Oral and Maxillofacial Surgery
https://doi.org/10.1007/s10006-022-01071-0

ORIGINAL ARTICLE

Evaluation of crestal sinus floor elevations using versah burs with simultaneous implant placement, at residual bone height ≥ 2.0 _ < 6.0 mm. A prospective clinical study

Jenna Z. Alhayati[1] · **Auday M. Al-Anee**[1,2]

Received: 25 January 2022 / Accepted: 4 May 2022

Abstract

Purpose To evaluate the efficacy of Versah drills in breaching the maxillary sinus floor while keeping the membrane intact, as well as measure the implant stability (primary stability at the time of implant placement by the osseous densification of the residual bone height (RBH) of ≥ 2.0 _ < 6.0 mm, and secondary stability after 6 months of osseous healing period).

Methods This prospective clinical study, which included twenty crestal sinus floor elevations, was conducted on 17 patients (10 males and 7 females, ages 29 to 70 years). The sinus membrane integrity was clinically checked at the time of osseodensification sinus lifting and confirmed by CBCT after sinus augmentation and implant insertion. Time of operation has been recorded from the first drill to implant installation. Primary implant stability was measured using an Osstell beacon at the time of implant placement, and secondary stability was measured after 6 months of osseous healing.

Results The mean of secondary stability in the current study is significantly higher than the mean of primary stability ($P \leq 0.011$), which was 74.22 ± 8.11 and 69.85 ± 9.74, respectively, in RBH 3.81 mm as a mean. There was no clinical evidence of membrane perforation or complication reports, and the average operation time was 11.2 ± 1.85 min.

Conclusion The current study found that at highly atrophic posterior maxilla with a residual bone height of ≥ 2.0 _ < 6.0 mm, osseodensification using Versah drills was effective in crestal sinus elevation with no membrane perforation, which was confirmed by cone-beam CT scan postoperatively, and showed higher primary and secondary implant stability.

Keywords Osseodensification · Crestal sinus floor elevations · Atrophic posterior maxilla · Implants stability

Introduction

The posterior maxilla is considered to have the lowest bone density, with 40% D4 bone type found in it [1]. D4 bone is more prone to induce implant mobility and failure in comparison with other types of bone, and it has the most significant crestal stress that extends the furthest apically along the implant body [2].

Rues et al. demonstrated that bone density could affect primary implant stability [3], which is consistent with the results of Pommer et al. [4], and de Elio Oliveros et al. [5].

In addition, the process of maxillary sinus pneumatization (MSP) towards the coronal direction and ridge resorption in the coronal part of the extraction socket can reduce the available bone height in the posterior maxilla for future implant placement [6]. This limited bone height and density, implying insufficient bone quality and quantity, impact the primary stability of the implant, which is critical for successful osseointegration, making implant placement in the posterior maxilla challenging [3].

The challenge is also to lift the sinus membrane and augment the ridge to increase residual bone height (RBH) and density while keeping the Schneiderian membrane intact and free of perforation. Traditionally, two techniques have been used to treat a vertically deficient, edentulous posterior

✉ Auday M. Al-Anee
audayalanee@gmail.com;
audayalanee@codental.uobaghdad.edu.iq

Jenna Z. Alhayati
jennadentistj@gmail.com

1 Department of Oral & Maxillofacial Surgery/Dental Implant Unit, College of Dentistry, University of Baghdad, Baghdad, Iraq

2 Oral & Maxillofacial Surgery, Medical City, Al-Shaheed Gazi Alhariri Teaching Hospital for Specialized Surgeries, Baghdad, Iraq

maxillary ridge with low bone density: direct and indirect [7]. When the RBH is equal to or less than 5 mm, the lateral maxillary sinus window approach is usually used [8], and the indirect transcrestal approach is used when the RBH is at least 5 mm [9].

Both augmentation techniques are clinically effective and have high implant survival rates [10–12], even though each has its own set of complications and limitations, such as the degree of invasiveness, patient morbidity [13], and danger of severing the alveolar antral artery with a lateral approach [14].

Even though it is performed blindly, the indirect sinus lift technique has many advantages over the lateral open approach. The benefits are: that it is more conservative, has a lower incidence of sinus membrane rupture, allows for simultaneous implantation, has good bone healing, better positioning of bone grafting material, it is not subject to resorption, and has a high predictable implant survival rate [15].

The main limitations of indirect sinus lift are the lack of > 5 mm RBH to effectively prevent membrane perforation and the implant's low primary stability [16–18]. Perforation of the sinus membrane (SM) is one of the more specific complications associated with sinus floor elevation [19, 20], occurring in a significantly wide incidental range ranging from 10 to 44% [21–23].

On the other hand, the concept of osteotomes is common for enhancing the density of prepared implant sites. This is a traumatic method that does not improve implant stability due to trabecular micro fracture, which causes prolonged bone resorption and delays osseointegration [24].

In 2015, Salah Huwais introduced the osseodensification technique, which uses a densifying bur to produce a low plastic deformation [25]. It is a novel biomechanical osteotomy preparation technique that helps preserve bone through a non-excavating drilling process that employs specially designed burs with tapered geometry and specially designed flutes that run counterclockwise to expand the osteotomy incrementally. In contrast, bone is compacted apically and laterally [26].

The nonexcavated compacted bone raises and penetrates the sinus floor without perforating the membrane or violating the sinus to increase vertical bone height [27]. Osseodensification has also increased the peripheral and apical bone mineral density around the implants, bone-to-implant contact (BIC), and percentage of bone volume (BV) around it, thereby improving implant stability [28–30].

Because of the viscoelastic nature of the bone, the condensed layer of autografted bone undergoes a spring-back effect [31], which creates compressive forces against the implant, thus enhancing bone-to-implant contact, which is shown to promote osteogenic activity through a mechanobiological healing process, leading to faster wound healing, which is highly associated with successful osseointegration [32, 33].

Arafat & Elbaz found that osseodensification (OD) sinus floor elevation was superior to osteotome elevation in 1ry and 2ry stability and bone gain [34].

In comparison to Summer's technique principle, that osteotome indirect sinus lift is employed when RBH is equal to or > 6 mm [18], Versah Osseodensification Crestal Sinus Lift is possible with RBH of < 6 mm, depending on densah protocol to take advantage of conservative crestal indirect approach and avoid the morbidity of lateral approach.

The study is aimed to assess the efficacy of Versah drills in breaching the sinus floor while keeping the membrane intact, as well as to measure the implant stability; primary stability at the time of implant placement with simultaneous sinus lifting by the osseous densification of the RBH of ≥ 2.0 _ < 6.0 mm, and secondary stability after 6 months of the osseous healing period.

Materials and methods

This prospective clinical study was approved by the Ethics Committee of the College of Dentistry/University of Baghdad (protocol number: 211120). All risks associated with the proposed procedure and the possibility of failure were clearly described to the patients, and a written informed consent was obtained from all research participants.

A total of seventeen patients aged 29–70 years, 10 males and 7 females who met the eligibility criteria, participated in this study that included twenty crestal sinus floor elevations.

Inclusion criteria for patient selection were: residual bone height of ≥ 2.0 < 6.0 mm, healthy individuals without any systemic disease or local condition that may compromise bone healing potential, or pathological lesion at the sinus zone, and without clinical and/or radiological evidence of rhinosinusitis or any other pathologies in the maxillary sinus (MS). Heavy smoking patients (> 20 cigarettes daily) or patients with alcohol abuse or cocaine addiction were excluded from the study.

Cone beam CT scan (CBCT) (Kavo OP 3D Pro, Karl Kolb, Germany) was requested for every candidate (2 weeks before surgery) for sinus augmentation to determine the exact alveolar bone height and width at the proposed implant site. Densah protocol has been followed, which includes that when RBH is 4–5 mm, the residual bone width (RBW) must be ≥ 5, and when RBH is 2–3 mm, the RBW must be ≥ 7 mm.

CBCT was essential to provide a guide for assessing the condition of the MS, ostium patency, presence of antral septa, and other pathologies that may influence the alveolar bone or the MS and the degree of sinus pneumatization and thickness of Schneiderian membrane.

The bone density of the planned implant site was measured using the Misch scale 2008, for density estimation: D1 > 1250 HU, D2 = 850–1250 HU, D3 = 350–850 HU, D4 = 150–350 HU, and D5 < 150 HU, recorded from the coronal view by ROI (region of interest using On-demand software).

The same surgeon operated all patients under local anesthesia (Lidocaine 2% with Adrenaline 1:80,000 /Septodont, France). Amoxicillin/clavulanate 1 g oral tablet for antimicrobial prophylaxis was given 1 h before surgery. In allergic individuals, the alternative was clindamycin 600 mg. Oral rinses with Chlorhexidine digluconate mouth wash 0.2% also were prescribed for up to 10 days.

Universal versah® osseodensification bur kit (Versah Co., LLC., USA) used for one stage sinus lift surgery and implant site preparation.

A full mucoperiosteal flap was reflected (extensive or limited flap design) selected depending on the case demand. The pilot drill has been avoided in all cases to prevent membrane perforation, especially since the subantral distance in all cases is less 6 mm (according to versah® Lift Protocol).

After determining the size of the dental implant according to the accurate CBCT measurements, drilling has been started with versah® Bur 2.0 (counterclockwise drill speed 800–1500 rpm–Densifying Mode with copious irrigation), running the bur until reaching the dense sinus floor.

The subsequent wider versah® Bur (3.0) has been used in the previously formed osteotomy with modulating pressure and a pumping motion. When reaching the dense sinus floor with the feeling of the haptic feedback of the bur, advance the past sinus floor in 1 mm increments (Maximum bur advancement past the sinus floor, must not exceed 3 mm at any stage). Bone will be pushed towards the apical end and begin lifting the membrane gently and autograft compacted bone up to 3 mm.

Then, sequentially wider Densah® Burs used in Densifying Mode to obtain additional width with a maximum membrane lift of 3 mm to reach the final desired width for implant placement. Versah burs have been used in full step increments which mean: 2.0, 3.0, 4.0, 5.0. So, when the implant diameter is 4.3, the final Versah bur was of 4.0 mm diameter, while for the implant size of 5.0, the final Versah bur was 5.0 mm diameter.

Under preparation of the implant cavity (by one size only) was applied only when the residual bone height was 2 or 3 mm to enhance the primary stability of the dental implant in such a poor quality and poor quantity of residual ridge bone.

The sinus membrane's integrity has been examined by slowly pushing normal saline into the osteotomy site with a disposable plastic medical syringe filled with normal saline (The end of the needle's protective cover has been cut off)

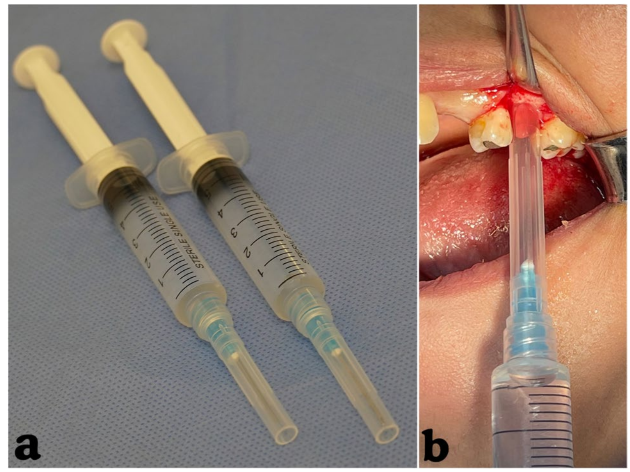

Fig. 1 **a** Disposable medical syringe filled with normal saline (The end of the needle's protective cover has been cut off), **b** examination of the sinus membrane's integrity, notice of the return of normal saline to the cover

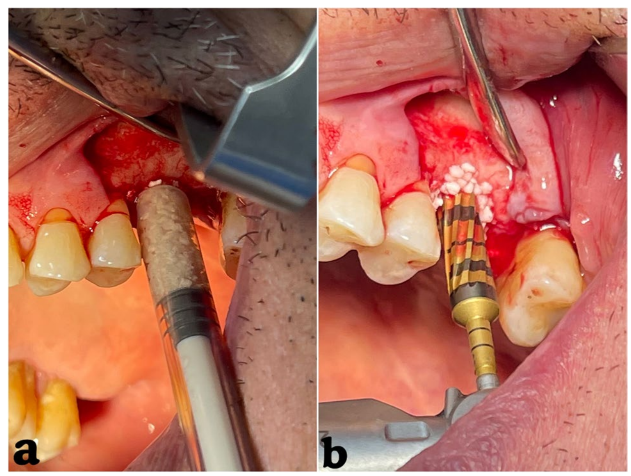

Fig. 2 Using the final Versah® Bur in Densifying Mode, to propel the alloplastic graft and lift the sinus membrane further

(Fig. 1 a). If the membrane is intact, the normal saline will return into the cover (Fig. 1 b).

During this test, the patient will be asked if he or she feels any liquid in the nasal passage. If the patient coughs and there is no saline flow back, that would indicate the perforation of the sinus membrane. In this situation, a collagen membrane must be inserted through the osteotomy site before bone grafting.

After reaching the final planned diameter, using the final vensah® Bur in Densifying Mode (Counterclockwise) at a low speed of 150–200 rpm with no irrigation to propel a well-hydrated, alloplastic bone graft (Osteon™ II Sinus, Syringe Type/Genoss Co., Korea) into the sinus (Fig. 2).

The versah® Bur is used to aid in the compaction of allograft material to lift the sinus membrane further and should not extend beyond the sinus floor by more than 2–3 mm. The graft propelling step has been repeated as needed to allow for additional membrane lift based on implant length.

Standard sizes of endosseous Quattrocone dental implants (Medentika®, Hügelsheim, Germany, a Straumann group brand) have been used in all cases (4.3 or 5.0 mm diameter, 09 or 11 mm in length). The body of the QUATTROCONE implant is root shaped and, in combination with a high-profile thread and three cutting edges, ensures high primary stability, even in challenging situations. It has a highly pure, sand-blasted and acid-etched surface extends the entire length of the implant to the machined implant shoulder. It possesses macro–micro roughness with the coronal microthread (Fig. 3).

Fig. 3 Macro design of Quattrocone dental implants (Medentika®, Hügelsheim, Germany, a Straumann group brand)

The Osstell Beacon (Gothenburg, Sweden) helps to objectively and non-invasively determine implant stability after implant was placed into the osteotomy site (primary stability), uses Resonance Frequency Analysis (RFA). The SmartPeg type 38 has been attached to the implant by screwing the SmartPeg Mount with a finger force of about 4–6 Ncm. A beeping sound is heard when the measurement begins, and the value is viewed in the upper display, along with a colored light indicator below the instrument tip. High stability means > 70 ISQ, 60–69 is medium stability, and < 60 ISQ is regarded as low stability.

Immediately postoperative, a second CBCT is performed (Fig. 4).

The timer has been set to record the time of the surgery, from the first drill to the implant installation. Flap reflection and wound closure were not included in the time frame to avoid time differences in cases involving inserting multiple implants simultaneously.

Follow-up appointments were scheduled after ten days for suture removal, one month for clinical observation, and six months for the final prosthesis and secondary implant stability record using Ostell.

Statistical analysis

The data analyzed using Statistical Package for Social Sciences (SPSS) version 26. The data presented as mean, standard deviation (SD). Categorical data presented by frequencies and percentages. As data had a normal distribution, the paired *t*-tests are employed. Probability values of less than 0.05 were considered statistically significant.

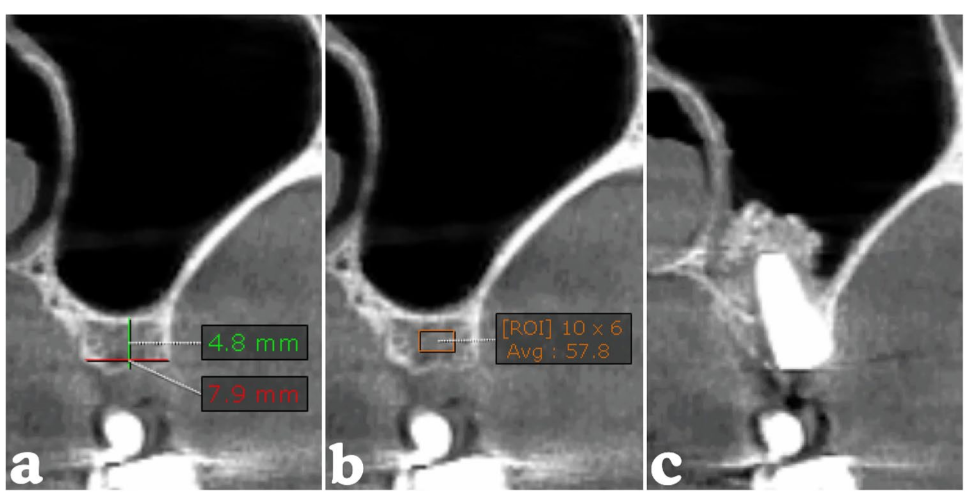

Fig. 4 Pre- and postoperative CBCT of missing tooth site #14. **a** Coronal view showing the available RBH 4.8 mm and RBW 7.9 mm, **b** the average bone density 57.8 D5, **c** postoperative CBCT coronal view of dental implant at missing tooth site

Results

Patients' ages vary from 29 to 70 years old, with an average of 47.3 years and a standard deviation (SD) of ± 11.5. The highest percentage of 70.6% was reported in ≥ 40 years old. Regarding gender, the proportion of males was higher than females, with 10 males and 7 females (58.8% vs 41.2%) respectively.

There was no clinical membrane perforation or complication report during sinus lift surgery or postoperatively in CBCT. At the end of this study, there was no early and late complication during the 6-month follow-up period, and all implants were Osseointegrated, making the implants' early survival 100%.

The dental implant of size (4.3/11) was utilized in 35% of cases, and the rest of the implants were of size (5.0/9). In the current study, most implants were placed in D4 bone density (55%), while the minority of implants were placed in D3 bone density (25%), and (20%) in D5 bone density. According to the tooth site number, First permanent molars #3 & #14 were the most prevalent tooth sites (40% & 35%), respectively, followed by second molars (15%) and second premolar (10%).

The mean of secondary stability in the current study is significantly higher than the mean of primary stability (P ≤ 0.011), which was 74.22 ± 8.11 and 69.85 ± 9.74 respectively (Table 1).

Based on the subsinus initial residual bone height, the two groups are classified into group A (2_3.9 mm) with an average of 2.92 ± 0.60 mm, and group B (4_5.9 mm) with an average of 4.73 ± 0.62 mm (Table 2).

The primary stability mean value for group A was 65.00 ± 9.54, while it was 74.70 ± 7.55 for group B. Moreover, the secondary stability mean value for group A was 68.80 ± 7.24 while it was 79.65 ± 4.59 for group B. Comparing ISQ values in both RBH groups, primary and secondary stability are significantly higher in group B(4–5.9 mm) than in group A(2–3.9 mm) during the study period.

The average time of surgery is 11.2 min, with a standard deviation (SD) of ± 1.85 min.

Table 1 The mean ISQ at surgery and 24 weeks after surgery

	Primary stability	Secondary stability	*P*-value
Mean ISQ (SD)	69.85 (9.74)	74.22 (8.11)	0.011 **[S]**
Minimum	50.50	51.00	
maximum	83.00	85.00	

SD, Standard deviation; *P*, probability value; *S*, significant

Table 2 The mean implant stability in comparison to RBH groups

	Group A: 2 _3.9 mm RBH Mean SD 2.92 ± 0.60	Group B: 4_5.9 mm RBH Mean SD 4.73 ± 0.62	*P*-value
Primary stability Mean ISQ (SD)	65.00 (9.54)	74.70 (7.55)	0.183 **[NS]**
Secondary stability Mean ISQ (SD)	68.80 (7.24)	79.65 (4.59)	0.023 **[S]**

RBH, Residual bone height; *SD*, Standard deviation; *P*, probability value; *S*, significant; *NS*, nonsignificant

Discussion

The remaining alveolar bone height at the implant recipient site is essential in determining the chance of sinus membrane perforation during crestal sinus elevation. Moreover, the main limitations of crestal indirect sinus lift are the lack of > 5 mm residual bone height to effectively prevent membrane perforation and the implant's low primary stability [16–18].

Rosen et al. concluded that RBH is directly related to survival rates, with 96% when 5 mm or more of bone is present and 85% when 4 mm or less bone is present [35].

Perforation of the SM is one of the most specific complications associated with sinus floor elevation [19, 20], occurring in a significantly wide incidental range from 10 to 44% [21–23].

According to Kasabah et al., sinus membrane perforation accounts for up to 56% of sinus lifting complications [36]. With crestal sinus floor elevation, the incidence of perforation ranges from 0 to 21.4% [37]; when an endoscope is used to confirm SM perforation, this rate rises to 40% [38].

Ardekian et al. found that sinus membranes with a residual ridge of 3 mm had a perforation rate of 85%, while residual ridges of 6 mm had a perforation rate of only 25% [19].

In the current study, the RBH range is between ≥ 2.0 mm and < 6 mm. This range is thought to be more challenging in terms of maxillary sinus floor elevation and morbidity, to examine and to compare the special features of Versah bur not only to the indirect approach (by traditional techniques), but also to the direct lateral approach.

The counterclockwise rotation of the Versah bur's unique design facilitates autogenous bone compacting along the osteotomy wall and apically toward the sinus floor. Additionally, the pumping action of the bur (in and out motion) and copious irrigation press the viscous bone graft, which serves as hydraulic pressure to atraumatically release and lift the Schneiderian membrane.

Furthermore, bone substitute material was efficiently pushed into the sinus, elevating the membrane further while demonstrating a low risk of perforation.

There is no clinical evidence of perforation in the present research, which is confirmed by CBCT postoperatively, even when the RBH was 2 mm. And the mean of secondary stability is significantly higher than the mean of primary stability, with values of (74.22 VS 69.85), respectively.

One such medium to high primary implant stability (depending on ISQ scale) in a study sample with poor bone quality and quantity is associated with the osseodensification concept.

OD is based on the preservation and collection of autogenous bone within the implant site via non-subtractive drilling and the compaction of cancellous bone, which has strong viscoelastic and plastic deformation properties.

Unlike traditional osteotomies, OD creates the osteotomy while preserving vital bone tissue and increasing the amount and density of peri-implant bone, as well as increasing the bone-to-implant contact (BIC) and percentage of bone volume (BV) around it; thereby improving implant stability [25–27, 39–41] with no impairment to osseointegration when compared to regular drilling [42].

Primary stability is regarded as an essential factor for secondary stability, and primary mechanical stability leads to more efficient biological secondary stability achievement [43].

The bone remodeling unit takes more than 3 months to repair the damage caused by conventional drills that remove a significant amount of bone to allow strains in the walls of osteotomies to reach or exceed the bone microdamage threshold [44]. Hence, OD will help keep bone bulk and increase density, shortening the healing period [39]. Also, the spring-back effect of the condensed layer of autografted bone [31] creates compressive forces against the implant, thus enhancing bone-to-implant contact, which has been shown to promote osteogenic activity via a mechanobiological healing process, leading to faster wound healing, which is highly associated with successful osseointegration [32, 33].

Bone density and implant stability have a positive correlation. The majority of implants in the current study, 55%, were classified as having D4 bone density. A preoperative measurement was taken from the CBCT coronal view using on-demand software. Cone Beam Computed Tomography (CBCT) is still the most widely used diagnostic tool for determining bone density [45]. Despite the fact that Hounsfield units (HU) are not directly applicable to CBCT, there has been some controversy [46]. Hendi & Beda, support the use of the OD technique to enhance bone density in low-bone density areas and demonstrate a statistically significant change in the mean bone density measured at the implant's apical location [41].

The densification depends on adequate trabecular bone volume to relatively fewer trabecular spaces to increase the percentage bone volume and bone-to-implant contact area. Trisi et al. observed that the increase of bone density in the OD site was evident in the most coronal implant site [40]. Pai et al., in their histomorphological analysis, revealed the presence of autogenous bone fragments in the osseodensified osteotomy sites, particularly in bone with low mineral density compared to regular drills. These fragments acted as nucleating surfaces, promoting bone regeneration around the implants and providing greater bone density and stability [39].

Conclusion

The current study found that at a highly atrophic posterior maxilla with a residual bone height of ≥ 2.0 _ < 6.0 mm, osseodensification using Versah drills was effective in crestal sinus elevation with no membrane perforation confirmed by cone-beam CT scan postoperatively and showed higher primary and secondary implant stability.

OD demonstrated a simplified, less traumatic, minimally invasive membrane elevation method with less morbidity and operation time.

At the end of this study, there were no early or late complications during the 6-month follow-up period, and all implants have achieved osseointegration successfully, making the implant's early survival 100%.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10006-022-01071-0.

Author contribution All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Jenna Z. Alhayati] and [Auday M. Al-Anee]. The first draft of the manuscript was written by [Jenna Z. Alhayati] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Ethics approval and consent to participate The study has been approved by the Ethics Committee of College of Dentistry/University of Baghdad (protocol number: 211120). Written informed consent was obtained from all participants prior to their enrollment.

Consent for publication The authors affirm that all participants provided informed consent for publication of the images (although that there is no image exposing any patient face or identity).

Competing interests The authors declare no competing interests.

References

1. Monstaporn M, Rungsiyakull C, Jia-mahasap W, Pleumsamran N, Mahrous A, Rungsiyakull P (2021) Effects of bone types on bone remodeling of a dental implant: a review of the literature. Chiang Mai Dental Journal (CMDJ) 42(2):14–17

2. Misch CE (1999) Bone density: a key determinant for clinical success. Contemp Implant Dent 8:109–118
3. Rues S, Schmitter M, Kappel S, Sonntag R, Kretzer JP, Nadorf J (2020) Effect of bone quality and quantity on the primary stability of dental implants in a simulated bicortical placement. Clin Oral Invest 25:1265–1272. https://doi.org/10.1007/s00784-020-03432-z
4. Pommer B, Hof M, Fadler A, Gahleitner A, Watzek G, Watzak G (2014) Primary implant stability in the atrophic sinus floor of human cadaver maxillae: impact of residual ridge height, bone density, and implant diameter. Clin Oral ImplantsRes25:e109–e113 https://doi.org/10.1111/clr.12071
5. de Elio OJ, Del Canto DA, Del Canto DM, JacoboOrea C, Del Canto Pingarron DM, SecoCalvo DJ (2020) Alveolar bonedensity and width affect primary implant stability. J Oral Implantol. https://doi.org/10.1563/aaid-joi-D-19-00028
6. Lim HC, Kim S, Kim DH, Herr Y, Chung JH, Shin SI (2021) Factors affecting maxillary sinus pneumatization following posterior maxillary tooth extraction. Journal of periodontal & implant science 51(4):285–295. https://doi.org/10.5051/jpis.2007220361
7. George J, Gopal S, Huda F, Thomas N (2020) Minimally invasive transalveolar sinus augmentation: an answer to sinus conundrum. Dentistry and Medical Research 8(1):4. https://doi.org/10.4103/dmr.dmr_3_20
8. Bhalla N, Dym H (2021) Update on maxillary sinus augmentation. Dent Clin North Am 65(1):197–210. https://doi.org/10.1016/j.cden.2020.09.013
9. Khehra A & Levin L (2020) Maxillary sinus augmentation procedures: a narrative clinical review. Quintessence international (Berlin, Germany: 1985), 51(7), 578–584. https://doi.org/10.3290/j.qi.a44632
10. d'Elia C, Baldini N, Gabriele G, Nuti N, Juloski J & Gennaro P (2019) The simultaneous sinus lift and implant placement using lateral approach in atrophic posterior maxilla with residual bone height of 5 mm or less. A systematic review. Journal of Osseointegration, 11(4), 525–534 https://doi.org/10.23805/JO.2019.11.03.12
11. Corbella S, Taschieri S, Del Fabbro M (2015) Long-term outcomes for the treatment of atrophic posterior maxilla: a systematic review of literature. Clin Implant Dent Relat Res 17(1):120–132. https://doi.org/10.1111/cid.12077
12. Del Fabbro M, Wallace S.S, & Testori T. (2013). Long-term implant survival in the grafted maxillary sinus: a systematic review. International Journal of Periodontics and Restorative Dentistry, 33, 773–783. https://doi.org/10.11607/prd.1288
13. Farina R, Franceschetti G, Travaglini D, Consolo U, Minenna L, Schincaglia GP, Riccardi O, Bandieri A, Maietti E, Trombelli L (2018) Morbidity following transcrestal and lateral sinus floor elevation: a randomized trial. J Clin Periodontol 45(9):1128–1139. https://doi.org/10.1111/jcpe.12985
14. Kim J, Jang H (2019) A review of complications of maxillary sinus augmentation and available treatment methods. J Korean Assoc Oral Maxillofac Surg 45(4):220–224. https://doi.org/10.5125/jkaoms.2019.45.4.220
15. Lo Giudice G, Iannello G, Terranova A, Lo Giudice R, Pantaleo G et al (2015) Transcrestal sinus lift procedure approaching atrophic maxillary ridge: a 60-month clinical and radiological follow-up evaluation. Int J Dent 2015:1–8. https://doi.org/10.1155/2015/261652
16. Sathvik N, Nessapan T, Ganapathy D (2019) Indirect sinus lift techniques: a literature review. Drug Invention Today 11(2):90–93
17. Emmerich D, Att W, Stappert C (2005) Sinus floor elevation using osteotomes: a systematic review and meta-analysis. J Periodontol 76(8):1237–1251. https://doi.org/10.1902/jop.2005.76.8.1237
18. Summers RB . (1994) A new concept in maxillary implant surgery: the osteotome technique. Compendium 1994 ; 15 : 152,154–156 , 158
19. Ardekian L, Oved-Peleg E, Mactei EE, Peled M (2006) The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. J Oral Maxillofac Surg 64(2):277–282
20. Proussaefs P, Lozada J, Kim J, Rohrer MD (2004) Repair of the perforated sinus membrane with a resorbable collagen membrane: a human study. Int J Oral Maxillofac Implants 19(3):413–420
21. Schwartz-Arad D, Herzberg R, Dolev E (2004) The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. J Periodontol 75(4):511–516. https://doi.org/10.1902/jop.2004.75.4.511
22. Timmenga NM, Raghoebar GM, Boering G, van Weissenbruch R (1997) Maxillary sinus function after sinus lifts for the insertion of dental implants. J Oral Maxillofac Surg 55(9):936–939. https://doi.org/10.1016/S0278-2391(97)90063-X
23. Sakkas A, Konstantinidis I, Winter K, Schramm A, & Wilde F (2016). Effect of Schneiderian membrane perforation on sinus lift graft outcome using two different donor sites: a retrospective study of 105 maxillary sinus elevation procedures. GMS Interdisciplinary plastic and reconstructive surgery DGPW 5 https://doi.org/10.3205/iprs000090
24. Wang L, Wu Y, Perez KC, Hyman S, Brunski JB, Tulu U, Helms JA (2017) Effects of condensation on peri-implant bone density and remodeling. J Dent Res 96(4):413–420. https://doi.org/10.1177/0022034516683932
25. Huwais S, & Meyer E (2015). Osseodensification: a novel approach in implant osteotomy preparation to increase primary stability, bone mineral density and bone to implant contact. Int J Oral Maxillofac Implants. https://doi.org/10.11607/jomi.4817
26. Podaropoulos L (2017) Increasing the stability of dental implants: the concept of osseodensification. Balkan Journal of Dental Medicine 21(3):133–140
27. Huwais S, Mazor Z, Ioannou A. L, Gluckman H, & Neiva, R. (2018). A multicenter retrospective clinical study with up-to-5-year follow-up utilizing a method that enhances bone density and allows for transcrestal sinus augmentation through compaction grafting. The International journal of oral & maxillofacial implants, 33(6), 1305–1311. https://doi.org/10.11607/jomi.6770
28. Yeh Y. T, Chu T. G, Blanchard S. B, & Hamada Y. (2021). Effects on ridge dimensions, bone density, and implant primary stability with osseodensification approach in implant osteotomy preparation. The International journal of oral & maxillofacial implants, 36(3), 474–484. https://doi.org/10.11607/jomi.8540
29. Gaikwad AM, Joshi AA, & Nadgere J.B. (2020). Biomechanical and histomorphometric analysis of endosteal implants placed by using the osseodensification technique in animal models: a systematic review and meta-analysis. The Journal of Prosthetic Dentistryhttps://doi.org/10.1016/j.prosdent.2020.07.004
30. Slete FB, Olin P, Prasad H (2018) Histomorphometric comparison of 3 osteotomy techniques. Implant Dent 27(4):424–428. https://doi.org/10.1097/ID.0000000000S0000767
31. Kold S, Bechtold J, Ding M, Chareancholvanich K, Rahbek O, Søballe K (2003) Compacted cancellous bone has a spring-back effect. Acta Orthop Scand 74(5):591–595
32. Padhye NM, Padhye AM, Bhatavadekar NB (2020) Osseodensification – a systematic review and qualitative analysis of published literature. Journal of oral biology and craniofacial research 10(1):375–380. https://doi.org/10.1016/j.jobcr.2019.10.002
33. Gayathri S (2018) Osseodensification Technique – a novel bone preservation method to enhance implant stability. Acta Scientific Dental Sciences 2(12):17–22
34. Arafat S. W, & A Elbaz M. (2019). Clinical and radiographic evaluation of osseodensification versus osteotome for sinus floor elevation in partially atrophic maxilla: a prospective long term

study. Egyptian Dental Journal, 65(1-January (Oral Surgery)), 189–195. https://doi.org/10.21608/edj.2015.71261
35. Rosen PS, Summers R, Mellado JR, Salkin LM, Shanaman RH, Marks MH, Fugazzotto PA (1999) The bone-added osteotome sinus floor elevation technique: multicenter retrospective report of consecutively treated patients. Int J Oral Maxillofac Implants 14(6):853–858
36. Kasabah S, Krug J, Simunek A, Lecaro MC (2003) Can we predict maxillary sinus mucosa perforation? ACTA MEDICA-HRADEC KRALOVE- 46(1):19–24
37. Tan WC, Lang NP, Zwahlen M, Pjetursson BE (2008) A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: Trans alveolar technique. J Clin Periodontol 35:241–254. https://doi.org/10.1111/j.1600-051X.2008.01273.x
38. Garbacea A, Lozada JL, Church CA, Al-Ardah AJ, Seiberling KA, Naylor WP, Chen JW (2012) The incidence of maxillary sinus membrane perforation during endoscopically assessed crestal sinus floor elevation: a pilot study. Journal of Oral Implantology 38(4):345–359. https://doi.org/10.1563/AAID-JOI-D-12-00083
39. Pai UY, Rodrigues SJ, Talreja KS, Mundathaje M (2018) Osseodensification–a novel approach in implant dentistry. The Journal of the Indian Prosthodontic Society 18(3):196. https://doi.org/10.4103/jips.jips_292_17
40. Trisi P, Berardi D, Paolantonio M, Spoto G, D'Addona A, Perfetti G (2013) Primary stability, insertion torque, and bone density of conical implants with internal hexagon: is there a relationship? Journal of craniofacial surgery 24(3):841–844. https://doi.org/10.1097/SCS.0b013e31827c9e01
41. Hindi A. and Bede S., (2020). The effect of osseodensification on implant stability and bone density: a prospective observational study. Journal of Clinical and Experimental Dentistry, pp.e474-e478. https://doi.org/10.4317/jced.56727
42. Lahens B, Neiva R, Tovar N, Alifarag AM, Jimbo R, Bonfante EA, Bowers MM, Cuppini M, Freitas H, Witek L, Coelho PG (2016) Biomechanical and histologic basis of osseodensification drilling for endosteal implant placement in low density bone. An experimental study in sheep. J Mech Behav Biomed Mater 63:56–65. https://doi.org/10.1016/j.jmbbm.2016.06.007
43. Monje, A., Ravidà, A., Wang, H. L., Helms, J. A., & Brunski, J. B. (2019). Relationship between primary/mechanical and secondary/biological implant stability. The International journal of oral & maxillofacial implants, 34, s7–s23. https://doi.org/10.11607/jomi.19suppl.g1
44. Frost HM (1998) A brief review for orthopedic surgeons: fatigue damage (microdamage) in bone (its determinants and clinical implications). J Orthop Sci 3(5):272–281. https://doi.org/10.1007/s007760050053
45. Al-Attas MA, Koppolu P, Alanazi SA, Alduaji KT, Parameaswari PJ, Swapna LA, Almoallim H, Krishnan P (2020) Radiographic evaluation of bone density in dentulous and edentulous patients in Riyadh. KSA Nigerian journal of clinical practice 23(2):258–265. https://doi.org/10.4103/njcp.njcp_154_19
46. Chappuis, V., Araújo, M. and Buser, D., (2016). Clinical relevance of dimensional bone and soft tissue alterations post-extraction in esthetic sites. Periodontology 2000, 73(1), pp.73–83. https://doi.org/10.1111/prd.12167