JO JOURNAL OF OSSEOINTEGRATION periodontics and prosthodontics

Sub-antral volumetric variation after a modified trephine sinus elevation approach: An 8-month prospective study

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TO CITE THIS ARTICLE
Freiha C, Kassir AR, Ghosn N, Mokbel N, Naaman N, Dagher M. Sub-antral volumetric variation after a modified trephine sinus elevation approach: An 8-month prospective study. J Osseointegr 2021;13(4):227-233.

DOI 10.23805 /JO.2021.13.04.8

ABSTRACT

Aim To overcome vertical deficiency of atrophic posterior maxilla, sinus floor elevation has been used for several decades either through a transcrestal or a lateral approach. In 1999, Fugazzotto et al. described a modified trephine/osteotome technique for sinus floor augmentation at the time of maxillary molar extraction without implant placement. A trephine was used to create a bone core in the middle of the extraction site and was gently malleted apically. In 2002, Fugazzotto et al. used the same principle to place dental implants in healed maxillary molars sites with limited residual height (RH). This procedure demonstrated a 98.3% implant survival rate at 4 years but lacked radiographic information. The aim of the present study was to assess the efficacy of the modified trephine/osteotome sinus elevation with implant placement, using a clinical and a radiographic cone beam evaluation.

Materials and methods Twenty-one implants were placed in premolar and molar sites with 3≤ RH ≤6mm using the modified trephine/osteotome sinus elevation approach and were evaluated clinically and radiographically at baseline (T1), 3 (T3) and 8 (T8) months.

Results Implant survival was 100% at 8 months. Sub-antral volumetric bone gain between T1 and T8 was 20.34%. Linear bone gain was 2.1 ± 1.1 mm buccally; 2.0 ± 1.4 mm palatally; 2.5 ± 1.6 mm mesially; and 1.5 ± 1.5 mm distally. Mean linear bone gain was 2.0±1.1 mm calculated on the CBCT. Implant stability quotient (ISQ) at T1 was 66.378±7.931, and 67.921±14.369 at T3 without a statistically significant difference between the two measurements. Residual height was positively correlated to vestibular, palatal, and mesial bone gain. Signs of Schneiderian membrane tearing were noticeable in one case.

Conclusion This study demonstrated that sufficient subantral bone formation can be obtained with the modified trephine/osteotome technique with high implant survival rate and low post-operative morbidity.

KEYWORDS Dental implants, sinus lift, osteotome technique, osteotome sinus floor elevation, transcrestal approach, survival rate, volumetric changes, osteotome internal sinus elevation, implant stability; implant success; no grafting.

INTRODUCTION

Extraction of maxillary molars and premolars results in remodeling of the residual alveolar bone in combination with sinus pneumatization (1–3). In fact, three-dimensional radiographic studies showed that the posterior maxilla undergoes more remarkable degrees of vertical bone resorption than the other edentulous areas of the oral cavity following extraction (4,5).

To overcome vertical deficiency of atrophic posterior maxilla, Tatum et al. proposed in 1975 the first approach for sinus floor elevation (6). This technique, known as lateral sinus floor lifting, has been used for several decades. Many authors reported results with 90% implant survival rates at 1 year (7–12). However, this technique remains highly invasive and requires a delayed implant placement to allow consolidation of the grafted bone. In 1986 Tatum et al. introduced the first crestal approach using "socket formers" with malleting forces. In 1994, Summers et al. elaborated a less invasive technique approaching the antral cavity from the crestal area. It consisted in elevating the sinus floor using osteotomes without drilling (13,14). Simple but disconcerting for the patient, the technique knew various modification aiming to reduce the malleting force required to dislocate the bone particles (15–17). The main alternative proposed to free the path of the osteotome was drilling up to 1 mm from the sinus floor. In this case, the trauma was considerably reduced but compromised the alveolar bone under the sinus. To overcome this drawback, Fugazzotto et al. described in 1999 a modified trephine/osteotome technique for sinus floor augmentation at the time of maxillary molar extraction without implant placement and without the use of drills. A trephine

was used to create a bone core in the middle of the extraction site and was gently malleted apically (18). In 2002, Fugazzotto et al. used the same principles of this technique to place implants in healed maxillary molars sites with small residual height (RH). A trephine is used to create a bone core that is released circumferentially and held into place by the alveolar apical wall. An osteotome of the same diameter is used to displace it apically. The path of the osteotome is facilitated and implant site is created without drilling. This procedure demonstrated a survival rate of 98.3% at 4 years but lacked radiographic information about the bone core transformation (19). Thus, the aim of the present study was to assess the efficacy of the modified trephine/osteotome sinus elevation approach with implant placement, using a clinical and a radiographic cone beam evaluation.

MATERIALS AND METHODS

Patient selection

Twenty-one maxillary edentulous sites were selected in 18 patients between November 2015 and June 2016 at the dental center of the faculty of dentistry at Saint Joseph University in Beirut. Six men and 12 women aged from 22 to 79 years old met the inclusion criteria and signed an informed consent. The study was approved by the faculty ethical committee (reference number : USJ-2017-22) and the surgeries took place in the Department of Periodontology of the Faculty of Dentistry at Saint Joseph University in Beirut.

The inclusion criteria of the study were as follows:

- Healthy patients with no systemic condition that contraindicates implant placement.
- Presence of a good oral hygiene and controlled periodontal disease under strict maintenance.
- Willingness to engage in a long-term post-therapy reassessment.
- Premolar or maxillary molar site with an indication of implant placement.
- The residual height (RH), evaluated on a retro-alveolar plate, should be between 3 and 6 mm (Primary evaluation: 3 mm <RH <6 mm). The RH is defined as the distance between the most coronal point on the bony crest and the most coronal point of the sinus floor connected, in the middle of the bone crest (Fig. 1). This distance was then confirmed on a cone bean computed tomography (CBCT), with a radiological guide in the mouth.
- A bone width of at least 6.8 mm at the implant site.

The exclusion criteria of the study were as follows.

- Presence of immune diseases or radiotherapy and chemotherapy in the head and neck area during the 12 months preceding the intervention.
- Presence of uncontrolled diabetes, risk of endocarditis, bone diseases and bisphosphonate intake.
- Smoking habit exceeding one pack of cigarettes per day (twenty cigarettes).
- Presence of acute sinus infection, or a history of recurrent inflammation of the maxillary sinuses.

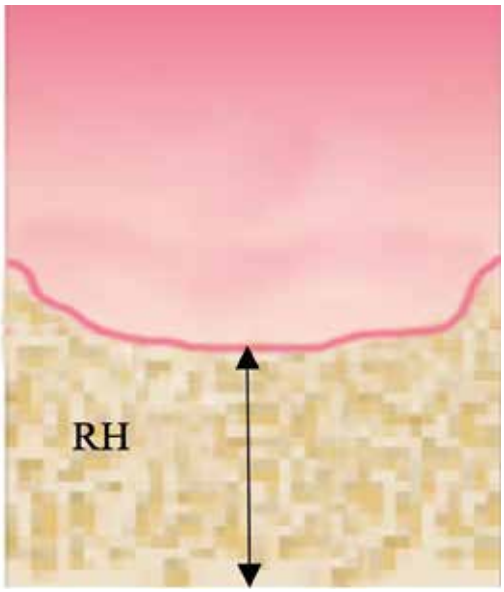

FIG. 1 The primary evaluation of the residual height was evaluated from the most coronal point on the bony crest and the most coronary point of the sinus floor in the middle of the bony crest. (RH: Residual bone height)

Surgical procedure

All patients received a single dose of antibiotic one hour before the surgery: 2 g of penicillin (Amoxicilline) or 600 mg of Clindamycin in case of penicillin allergy. All surgical procedures were performed by the same operator (CF) at T1. A midcrestal incision was performed for flap elevation, without any vertical or periosteal releasing incision. Crestal bone was debrided to eliminate all residual fibers. A pointed bur was used to mark the preparation position (ACT Pointed Starter Drill, Biomet 3i™, Florida USA). A trephine bur (STD 3525L or STD 4030L of the TR sinus system DIO® kit) was used at a speed of 800 rpm (as indicated by the manufacturer) to create a bone core. The diameter of the trephine bur was 3.5 mm (STD 3525L) and 4.0 mm (STD 4030L) when the chosen implant was of 4.5 mm and 5.0 mm, respectively. The trephine was inserted up to -1 mm from the sinus floor to avoid tearing the Schneiderian membrane and keeping the bone core attached by its apical wall (Fig. 2). The depth of preparation was confirmed by means of "stoppers" (ST 4009, ST 4010, ST 4011 of the TR sinus system DIO® kit). The length of the "stopper" was calculated by subtracting 1 mm from the RH. A depth gauge (SDG 2515) was then used to ensure that the core was still attached to the last millimeter of the osteotomy site. In case the core was stuck in the lumen of the trephine bur and was detached from the bone site, it was gently brought back to the site by means of a surgical forceps. At this stage, the bone type (I II III IV) was recorded according to Lekholm and Zarb classification (20).

After creation of the bone core, a parallel angled 3.5 mm diameter osteotome with concave head (Ergoplant Sinutomes DX577R Aesculap®, B l Braun company USA) (Fig. 2, 3) was used to move the core apically. This was

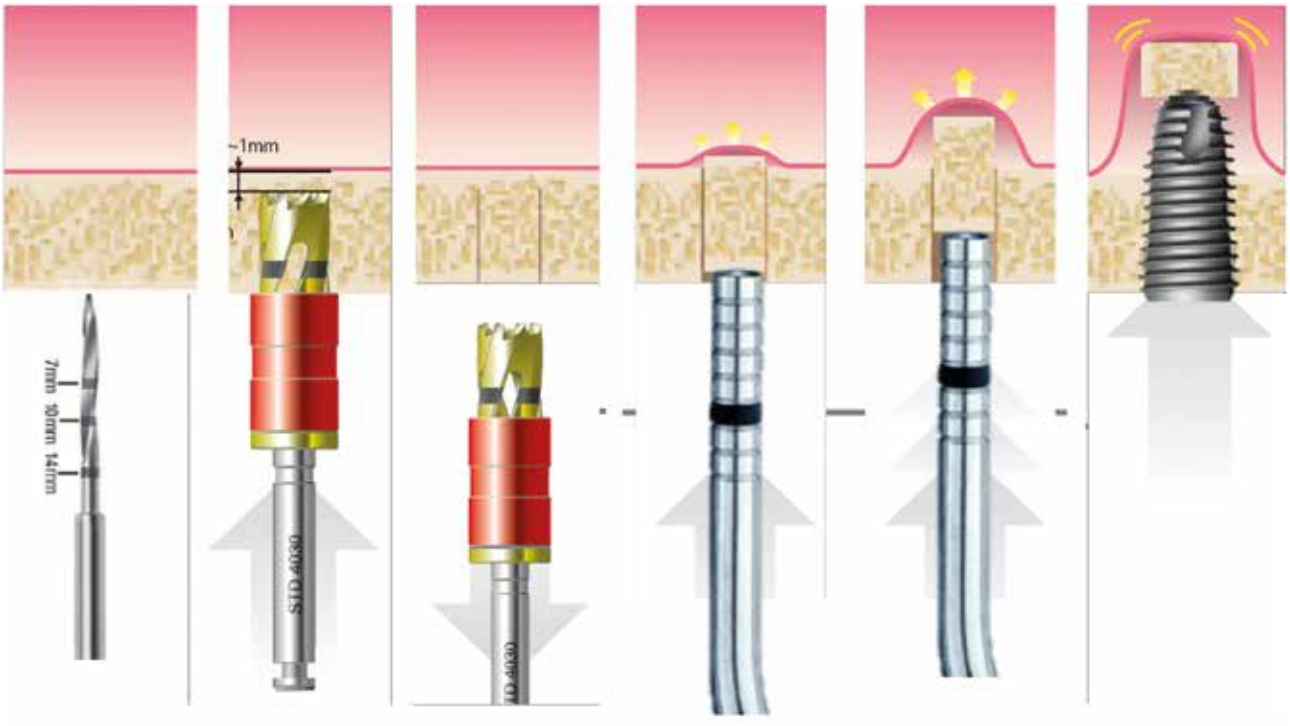

FIG. 2 A schematic presentation of the modified trephine sinus elevation approach.

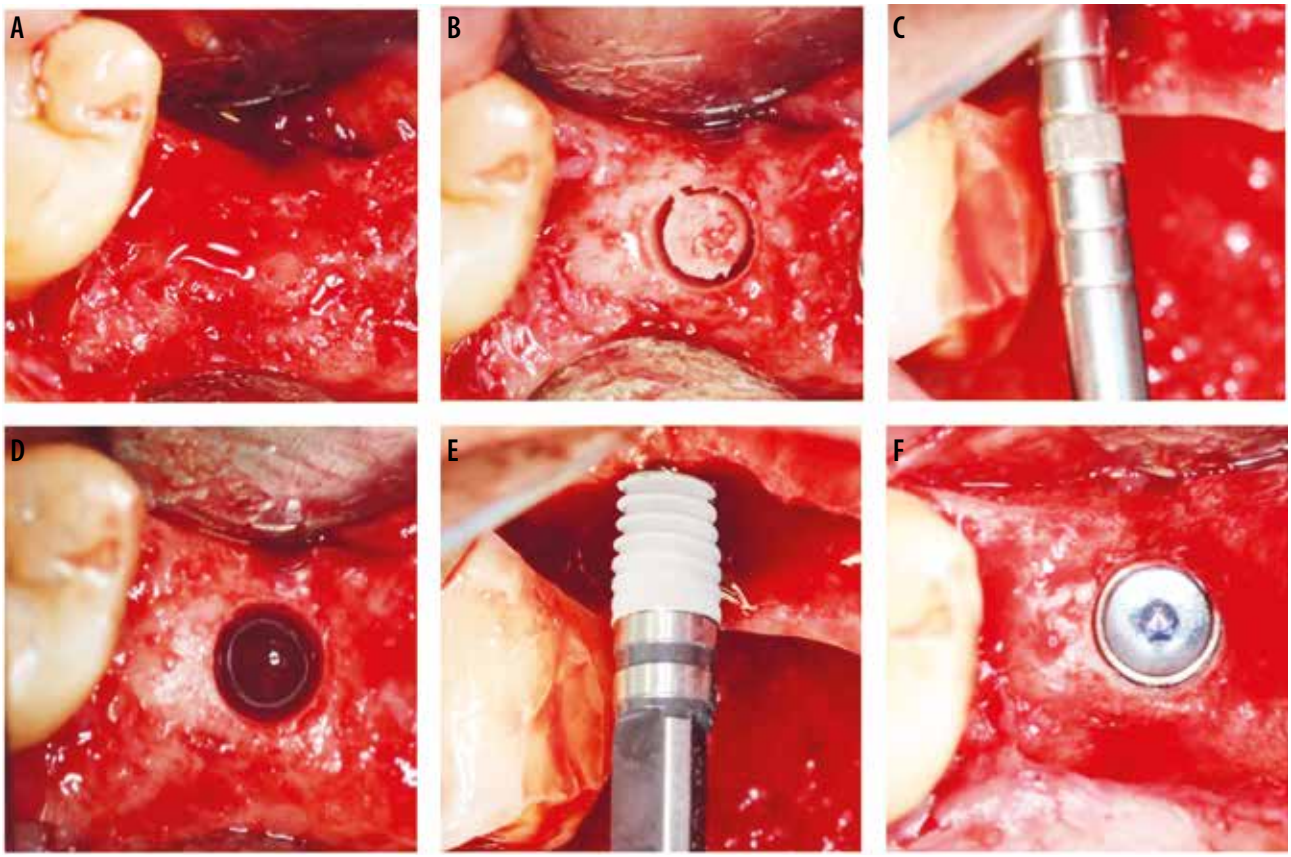

FIG. 3 Clinical pictures of a case treated using the modified trephine sinus elevation approach.
A: bone crest after flap elevation. B: bone core created with the trephine bur. C: apical displacement of the bone core using an angulated osteotome.
D: occlusal view after the apical displacement. E: implant placement. F: cover screw placement before flap suturing.

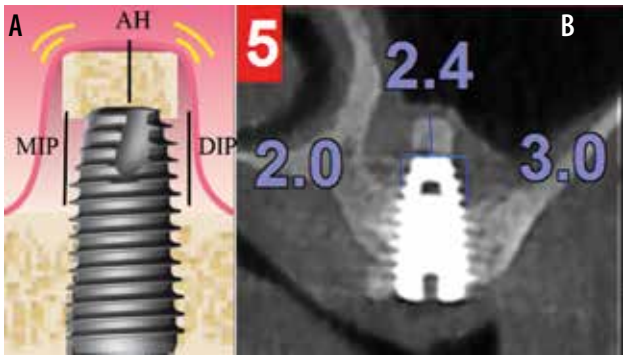

FIG. 4 Measurments taken on the axial and panoramic sections.
A: schematic view of the measurements. B: a panoramic view of the linear measurements using the "NNT ™" software. (
MIP: mesial implant protrusion, DIP: distal implant protrusion, AH: height of the bone core.

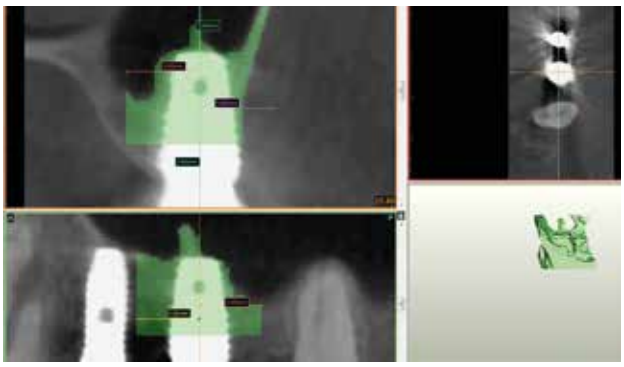

FIG. 5 Tracing, cropping and calculation of the periapical bone volume using SimPlant Pro 15 ® software.

done with light taps on the mallet since the carrot was already released from the bony walls around its circumference. The displacement of the bone core was made up to -1 mm from the sinus floor only to maintain the bone core in the axis of the preparation. The length of the implants has been standardized to 8.5 mm for the 21 implants placed. A DIO® UF II implant (Busan-Korea) 4.5 x 8.5 mm was inserted in sites where the bone width was between 7.5 mm and 7.9 mm. When the bone width was 8 mm and more, a 5.0 x 8.5 mm DIO® UF II (Busan-Korea) implant was used. Implants were inserted using a 20:1 reduction counter angle (NSK S-max SG20-Tochigi, Japan) and a motor (NSK SurgicAP-Tochigi, Japan) at a speed of 25 rpm/min and at an initial torque of 35N/cm. In cases where the motorized insertion torque had reached 35 N/cm before complete insertion of the implant, it was continued using a manual torque. The final insertion torque was noted. A SmartPeg 100478 (type 47) (SmartPeg reference guide) from Osstell ISQ (Osstell ™, Integration Diagnostics, Sävedalen, Sweden) was connected to the implant head to measure the implant stability quotient (ISQ). A cover screw was then placed, and the site was sutured using 5-0 PGA sutures (Novosyn B I Braun, Melsungen). Post-operative complication was monitored using a visual analogue scale (VAS). Implants were uncovered three months after the surgery (T2). ISQ was measured as described previously.

Radiographic evaluation

Two Cone Bean Computed Tomography (CBCT) were made for each implant. The first named "CBCT T1" performed on the day of surgery, and the second named "CBCT T8" performed 8 months postoperatively. CBCT were made using the machine Newtom vgi (Newtom, Verona, Italy) on a field of 12 x 8cm in high resolution mode (voxel size 150 µm), 1-20 mA in "pulse" mode during 3.6 to 5.4 seconds. All radiographs were standardized with the same axe and the same color balance. CBCT T1 and T8 were used to achieve linear, volumetric, and qualitative measurements.

Linear measurements were done on NNT™ software (Version 3.10 NewTom Verona - Italy) in the "multiplanar" section. Five measurements were taken on the axial and panoramic sections. They represent the protrusion of the implant in the sinus on the mesial (MIP), distal (DIP), vestibular (VIP), palatal side (PIP). These distances were measured vertically between the last thread covered by the bone and the most apical point of the implant on the vestibular, palatal, mesial and distal surfaces. The height of the bone core displaced apically was also measured (AH) (Fig. 4).

The ten most radiographically readable cases at T1 and T8 (without artifacts, without image splitting) were selected for volumetric measurements. The selection was approved by a second experienced examiner (NG). On the software SimPlant Pro 15® (Densply, Sirona, Mölndal, Sweden) the smallest section thickness (0,15 mm) was chosen. The peri-implant bone volume was drawn on every coronal section then checked on the coronal and transverse sections.

This volume was then cropped tridimensionally in a standard way to all implants (Fig. 5). The selected volume was calculated in mm^3 and in cc and noted as "vol T1" and "vol T8". The quality of the sinus elevation obtained was evaluated by an experienced examiner using the sinus grafting remodeling index (SGRI) proposed by Brägger et al. in 2004 (21) as follows.

- 0 = no visible bone or graft.
- 1 = cloudy appearance of the new bone or graft at the apex of the implant, the original sinus cortex is still clearly visible.
- 2 = new bone/graft clearly visible at the apex of the implant, early disappearance of the original sinus cortex.
- 3 = new bone/dense graft at the apex of the implant, total disappearance of the original sinus cortex and formation of a new sinus cortex.

Statistical analysis

Statistical analyses were performed using SPSS for

Implant dimension (mm)	
3.8 x 8.5 (%)	1 (4.8%)
4.5 x 8.5 (%)	13 (61.9%)
5.5 x 8.5 (%)	1 (4.8%)
5 x 8.5 (%)	6 (28.6%)
Bone type	
Type I (%)	1 (4.8%)
Type II (%)	9 (42.9%)
Type III (%)	8 (38.1%)
Type IV (%)	3 (14.3%)
Number of implants placed during the intervention	
1 implant (%)	4 (19.0%)
2 implants (%)	11 (52.4%)
3 implants (%)	6 (28.6%)
Final Torque (N/cm)	
Mean ± Standard Deviation	43.81 ± 23.287
	(Amplitude: 15 – 85 N/cm)
ISQ T1	
Mean ± Standard Deviation	66.38 ± 7.931
	(Amplitude: 53.67 – 77)

TABLE 1 Clinical results at T1.

Windows (Chicago, IL, USA, version 22.0). The level of significance was set at p ≤0.05. The normality distribution of the continuous variable was assessed using the Kolmogorov-Smirnov tests. Pearson's and Spearman's correlation coefficients were used to calculate the relationship between quantitative measures. The test of Student was performed to compare the changes in ISQ between T1 and T3. The Student test was also used to compare the volumetric measurements between T1 and T8. Wilcoxon and Student tests were performed to study new bone formation around the implants in T1 and T8. Kruskal-Wallis tests and analyses of variances were carried out to study the association between the radiological parameters in T8 and SGRI.

RESULTS

Eighteen participants with a mean age of 54.50 ± 14.5 years (range: 20-78 years) were included in the study. Twenty-one implants were placed using the modified trephine/osteotome technique. Most of the implants were placed in the sites of the upper first molar (85.7%). The average RH was 4.810 ± 0.992 mm with values ranging between 3 and 6 mm.

At T1

The bone was a type I in 4.8%, type II in 42.9%, type III in 38.1% and type IV in 14.3% of the cases. The most widely used implant dimension was 4.5*8.5 mm (placed in 61.9% of the cases. The ISQ at T1 averaged 66.38 ± 7.931 with values ranging from 53.67 to 77 (Table 1). The final insertion torque was 43.81 ± 23.28 with an amplitude ranging from 15 to 85 N/cm. Six implants (28.6%) had a final torque ≥ 60 N/cm. The ISQ at T1 was significantly associated with the bone type (-p value 0.015).
Only two patients had post-operative oedema with a mean of 3.06 ± 2.38 over 10 using the VAS. The mean of localized pain was 2.22 ± 2.73. Nose bleeding and congestion as well as vertigo had a mean lower than 0.44 ± 1.46 over 10.

At T3

The mean ISQ at T3 was 67.92 ± 14.37 with values ranging from 20.33 to 84.00. ISQ increased between T1 and T3 with no statistically significant difference (p value = 0.136).

At T8

Implant survival rate was 100% after 8 months. Sub-antral bone volume increased significantly between baseline and T8 by 20.34% (-p-value = 0.007) (Fig. 6). Implant protrusion decreased significantly between baseline and 8 months. Linear bone gain was 2.1 ± 1.1 mm buccally; 2.0 ± 1.4 mm palatally; 2.5 ± 1.6 mm mesially; and 1.5 ± 1.5 mm distally. Mean linear bone gain was 2.0±1.1 mm as calculated on the CBCT. The height of the bone core displaced apically decreased significantly by 67.74% (-p-value=0.007) (Fig. 7). SGRI score 2 was the most prevalent finding between the cases (42.9%).

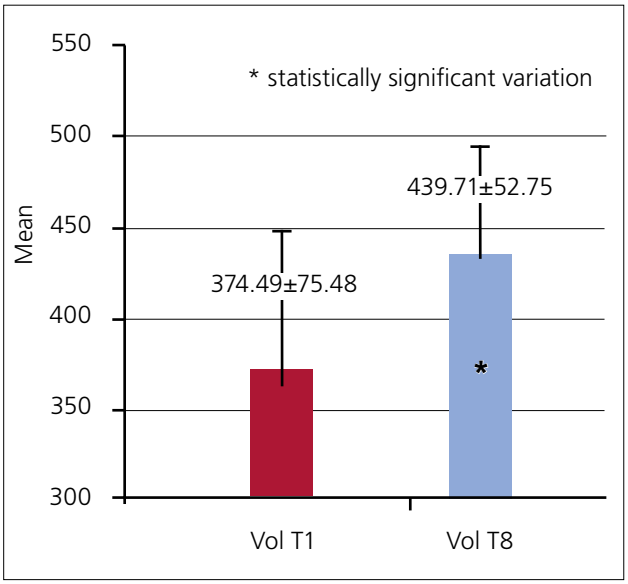

FIG. 6 Sub-antral bone volumetric variation between T1 and T8. Notice the increase between baseline and after 8 months.

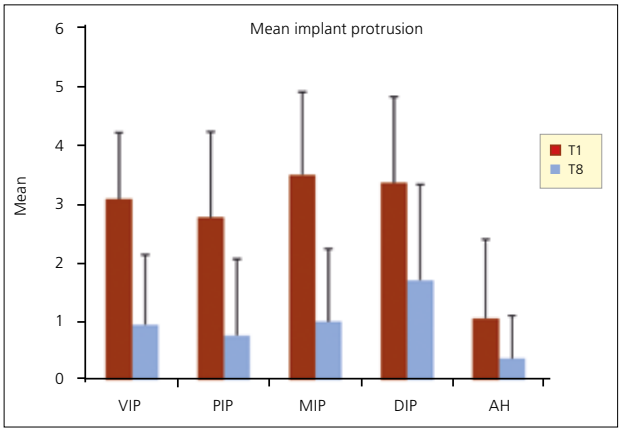

FIG. 7 Linear variation between T1 and T8. Notice how implant protrusion decreased between baseline and 8 months.
VIP: vestibular implant protrusion, PIP: palatal implant protrusion, MIP: mesial implant protrusion, DIP: distal implant protrusion, AH: height of the apical bone core.

DISCUSSION

This 8-month prospective study evaluated various clinical and radiographic aspects of sinus elevation using the simplified trephine/modified osteotome technique. Twenty-one sites with RH ranging between 3 and 6 mm were selected. The main purpose of the study was to evaluate periapical bone formation at eight months from the date of surgery by linear and volumetric X-ray measurements.

The commonly accepted residual height for crestal sinus elevation have been reported to be between 5 to 6 mm, and multiple studies have shown that implant survival rates decrease below these values (10,15,22). This was explained by the need to have a sufficient bone height to assure implant primary stability while avoiding the risk of sinus membrane perforation. However, recent publications reported high implant survival rates with lower residual height values, including cases with 2.4 mm residual crest (23–25). These results are in accordance with our study where a 100% implant survival rate was observed in sites with a mean RH of 4.8 ± 0.99 mm. Moreover, the inclusion in our study of sites with only 3 mm of RH did not negatively affect the outcome of the procedure when performed carefully.

In the present study, no drills were used for implant site preparation. In fact, only trephine burs and osteotomes prepared the recipient site to receive the adequate implant diameter. The utilization of the trephine bur during the osteotomy allowed the preservation of an apical bone core that served as an autogenous graft under the sinus membrane (15–17,23–26). In fact, the use of drills for implant site preparation in conventional techniques reduces the quantity of bone available in the site and do not take advantage of its possible potentials. Moreover, "stoppers" were applied with every trephine bur in our study. This permitted the trephine to stop 1 mm from the sinus floor in order to preserve the integrity of the Schneiderian membrane. The original modified osteotome/trephine technique as proposed by Fugazzotto et al. did not mention the use of "stoppers" (18,19). However, the authors of the present article preferred to add "stoppers" to increase the safety and the precision of the procedure. Moreover, the depth of penetration of the osteotome was also limited to 1 mm below the sinus floor in order to keep the bone core attached apically to the site of the osteotomy and to increase the chances of keeping the core in the direction of the implant axis when pushed apically (Fig. 2). Indeed, the cone-beam CT evaluation showed that in most cases (81%) the bone core remained in contact with the implant apex. More precisely, it was found perfectly centered above the apex in the extension of the major axis of the implant in 23% of cases, while in 57.2% it remained at the apex of the implant but not in its main axis.

The modified trephine/osteotome technique used in this study is considered a graft-free procedure that elevates the sinus floor without any substitute material. Only the bone core of the crestal ridge, created by the osteotomy, is moved apically into the sinus. Several studies have compared implant survival rates in cases of crestal sinus lift procedures with and without bone grafts. In this context, Nedir et al. in 2012 compared 17 implants placed without a bone graft to 20 implants inserted with a bone graft using the crestal approach. Both groups yielded a survival rate superior to 90% with no difference found related to the use or not of bone graft (25). According to a recent meta-analysis examining the results of 37 studies, the cumulative survival rate was significantly higher in the group without bone graft compared to the group with grafted bone (27). In 2016, Jensen et al. evaluated 90 studies comparing crestal sinus floor elevation with and without grafting material and demonstrated that in both cases, bone was able to generate when a "tent effect" was physically maintained.

In our study, the autogenous bone core provided this "tent effect" and induced bone formation. In fact, a mean linear bone gain of 2.0 ± 1.1 mm was calculated at the 8-month radiographic evaluation. This was also determined from the statistically significant decrease in implant protrusion in the sinus that accounted for 73.20%, 75.6%, 72.05% and 50.32% on the vestibular, palatal, mesial and distal sites, respectively. This phenomenon could be explained by the formation of a blood clot that may have filled the new space created between the membrane and the sinus floor. This clot was probably colonized by mesenchymal progenitor cells from the surrounding margins: bone walls and sinus membrane as explained by histological studies (28–32).

CONCLUSION

This 8-month prospective clinical and radiological study demonstrated that sinus elevation using the modified trephine/osteotome technique resulted in a high implant survival rate (100%), mean linear bone gain of 2.0 ± 1.1 mm, and mean volumetric gain of 20.34%. The autogenous bone core displaced apically resorbed after eight months in 66% of the cases. The present study also proved that the modified trephine/osteotome technique offers simplicity and reduced surgical time, high primary and secondary implant stability, and minimal post-operative morbidity.

Acknowledgments

The authors report no conflict of interest related to this study.

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