (Figure 3).

Figure 3: Ridge width measurement before splitting and expansion.

Starting from the pilot drill hole, we used the piezosurgical micro-saw tip (OT7) to create a sagittal (mid-crestal) osteotomy at the center of the ridge. As shown in Figure 4, we increase the depth of the cut to match the level of the dental implant, inserting it 1-2 mm subcrestally.

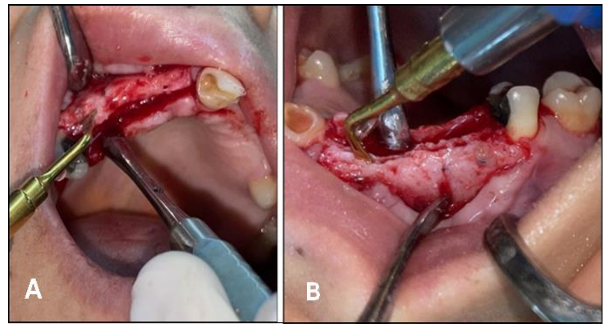

Figure 4: alveolar Ridge crestal bone cut (A) before creation of the crestal bone cut (B) after the bone cut, showing the depth of the cut.

Next, we use Versah Drills in reverse rotation, heavily irrigating with cold, sterile normal saline solution at a torque of 35 N/CM and 800 rpm (Figures 5 and 6).

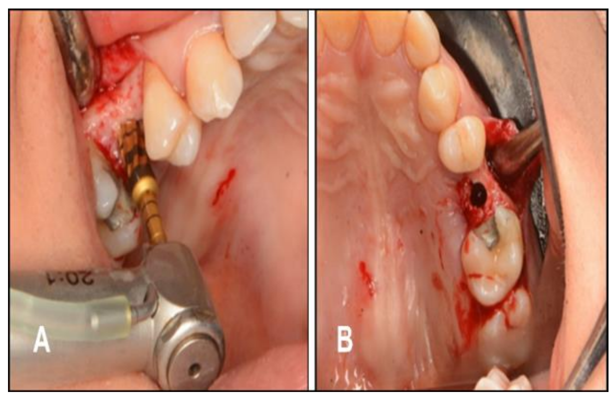

Figure 5: Bone compaction technique by osseodensification after piezo bone cut in single implant case. (A) During drilling (B) after drilling.

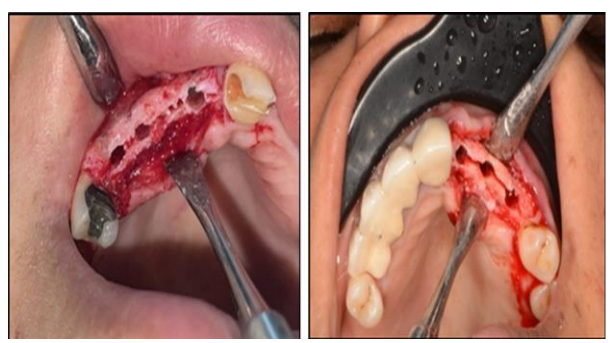

Figure 6: The shape of the alveolar ridges after splitting and osseodensification in cases of multiple implants.

When drilling with the final Versah Drill, the prepared implant site was 2 mm deeper and had the same diameter as the desired implant fixture in the lower jaw. The preparation site was 0.2 mm narrower than the implant fixture in upper jaw cases. A self-threaded titanium implant (Quattrocone Medentika® Implants, Germany) was placed and tightened until the dental implant was 1-2 mm below the crestal bone level. This insertion was performed manually with a gaded hand wrench (Ratchet), and the insertion torque was measured. Next, we greased the lid screw with 2% fucidin ointment before screwing it into the fixture. The additional ointment component was removed. The vernier measurement of the newly gained breadth following expansion from the same 2 mm subcrestal markings was taken. After inspecting the implant site for the presence of a thin buccal bone plate, fenestrations, or bony defects, we performed an appropriate guided bone regeneration operation and removed the patient from the research. Following repositioning, the flap was sutured using a tension-free wound closure. Finally, an interruptive suturing technique was employed to repair the flap using a 4/0 black silk, non-resorbable material. Patients were given a prescription for the proper antibiotics.

Second-stage surgery, prosthetic rehabilitation, and follow-up

Six months after the initial surgical intervention, the surgical site was opened again under the influence of local anesthesia with a crestal incision and simple flap reflection. The cover screw was removed, and the healing abutment was inserted into the implant fixture for 2 weeks, followed by a digital impression using a scan body mounted over the implant fixture and a 3-shape scanner device to transfer the implant position into the lab. We constructed and fixed the prosthetic parts over the implants, using a torque ratchet to tighten the abutment screw to 25 Ncm. All patients were followed up for 6 months after the insertion of the prosthetic part.

Statistical analysis

Data description, analysis, and presentation were performed using Statistical Package for Social Science (SPSS version 22, Chicago, Illinois, USA). Pearson correlation is a parametric test for the linear correlation between two quantitative variables. The Shapiro-Wilk test evaluates the normality of the quantitative variable's distribution. Repeated Measure One-Way Analysis of Variance (ANOVA): a statistical test for the difference between k-related means using Tukey's HSD. The two independent sample t-test is a parametric test that measures the difference between two independent groups. The paired *t*-test examines the differences between two related points. *A p* value less than 0.05 is considered significant.

RESULTS

Seventy implant sites in 43 patients were assessed for eligibility; 34 implant sites were excluded for different reasons, and the remaining thirty-six implant sites in 16 patients were included in the study. Two patients with five implant sites (2 implant sites in the mandible and 3 implant sites in the maxilla) were excluded from the study after intervention because of the development of a thin buccal bone plate and the need for GBR around these sites after implant insertion. The full details of the process are illustrated in Figure 1. Fourteen patients, 4 males and 10 females, aged in the range of 22–60 years old (mean age = 40.07 years), were included in this clinical study. The total number of dental implants is 31, as shown in Table 1.

Table 1: Distribution of implants by demographic data

Variables		n(%)
Gender	M	8(25.81)
	F	23(74.19)
Arch	Maxillary	19(61.29)
	Mandibular	12(38.71)
ID	3.5	31(100)
IL	9	6(19.35)
	11	25(80.65)

n: number of dental implants, M: male, F: female, ID: implant diameter, IL: implant length.

The maxillary arch received 19, and the mandible received 12 dental implants. All implants have a width of 3.5 mm, and the majority are 11 mm in length, followed by 9 mm. All studied variables are normally distributed using the Shapiro-Wilk test at p>0.05 (0.051-0.156), as shown in Table 2.

Table 2: Normality of the distribution of study variables

Variables	Shapiro-Wilk test		
	Statistic	sites	*p*-value
Bone height	0.938	31	0.071
Bone density	0.933	31	0.053
Initial bone width in CBCT at 2 mm subcrestally	0.943	31	0.100
Initial bone width clinically at 2 mm subcrestally	0.942	31	0.096
Bone width after splitting and osseodensification at 2 mm subcrestally	0.939	31	0.078
Bone width after 6 months at 2 mm subcrestally	0.943	31	0.099
Insertion torque	0.932	31	0.051
Vit D3	0.941	31	0.087
Expansion Gain immediately	0.950	31	0.156
Expansion gain after 6 months	0.940	31	0.082

The findings of this study showed that the mean preoperative bone width clinically in the maxillary arch is 4.460 mm, then increases after ridge splitting and osseodensification with simultaneous dental placement to become 5.811 mm. In the mandibular arch, the mean pre-operative bone width measured clinically is 3.918 mm, and it increases immediately after ridge splitting and osseodensification to 6.133 mm. This significant change in the mandible is slightly higher than that in the maxillary arch, as shown in Table 3.

Table 3: Comparing clinical Bone width measurement between arches and among phases

Arch		Initial bone width	Bone width after splitting & osseodensification	Bone width after 6 months	F	*p*	ES
Max.	Range	3.71-4.0	5.7-6.0	5.5-5.8	284.206	0.000	0.971
	Mean±SD	4.46±0.324	5.811±0.094	5.626±0.087			
Mand.	Range	3.3-4.8	5.7-6.8	5.6-6.3	1128.639	0.000	0.996
	Mean±SD	3.918±0.374	6.133±0.342	5.867±0.223			
Independent *t*-test		4.138	3.195	3.567			
p-value		0.000	0.008	0.003			

Max.: maxillary arch, Mand.: mandibular arch, ES: effective size, F: repeated measure ANOVA, SD: standard deviation.

For both the maxillary and mandibular arch, all clinical measurements of bone width show statistically significant differences when comparing all phases with each other (preoperative bone width, bone width after splitting and osseodensification with simultaneous dental placement, and bone width after six months).

DISCUSSION

Although piezosurgery is a great method for precisely cutting bone, more is needed to solve the problem of low bone density. When used alone, it may not be able to provide enough primary stability for dental implants, particularly when the quality of the bone is low. Osseodensification increases bone stability and density, although it may need to be more precise in cutting the bone, as in piezosurgery. Imprecise control in the bone cut could lead to inaccuracies, potentially complicating implant placement. Additionally, the inherent problems with using osseodensification alone to expand dense, compact bone could lead to heat production and subsequent bone resorption, which could cause the implant to fail. Most studies on alveolar bone expansion do not combine piezosurgery and osseodensification drills at the same time, but rather use each method separately. When comparing the mandible and the maxilla, there are significant differences in anatomy, bone density, and biomechanics that influence the extent of expansion gain achievable in each region [19]. According to this study's findings, the mandibular bone density was considerably higher than the maxilla. Different prenatal and postnatal development processes, along with evolutionary pressure to keep the skull appropriately light, could account for the two different densities [20]. Additionally, the differences in bone density levels and distribution between the two jaws could be the result of the maxilla functioning as a force distribution unit and the mandible acting as an absorption unit [21]. The piezoelectric sagittal bone cut, which extends to the full drilling depth with osseodensification drills, may ease the expansion process and minimize the plastic deformation of the alveolar ridges in areas of increased density, particularly in the mandible. The findings of the current study showed that the plastic deformation in the mandibular areas was statistically significant when compared to the maxilla. These results are in line with other studies that proved that mandibular bone is generally denser and more cortical compared to the maxilla. This high-density bone can lead to greater expansion gain without compromising bone structural integrity, while the maxillary bone is typically more trabecular (spongy) and less dense. This lower density can make it able to accommodate expansion forces [22]. Another study by Elgrany *et al.* in 2019 showed that mandibles can achieve significant initial expansion gains using techniques like ridge splitting and osseodensification. The dense bone can be compacted efficiently, providing a substantial width increase. The higher density contributes to better mechanical stability post-surgery, reducing the risk of collapse and maintaining the expansion gain over time, except for the slight change that occurs after a certain period as a result of the healing of the operation site [23]. The osseointegration process of dental implants remains unaffected by the variations in plastic deformation between the maxilla and mandible, as all implants successfully achieve osseointegration, complete prosthetic rehabilitation, and undergo follow-up for the subsequent six months.

Study limitations

The limitations of this study include the short follow-up period and the absence of a follow-up CBCT to assess crestal bone resorption in both groups.

Conclusion

Despite the significant plastic deformation in alveolar ridge width immediately after the procedure in the mandible compared to that in the maxillary arch, this combination strategy efficiently permits proper, simple expansion in severely atrophied alveolar ridges without compromising subsequent bone healing and the osseointegration process.

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Conflict of interests

No conflict of interests was declared by the authors.

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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