Sinus Cortical Verticalization technique for atraumatic sinus lift: a case series with 18 months follow-up

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Abstract

Background
Crestal sinus lift is considered a predictable and increasingly used technique, with the aim of augmenting the bone quantity in the posterior-superior maxilla while reducing the invasiveness of implant-prosthetic regenerative treatment. The case series presented in this article analyzes a new minimally invasive technique introduced to limit the postoperative morbidity of crestal sinus floor elevation procedures, while managing an increasingly large number of clinical conditions.

Materials and methods
41 implants were placed in the posterior maxilla of 33 patients using the proposed technique. The surgery duration, postoperative pain and discomfort reported by the patient, assessed using the NRS analogue scale with values between 0 and 10, and any complications were recorded. At 18 months after surgery, implant survival, the amount of vertical increase in regenerated hard tissue, the health status of the maxillary sinus were evaluated. Width and height of the residual alveolar process and vertical bone augmentation were assessed by radiology. The technique is based on the use of special rotating drills and bone condenser designed to make the surgical procedure faster, more efficient and predictable. The floor of the maxillary sinus is initially deformed, increasing the vertical dimension of the infrabony path of the implant site. Subsequently, a round portion of cortical is detached and repositioned apically, forming a roof over the graft and the inserted implant at the same time.

Results
The sites where this technique was applied showed an average residual bone height of 3.5 ± 1.2 mm while the length of the inserted implants was 8.5 mm and the diameter between 3.5 and 5 mm. Postoperative scores reported by patients on NRS scale from 0 to 10 showed an average for intraoperative pain of 0.6 ± 0.8 and for perceived discomfort in the first week post-surgery a mean of 1.5 ± 1 ,1. One case presented complications during surgery with a small tear in the sinus membrane, while only one case reported above-normal pain after surgery. 18 months after surgery, in all cases treated, newly formed mineralized tissue was appreciated around the implants inserted at the same time.

Conclusions
Limited to the cases treated, the proposed protocol appears to be an effective and predictable option for sinus elevation. Due to the deformation and subsequent apical displacement of the sinus floor, this technique has been shown to be effective in treating even wide sinus cases, with very limited residual bone height (1-3 mm), showing low postoperative morbidity.

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Keywords

Sinus lift, Dental implant, Bone regeneration, Osseointegration

INTRODUCTION

The maxillary sinus floor elevation represents a reliable and predictable surgical procedure to manage vertical atrophy in the posterior maxillary sectors in cases of implant-prosthetic rehabilitation. It is particularly indicated in the absence of a significant supracrestal defect(1), allowing the placement of implants of appropriate morphology. The sinus floor elevation techniques initially proposed in the literature involve a lateral approach, i.e. a vestibular corticotomy performed at the edentulous area, or the possibility of a crestal or transalveolar approach. In the latter case, the procedure involves performing a green-stick fracture of the sinus floor, pushing an instrument by hand through the coronal portion of the residual alveolar process, chosen according to the shape of the implant to be inserted(2,3). For both procedures, hard tissue regeneration is achieved through the grafting of an osteoconductive support substrate, placed within the sinus, obtained by the use of autologous bone, biomaterials or a mixture of both.
Subsequently, a technique using a specific set of osteotomes was proposed for implant site preparation and elevation of the sinus floor through the coronal portion of the residual alveolar process(4). In 2000, Cosci et al. proposed a new crestal surgical approach for placing implants in deficient alveolar ridges; it involves the use of drills of different and increasing lengths, which allow them to approach Schneider's membrane with low risk of laceration(5). Since then, have been proposed in the literature many surgical techniques with instruments specially designed for the transcrestal approach(6-9). The different characteristics of these techniques mainly concern two fundamental elements common to all crestal sinus lift procedures: the mode of access and the detachment and enlargement of the membrane. As regards the methods of access to the maxillary sinus, they can be grouped into two main categories: expansive-compacting and ablative-subtractive. Expansive-compacting techniques involve the use of different manual or handpiece-inserted instruments, such as osteotomes, bone-expanders and rotary instruments, while ablative-subtractive techniques have been characterized by the use of burs or ultrasonic instruments. Regarding the methods for obtaining detachment and expansion of the Schneiderian membrane, two main groups can be distinguished: techniques using hydraulic pressure and those using air pressure. In 2006 Carusi et al. (10,11) proposed a technique that provides access to the maxillary sinus through an expansive-compacting approach, using specific rotating instruments capable of vertically deforming the sinus floor. The study demonstrates that this deformation occurs for approximately 2mm before causing a greenstick fracture of the cortical bone, thus allowing for an increase in the height of the residual alveolar bone and the intraosseous path of the implant preparation site. This increases the primary stability of the implant by allowing contextual insertion in class II and III cases according to the Favero Brånemark classification(19). The membrane is also detached using hydraulic pressure: blood is pushed from the graft inserted through the bone filling carriers on the basis of Pascal's fluid principle, imparting equal and uniform pressure on the sinus walls and causing a progressive detachment and expansion of the sinus mucosa. Systematic reviews of the literature demonstrate good long-term stability of implants inserted in association with crestal sinus lift procedures (12-14). Collected data show survival rates similar to those of implants placed in the same positions in native bone, with follow up between 1 and 3 years. In 2015 Spinato et al. (15) associated the long-term success rate of crestal augmentation techniques with the width of the maxillary sinus, conventionally measured 10mm apical to the most coronal point of the residual bone crest (Fig. 1). This retrospective study in fact distinguishes narrow from wide sinuses, calculating a width value equal to 13.72mm as a dividing factor between the two categories. In 2020 Stacchi et al.(16) proposed a new classification to determine the type of approach in cases of maxillary sinus lift. The study identifies a residual bone height of at least 3mm to achieve primary stability suitable for implant placement at the same time as regenerative surgery. They also establish the division between narrow and wide sinuses for width values greater or less than 12mm, indicating vestibular access to the sinus lift as the first choice in cases of wide sinuses. Numerous studies confirm the reliability and predictability of sinus lift procedures (17,18), identifying the essential elements for the long-term success of the regenerative technique in achieving a rigid roof, an effective tenting effect and adequate support of the clot within the

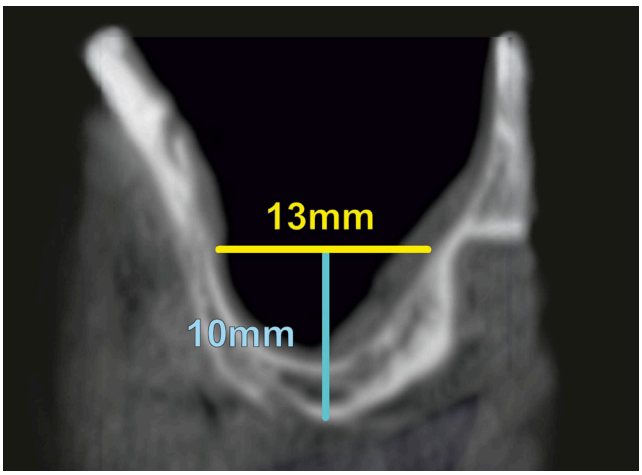


Fig. 1 Sinus width measurement

regenerative space.
In this study, a minimally invasive crestal sinus lift technique is proposed, characterised by the use of specific rotary instruments and bone compactors used with the aid of depth stopsThe most innovative feature of the technique lies in the fact of deforming and compacting the residual bone by increasing its vertical volume by at least 2mm as proposed by Carusi's protocol (9,10), but subsequently detaching a rigid cortical operculum, concave in the coronal direction, which it will position itself apically to the graft and the inserted implant. By exploiting this principle it therefore appears possible, by deforming and compacting the residual native bone, to manage cases in which the starting bone height is equal to or greater than 1mm, with crestal access and in a single step. By achieving sufficient primary stability of the implant, it itself acts as a support structure for the detached bone operculum and the underlying blood clot, improving the placement of a suitable graft, even in clinical conditions where the sinus width is greater than 12mm. The purpose of this case series is to present data on the clinical outcomes and intra- post-operative morbidity perceived by patients after sinus lift surgery performed with this new technique.

MATERIALS AND METHODS

Inclusion criteria

Thirty-three patients requiring implant-prosthetic rehabilitation of 41 edentulous sites in the upper jaw sectors were enrolled in the present study and treated consecutively. The age range was 39 to 71 years (average 52) and the procedures were performed between February and July 2022 by the same operator at the same dental center. All clinical procedures were performed in full compliance with the Declaration of Helsinki and according to the guidelines defined by the 'Convention on Human Rights and Biomedicine' (Oviedo Convention). Each patient provided written informed consent prior to participation and underwent pre-surgical CBCT radiography on which, using 3D measurement and processing software, treatment was planned. All selected cases had one or more missing teeth in the area of the posterior maxilla. The residual bone height (rBH), measured through CBCT as the distance between the bone crest and the floor of the maxillary sinus at the implant insertion site, was ⩽ 6 mm with a residual alveolar process width (rBW) ⩾ 4.5 mm(Tab. 1).
Patients with systemic diseases or the presence of compensated systemic diseases (diabetes, heart failure, hypertension, renal failure, liver failure, respiratory failure, other endocrine/metabolic diseases or coagulation disorders) were excluded from this study). Patients without an adequate level of compliance (such as psychiatric pathologies, etc.), severe

Case	Patient	Implant site	rBH (mm)	rBW (mm)	Implant diameter	Implant type
1	1	16	4,3	6,8	3,8	Intramucosal**
2	2	27	2,8	7,1	4,25	Intramucosal**
3	3	15	5,1	6,2	4,0	Bone level*
4	4	27	1,8	7,6	4,25	Intramucosal**
5	5	25	3,5	6,5	3,5	Bone level*
6	5	26	4,9	8,3	4,25	Intramucosal**
7	6	17	2,2	7,4	4,0	Bone level*
8	7	16	3,5	9,1	5,0	Intramucosal**
9	8	16	4,0	6,9	3,8	Intramucosal**
10	8	17	3,8	5,6	4,0	Bone level*
11	9	25	5,1	4,8	3,5	Bone level*
12	10	14	6,0	5,0	3,5	Bone level*
13	11	26	2,5	9,2	5,0	Bone level*
14	12	26	3,0	7,9	4,25	Intramucosal**
15	13	17	1,5	9,8	5,0	Intramucosal**
16	14	15	3,3	5,7	3,8	Intramucosal**
17	14	16	4,4	8,0	4,25	Intramucosal**
18	14	26	2,7	7,2	4,25	Intramucosal**
19	15	27	1,8	7,7	4,25	Intramucosal**
20	16	25	4,7	5,4	3,5	Bone level*
21	17	24	5,4	4,9	3,5	Bone level*
22	18	15	3,4	5,6	3,8	Intramucosal**
23	18	17	2,6	9,9	5,0	Bone level*
24	19	26	1,2	8,0	4.25	Intramucosal**
25	20	16	3,7	9,2	5,0	Intramucosal**
26	21	27	4,1	7,5	4.0	Bone level*
27	22	15	3,7	7,9	3,8	Intramucosal**
28	22	26	2,1	9,1	5,0	Bone level*
29	23	17	3,5	6,7	4,0	Bone level*
30	24	15	4,7	4,6	3,5	Bone level*
31	24	25	3,5	4,9	3,5	Bone level*
32	25	27	2,5	10,1	5,0	Intramucosal**
33	26	16	3,4	8,8	4,25	Intramucosal**
34	27	25	4,8	5,4	3,5	Bone level*
35	27	27	5,6	7,2	4,0	Bone level*
36	28	26	2,3	8,1	4,25	Intramucosal**
37	29	16	3,6	6,9	3,8	Intramucosal**
38	30	17	4,8	7,7	4,25	Intramucosal**
39	31	15	4,9	4,9	3,5	Bone level*
40	32	26	2,6	6,8	4,0	Bone level*
41	33	26	1,9	9,3	5,0	Bone level*

* BNX Evo, Ghimas, Casalecchio di Reno, Italy.
** Prama, Sweden & Martina, Due Carrare, Italy.

Tab. 1

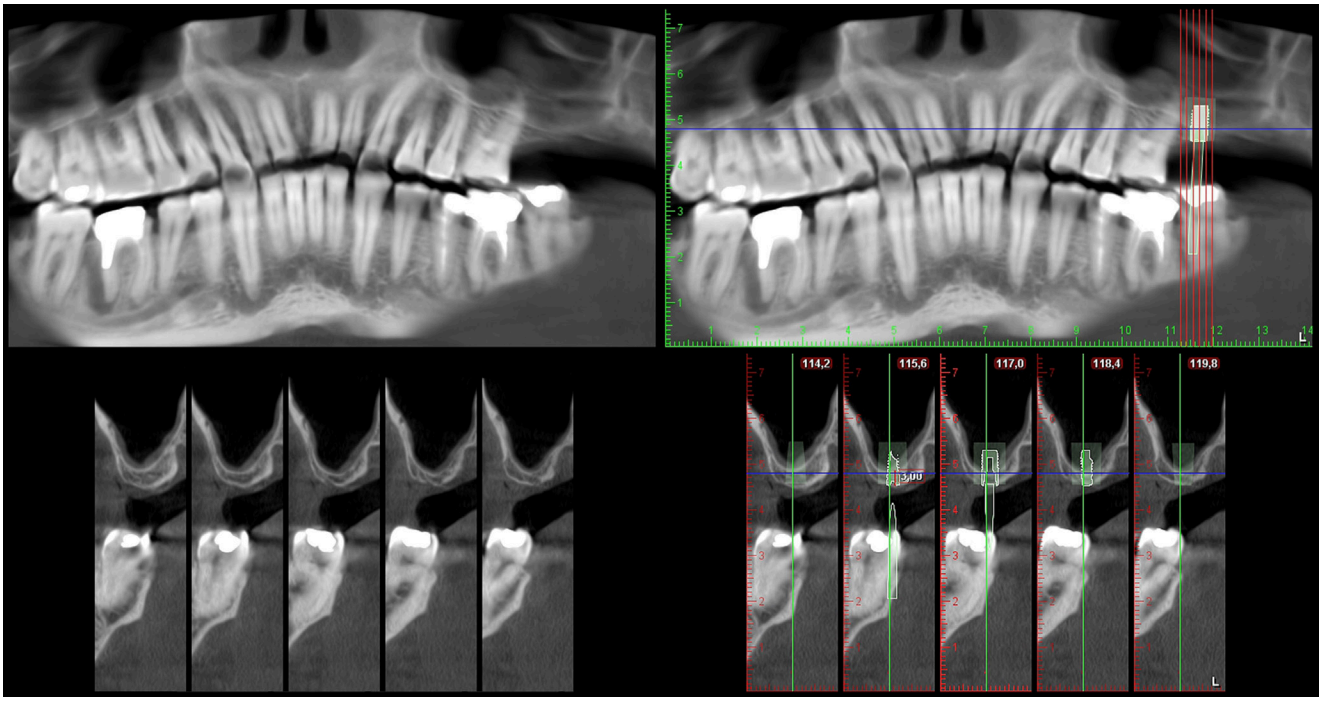


Fig. 2a-2d Case analysis and prosthetically guided regenerative and implant treatment design

congenital/acquired malformations, severe disabilities were excluded. Patients with altered health status of the maxillary sinuses such as sinusitis, presence of endosinusal neoformations and cases with systemic pathologies that could cause sinus involvement (Wegner's granulomatosis, midline lethal granuloma etc.) were excluded. Patients with oral mucosal diseases such as lichen planus in the treatment area and cases of severe active periodontal disease were excluded. Patients on cancer therapy or with a history of radiotherapy in the head and neck area, patients who have taken or are taking bisphosphonate drugs and smoking patients were excluded. Before surgery, all patients with periodontal disease were treated with causal therapy, and all patients enrolled in this study underwent a professional dental cleaning session one week before the surgery. On the day of surgery, a plaque index check was performed, and only subjects with a value < 20% were accepted. An antibiotic therapy consisting of 1g of amoxicillin + clavulanic acid was administered every 12 hours for 7 days starting the day previous surgery. Before the surgical procedure, patients rinsed for 1 minute with a 0.3% chlorhexidine mouthwash. Two patients reported penicillin allergies and were prescribed a clarithromycin-based antibiotic therapy (500mg every 12 hours for 7 days). In case of post-operative pain, ketorolac (10mg every 8 hours) was prescribed, and in case of severe and persistent pain, patients were advised to contact the dental office for further evaluation.

Surgical Procedure

The surgical treatment was planned based on CBCT (Cone Beam Computed Tomography) scans conducted before the surgery using 3D software (Romexis 4.4.0.R, Planmeca, Helsinki, Finland) for the measurement of height and width of the residual alveolar process (Fig. 2a,2b,2c, 2d). The procedure, called SCV (Sinus Cortical Verticalization) technique, involved a flapless surgery for all clinical cases after local-regional anesthesia (40 mg/ml articaine + 0.01 mg/ml adrenaline). Following anesthesia, a mucotomy was performed using a circular scalpel with a diameter of 3mm mounted on a micromotor and operated at a speed of 700 rpm in the planned implant insertion position. The mucotomy and subsequent steps with rotating instruments could also be performed in guided surgery, depending on the specific prosthodontic treatment plan. Subsequently, using a Lucas surgical curette #85, the mucotomy was detached and removed, and the thickness of the overlying soft tissue at the surgical site was measured using a CP 15 periodontal probe (Fig. 3a, 3b). The protocol analyzed in this study utilized a surgical kit consisting of 7 different rotating instruments, a series of depth stops with variable lengths ranging from 1 to 13mm, a bone condenser with two different diameters, and a button-like atraumatic probe (Fig. 4). The surgical procedure continued with the use of a surgical drill FC 20, with a diameter of 2.0mm and a 120° apex, working both at tip and laterally. The drill was used clockwise at 700 rpm with the corresponding depth stop. The stop considered the residual bone height and the thickness

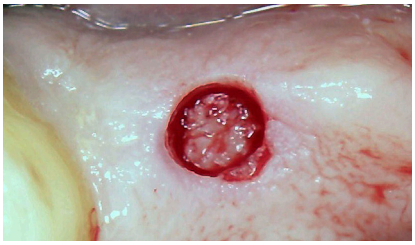


Fig. 3a Performance of mucotomy for flapless access

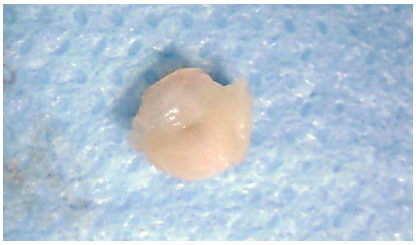


Fig. 3b Soft tissue removal

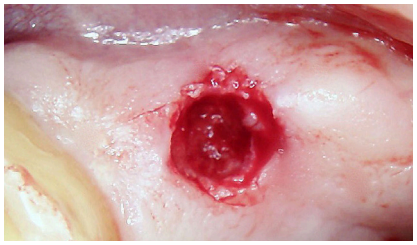


Fig. 3c Use of burs 20, 26 and 31 for implant site preparation

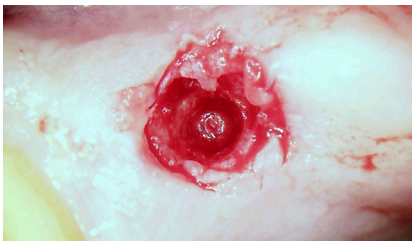


Fig. 3d Use of burs 31PTX for sinus floor deformation

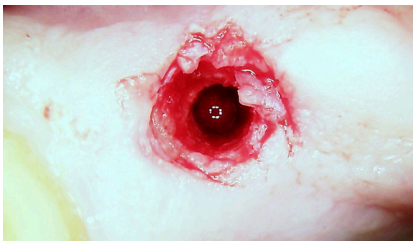


Fig. 3e Use of burs 31P for a 3mm circular portion of sinus floor detachment

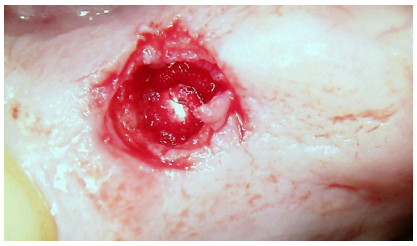


Fig. 3f Insertion of hemostatic collagen into the surgical site

Fig. 3a-3f SCV Sinus Lift surgical steps part 1

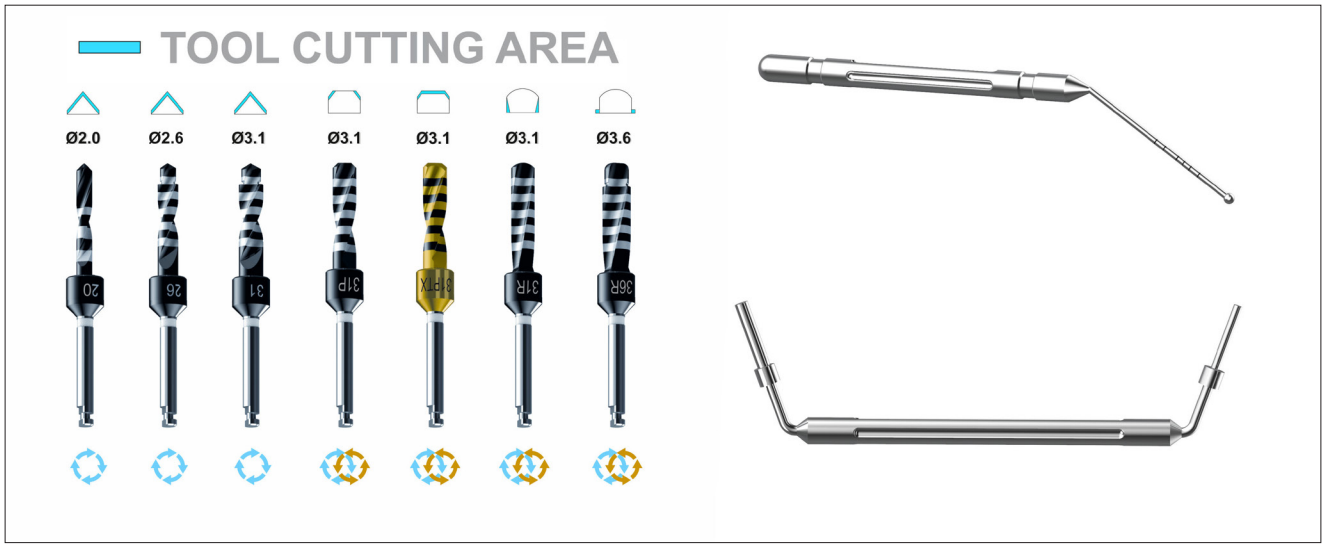


Fig. 4 Set of instruments contained in the surgical kit: 7 burs, a double-tipped bone condenser, an atraumatic probe

of the overlying soft tissue, maintaining a distance from the floor of the maxillary sinus, based on the initial values of the residual bone crest height, summarized in (Tab 2).

In cases where the initial residual bone height was ⩽ 1.5mm, the use of the first 3 drills was avoided, and the procedure moved directly to the 31PTX drill. In all other cases, after using the FC 20 drill with the same depth stop, the protocol involves the use of the FC 26 and FC 31 drills, always operating at 700 rpm

Sinus height	FC 20	FC 26	FC 31
≥ 3 mm	-2 mm	-2 mm	-2 mm
< 3 mm			
≥ 1,5 mm	-1 mm	-1 mm	-1 mm
< 1,5 mm	NO	NO	NO

Tab. 2

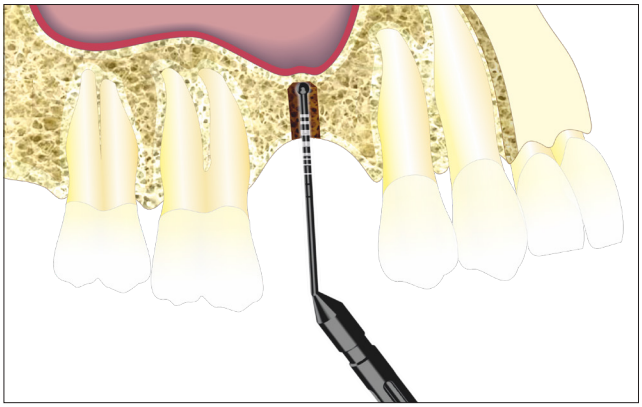


Fig. 5 Atraumatic probing of the still intact surgical site bottom

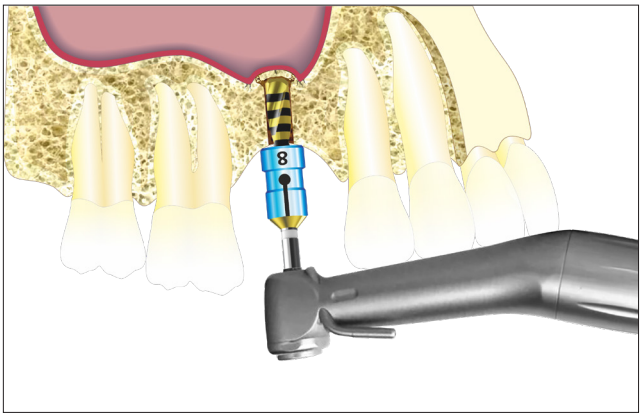


Fig. 6 Deformation of the sinus floor with the 31PTX bur

clockwise. These last two drills are identical to the previous one but with larger diameters, specifically 2.6mm and 3.1mm, respectively (Fig. 3c). The next step involved the use of the 31PTX drill, equipped with a flat yet sharp apex portion (triangular cross-section), two 45° angles and with both sides cutting. It was used clockwise at 700 rpm with the same depth stop used for the previous drills. In cases where the vertical height of the residual alveolar process was ⩽ 1.5mm, it would be the first drill to be used with a infrabony working depth stop set at 1mm. In cases where a flapless surgery had been performed, as per the suggested protocol, the thickness of the overlying soft tissue had to be added to the stop value. After this step and after each subsequent step, probing of the bottom of the surgical preparation was indicated, using the atraumatic probe with a rounded tip of 1.6mm in diameter (Fig. 5). The probing was performed utilizing only the weight of the instrument, and at this point in the protocol, it was essential not to perceive any mobility at the bottom of the preparation. Following this, the 31PTX drill was used again with the same settings but with subsequent stops until reaching the floor of the maxillary sinus (Fig. 3d). With the same drill and settings, the next stop was applied, with an intraosseous working portion at +1mm from the level of the maxillary sinus floor. This step initiated a process of deformation of the sinus floor, with a coronal-apical increase of 1mm in the initially calculated height of the residual alveolar process. The probing with the atraumatic probe confirmed the presence of a still rigid and compact bottom of the preparation in all cases. Next, the 31PTX drill was used with the same settings and the subsequent stop set at +2mm from the original height of the maxillary sinus floor. This caused further deformation, compaction, and an increase in the intraosseous path of the implant site preparation (Fig. 6). The probing with the atraumatic probe confirmed the maintenance of the integrity and rigidity of the preparation bottom in all cases. The subsequent step involved the use of the 31P drill, similar in shape and diameter (3.1mm) to the previous drill but with a flat, non-cutting apical portion, working only on the chamfered angles and laterally. This drill was used with the next depth stop, thus at +3mm from the initial height of the maxillary sinus floor, at 50 rpm counterclockwise. In cases of thin cortical bone, this step caused the detachment of a round portion of cortical bone approximately 3mm in diameter, checkable with the depth probe and perceptible as mobility with elastic return of the rigid bottom of the surgical site (Fig. 7). In cases of thick cortical bone or small variations in depth compared to the initially calculated CBCT values, the drill could not advance. In such cases, it was not advisable to insist for more than 2-3 seconds but to vary the counterclockwise rotation speed of the instrument to 700 rpm. In cases of thicker cortical bone, this caused the detachment of a rounded osseous portion of 3mm, making mobility perceivable during atraumatic probing (Fig. 3e). In cases of a particularly thick and irregular floor, the 31P drill still struggled to advance. In these rare cases, the protocol involved an additional step with 31PTX, at 700 rpm clockwise with the same depth stop just used with the 31P drill, to produce further deformation of the maxillary sinus floor. After this step, the use of the 31P drill was resumed, with the same settings (50 rpm counterclockwise), and the procedure continued with the next stop (+4 from the original measurement of residual bone height). In cases of non-advancement, as before, the rotation speed was varied to 700 rpm counterclockwise with the same drill and depth stop. At this point, in all cases treated in this study, detachment of the cortical bone occurred, resulting in access to the sinus cavity. If access to the maxillary sinus had not yet occurred, the protocol involved repeating the just-described sequence (31P 50rpm counterclockwise, 31P 700rpm counterclockwise, 31PTX 700rpm clockwise) with the subsequent stops used in sequence until the detachment of the osseous

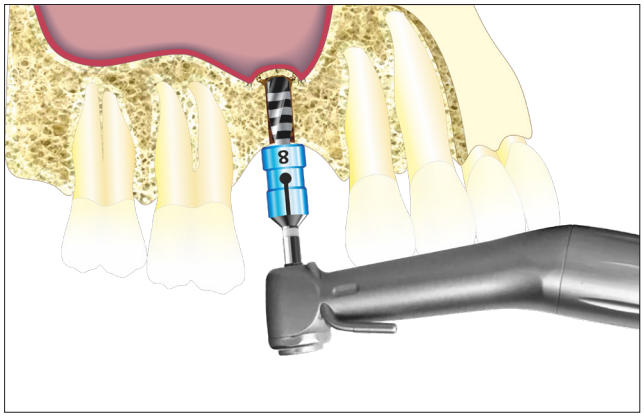


Fig. 7 Detachment of the sinus floor with the 31P counterclockwise bur

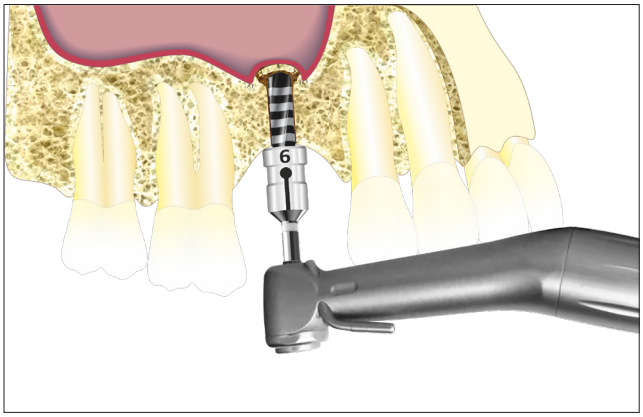


Fig. 8 Use of the 31R bur counterclockwise to ream the bottom of the surgical site

portion of the maxillary sinus floor was achieved.
Once accessed to the maxillary sinus, the mobility of the bottom of the surgical site was gently probed and the 31R drill was used, with a diameter of 3.1mm and a completely rounded non-working tip, at 50rpm counterclockwise and with the last depth stop used. The passage with this instrument refined the entrance to the sinus in an atraumatic and safe manner, and thanks to the counterclockwise rotation, it imparted a coronal-apical fluid push (blood and physiological saline used for irrigation of the rotating instruments), causing an initial detachment of the Schneiderian membrane perimeter wise to the access cavity (Fig. 8). In cases where the insertion of an implant with a diameter >4mm was planned, after the 31R drill, an additional step was performed with the 36R drill of similar shape but with a diameter of 3.6mm, with the same settings (50rpm counterclockwise) and with the same depth stop. The rationale for using this tool was based on the need to widen the surgical site for the insertion of an implant with a diameter greater than 4mm. After these steps, the bone condenser was used on the side with a diameter equivalent to the last drill used (one side indeed had a width of 3.1mm, the other of 3.6mm) and with the depth stop equivalent to -1mm from the initial distance from the maxillary sinus floor. With the bone condenser, a cylinder of hemostatic collagen type I, sized 12x8mm (Collagen Plast, MVG Medical Devices, Italy), was inserted, separated into two or three portions and compacted to be easily grafted into the prepared surgical site (Fig. 3f). Subsequently, a mixture of grafting biomaterial was prepared, consisting of 50% 0.5-1.0mm granulated beta-tricalcium phosphate (ADbone, Medbone, Sintra, Portugal) and 50% gel based on polylactic and polyglycolic acid (Fisiograft gel, Ghimas, Casalecchio di Reno, Italy). This mixture was progressively inserted into the surgical site in loads and compacted with the bone condenser (Fig. 9a). One load of biomaterial corresponded to the amount transportable with a Lucas surgical curette #85, and the quantity of loads inserted was proportional to the mm of lift and the width of the maxillary sinus calculated at 10mm height from the crestal bone margin according to the scheme reported in (Tab. 3).
Once the required number of loads was reached, the planned implant was inserted at 15 rpm using a gradual procedure, characterized by brief pauses of 10-15 seconds for every millimeter of advancement (Fig. 9b). After the fixture was positioned, if necessary, the connective

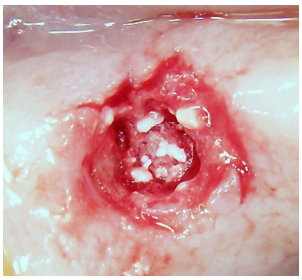


Fig. 9a Insertion of graft charges

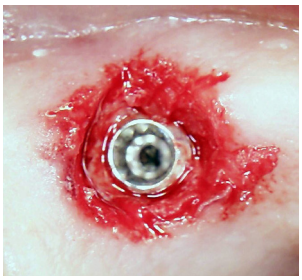


Fig. 9b Gradual implant insertion

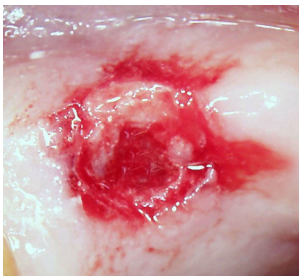


Fig. 9c Connective tissue graft from de-epithelized mucotomy

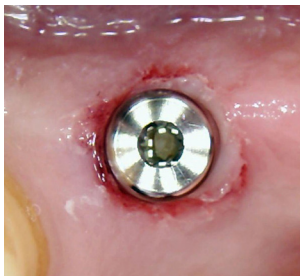


Fig. 9d Transmucosal healing screw placement

Fig. 9a-9d SCV Sinus Lift surgical steps part 1

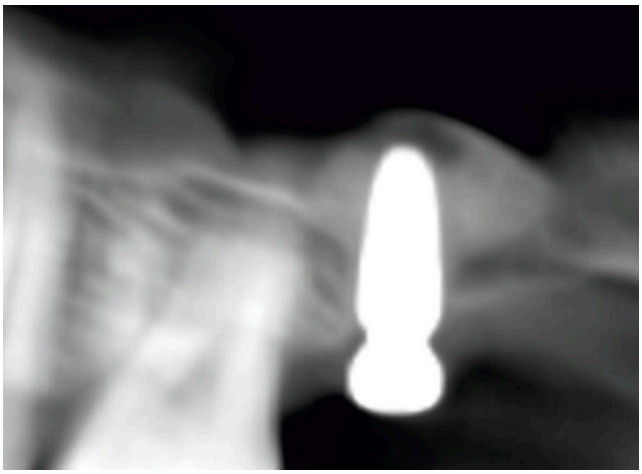


Fig. 10 Post-surgery radiographic check-up

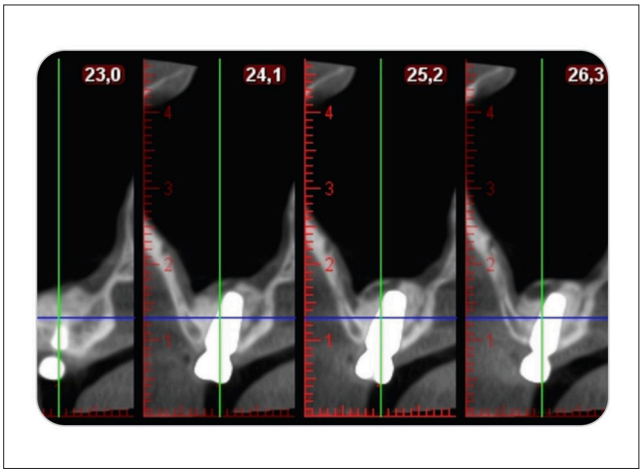


Fig. 11 After surgery the implant acts as a support for the graft

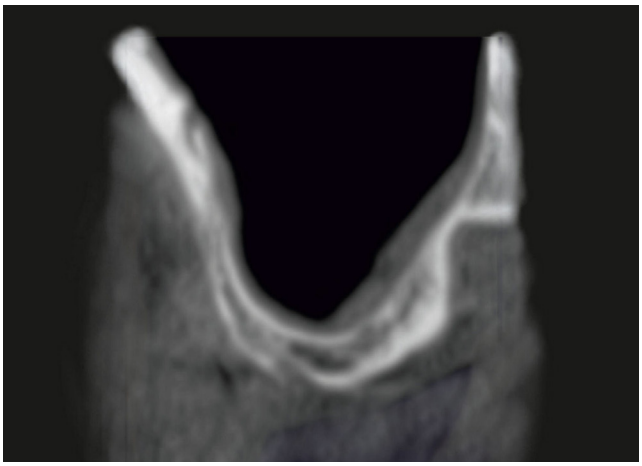
tissue portion retrieved from the mucotomy was partially vestibularly pocketed (Fig. 9c). Subsequently, manual tightening of the transmucosal healing screw of adequate height was performed (Fig. 9d). Among the 41 treated cases, two showed the presence of an Underwood septum with a bucco-palatal orientation in the area of sinus implant placement. In these cases, the protocol involved shifting the center of the surgical site preparation axis at least 1 mm mesially or distally from the center of the septum. The 31PTX bur, with clockwise rotation at 700 rpm, was used until access to the sinus was achieved, without using the 31P bur. After creating the access, which occurred in both cases at +3mm height compared to the original position of the sinus floor, the preparation was completed using only the 31R bur at 50 rpm counterclockwise, with the stop equivalent to the implant length. Subsequently the bone condenser was used for the insertion of the graft material, followed by implant placement, as for all other cases.

SINUS WIDTH	UP TO 12	14	16	18
CHARGES PER MM	3	4	5	6
SINUS LIFT +1	0	0	0	0
SINUS LIFT +2	0	0	0	0
SINUS LIFT +3	9	12	15	18
SINUS LIFT +4	12	16	20	24
SINUS LIFT +5	15	20	25	30
SINUS LIFT +6	18	24	30	36
SINUS LIFT +7	21	28	35	42

Tab. 3

Data analysis

At the end of the procedure, the surgery duration was recorded at 30-second intervals. In cases where multiple implants were planned in the same surgery, the time taken for each individual surgical site was considered. Intraoperative complications were noted,



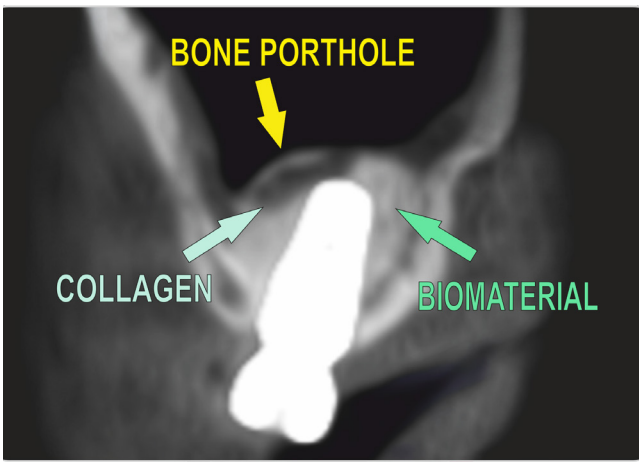


Fig. 12 Pre- and post-operative check-up, the bone operculum supported by the collagen, the implant and the graft material is evident

and a verification CBCT with a reduced FOV of 30x30mm and low-dose targeted to the intervention area was performed. The digital software assessed the correct placement of the graft perimeter and apically to the implant (Fig. 10,11), verifying the absence of membrane lacerations and dispersion of biomaterial within the sinus. The use of a high radio-opacity graft made the postoperative radiographic evaluation more accurate (Fig. 12). Furthermore, the pain during surgery assessed by the patient according to the Numerical Rating Scale (NRS) analogue scale was recorded, with a score ranging from 0 (no perceived pain) to 10 (maximum imaginable pain). Patients were called back 10 days post-surgery, and any postoperative complications such as nasal bleeding, persistent pain, swelling, or edema in the operated area were noted. A second assessment of perceived pain by the patient in the days following surgery, quantified using the NRS, and the amount of anti-inflammatory medication taken for pain control, were also recorded. At 6 months post-surgery, a follow-up was conducted with intraoral X-rays, and implant prosthetics were performed. At 18 months post-surgery (1 year after prosthetics) patients were called back for a new checkup with intraoral X-rays using a centering device, evaluating implant survival, absence of complications, sinus health status, and the amount of newly formed bone around the implant. All measurements were taken by a single clinical investigator who did not participate in the surgical procedures.

RESULTS

A total of 41 implants were placed in 33 patients in the posterior maxilla using the presented maxillary sinus crestal lift technique. Data about pre-surgical residual alveolar bone height and width were recorded for each case and were reported in Table 1. Residual bone height (rBH) ranged from 1.2mm to 6.0mm, with a mean of 3.5 ± 1.2mm, and residual bone width (rBW) ranged from 4.6mm to 10.1mm, with a mean of 7.2 ± 1.5mm. The height of all inserted implants was 8.5mm, and the width was reported in Table 1. One out of 33 patients reported swelling and pain beyond the third day post-surgery. One case presented a perforation of the sinus membrane during the procedure. The perforation was detected due to reduced resistance to pressure of the biomaterial during grafting and verified intraoperatively with intraoral X-rays. The Valsalva maneuver was not performed as it was contraindicated at this surgical stage since part of the graft had already been inserted. The surgery was nonetheless completed, and the low-dose postoperative CBCT showed a small extrusion of biomaterial apically to the implant, which was still surrounded by bone and graft. The vertical bone dimension of the alveolar process at 18 months post-sinus lift (lifted Bone Height = lBH), calculated as the distance from the bone crest to the most apical point of the regenerated bone around the implant, was reported in Table 4. The measurement ranged from 7.4mm to 10.4mm, with a mean of 9.0 ± 0.6mm. The obtained increase (augmented Bone Height = aBH), calculated as lBH – rBH, was also reported in Table 4. and it ranged from 2.9mm to 7.5mm, with a mean of 5.5 ± 1.0mm. The time calculated for the execution of each individual lift and the subsequent implant placement was also reported in Table 4. and it ranged from 18'00'' to 38'30'', with an average of 26'15'' ± 4'30''. The pain quantified by the patient according to the analogue NSR scale with a range between 0 and 10, during surgery (surgery NRS = sNRS) and in the first week after surgery (first week NRS = 1wNRS), was reported in Table 4. The mean value after surgery was 0.6 ± 0.8, and after the first week, it was 1.5 ± 1.1. Prosthetic restoration was performed 6 months after surgery for all cases, and no implants were lost during the 18-months follow-up period.

DISCUSSION

In this study, a new minimally invasive technique for maxillary sinus crestal lift was proposed with the aim of minimizing discomfort for patients both during and after the operation. The surgical procedure is designed to be swift, allowing for simultaneous implant placement and addressing a growing number of clinical cases. The scientific literature extensively documents the post-extraction alveolar process remodeling (20,21) and maxillary sinus pneumatization resulting from the loss of upper posterior teeth(22). This process leads to significant reshaping of the residual alveolar bone in this area, often complicating guided implant prosthetic rehabilitation. For this reason, sinus lift is still considered a widely used and indicated technique, although the crestal access variant still has limitations beyond which the approach of first choice remains vestibular access(16), which is, however, considered more invasive and with greater risks of complications(24). On the other hand, the use of a flapless access, which can only be performed in conjunction with crestal elevation, can speed up the surgical procedure and reduce post-operative discomfort and possible complications(25-27). Performing a mucotomy, for access to the bone plane, allows stitchless surgery and transmucosal healing with the insertion of a healing screw tightened to the implant, avoiding subsequent reopening of the surgical site. The flapless surgery, due to reduced visibility, necessitates computer-assisted planning of the intervention(28,29). The use of a specific bur designed to gradually compact and deform the maxillary sinus floor by approximately 2mm in a coronal-apical direction enhances the native bone portion around the implant and its primary stability. This allows managing cases where residual bone height is between 1 and 3mm(11). Moreover, the tenting effect on the membrane achieved by inserting the implant fixture, in conjunction with the maxillary sinus lift procedure, appears to enhance the stability

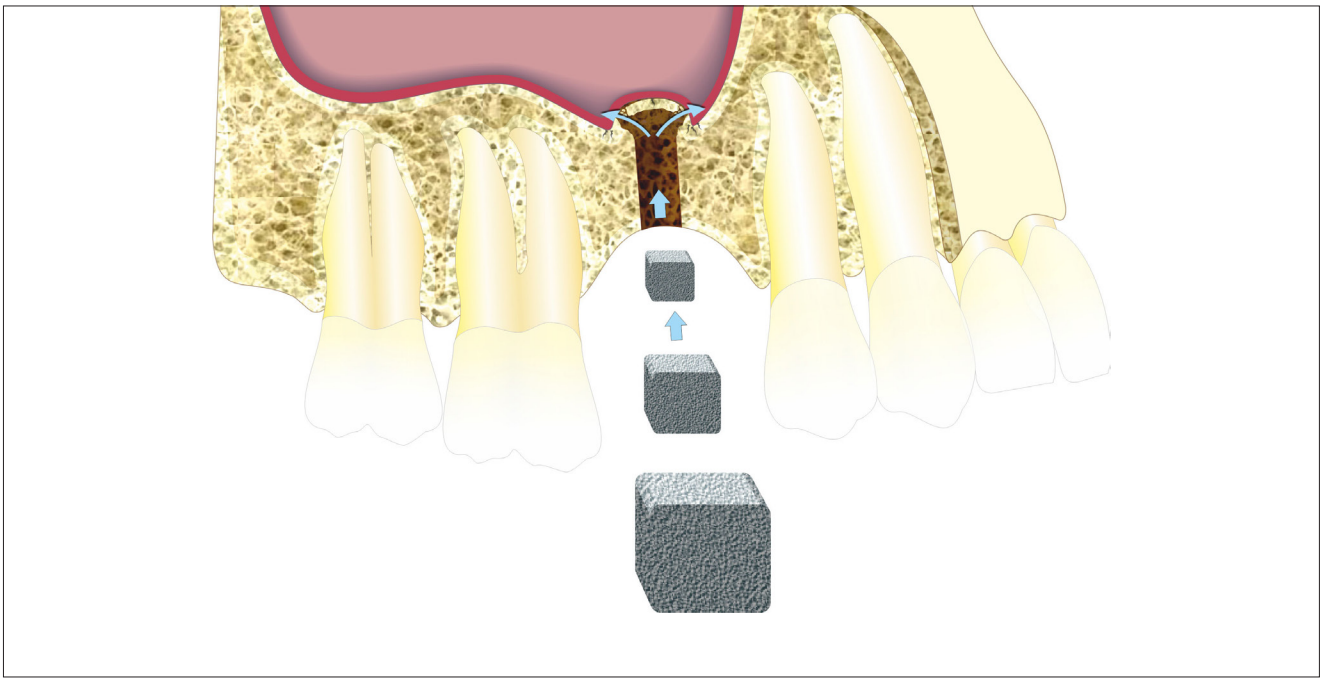


Fig. 13 The insertion of the biomaterial graft allows the detachment of the membrane and the support of the blood clot

of the blood clot, positively influencing the quality and effectiveness of bone regeneration(30). The technique's rationale, employing specific rotary instruments, lies in the ability to detach a circular bony portion after deforming the maxillary sinus floor. In fact, the bone operculum remains attached to Schneider's membrane, forming a rigid roof apical to the graft area and the implant, which becomes its support. This anatomical condition, besides promoting clot formation in the regeneration area, crucial for new bone formation, 31 creates a rigid roof that laterally directs hydraulic pressure (Fig. 13). The hydraulic force evenly distributed on all cavity walls generates a yielding of the more elastic portion thus offering less resistance and this phenomenon induces the membrane detachment in a centrifugal direction relative to the sinus entry hole(32). It has been demonstrated that, through the pressure of a liquid, whose volume remains constant, it is possible to lift the Schneiderian membrane by inducing the detachment of the mucosa from the underlying bone. Pascal's law states that the pressure exerted on a portion of liquid is transmitted unchanged to the walls of the container through the entire volume of the liquid itself, thus acting on the detachment and expansion of the mucosa, which is the anatomical structure that offers less resistance compared to the bony walls(33). Effective detachment appears to allow for better graft distribution horizontally and vertically, facilitating adequate filling even in cases of large sinuses regenerations (>12 mm). Analyzing the literature data, the major limitation of crestal lift compared to the vestibular approach seems to be the quantity and distribution of graft material, less predictable in wide sinuses, recommending vestibular access in these cases(16). However, the proposed technique, by achieving sinus floor deformation, circular bone detachment through crestal access and contextual implant insertion reproduces an anatomical condition favorable to regeneration. This includes a rigid bony roof, an equally rigid support obtained from the implant fixture, and more effective graft distribution due to centrifugal membrane detachment, factors creating optimal conditions for clot support. The neoangiogenesis and migration of growth factors from the bony walls, such as endothelial cells and mesenchymal cells, are direct consequences of the surgical microtrauma caused by membrane detachment. Cytokines and bone growth factors, like bone morphogenetic proteins (BMPs), are released and accumulate into the clot, together with graft material, forming an optimal space-making and maintaining scaffold for effective bone healing and regeneration(34,35). Numerous studies demonstrate a close correlation between adequate membrane detachment and expansion, graft stability, and new bone formation(36,37). Any maxillary sinus lift technique poses risks of Schneiderian membrane injury, regardless of execution quality, technique type, or maxillary sinus health. Higher risks of membrane injury are reported for crestal approaches, considered blind, and for membranes less than 1mm thick(38). Aimetti et al. (39) have demonstrated a correlation between the gingival phenotype and the thickness of the sinus membrane. This would allow a further method of analysis, in addition to radiology, to predict the thickness and thus the resistance to expansion of the schneiderian mucosa.

The proposed technique involves the vertical movement of a bone lid that remains attached to the membrane at the elevation center. This rigid structure, positioned apically to the sinus entry point, directs the hydraulic force horizontally, allowing more targeted and efficient detachment and reducing the risks of membrane laceration and oro-antral communication(40,41). The case where a small membrane tear occurred among the 41 considered in this study had a very thin membrane (<1mm) in the pre-surgical CBCT, reduced and irregular residual alveolar process height, and lower distal height in correspondence of the adjacent natural tooth roots, which were observed as a vertical anatomical obstacle inside the maxillary sinus. This anatomical condition posed a high membrane laceration risk during the detachment procedure.

CONCLUSIONS

The crestal approach to maxillary sinus lift is now considered a reliable and predictable technique for bone regeneration and dental implant placement in the posterior maxilla. Many variants of this technique have been proposed, but the scientific literature still recognizes limitations to the surgical field of application. The Sinus Crestal Vertical (SCV) technique offers a minimally invasive approach, facilitated by specific rotary instruments, depth stops, and the possibility of flapless surgical access. The aim of this study is to safely expand the application of a crestal approach protocol to the maxillary sinus to an increasing number of clinical cases and to be able to do so in a single, short-duration surgery. Indeed, data collected confirm a satisfactory result even in cases of sinuses wider than 12mm and with residual ridges between 1 and 3mm in height. The amount of regenerated bone at 18 months, an average operation time of 26'15" and the low number of complications reinforce this assumptions. However, further clinical studies and longer follow-ups will be necessary to confirm the effectiveness of this protocol equally with other sinus lift procedures.

Acknowledgment

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Conflict Of Interest

The authors declare that they have no conflicts of interest related to this study.

Case	Patient	Implant site	IBH (mm)	aBW (mm)	Surgery time	sNRS	1wNRS
1	1	16	8,9	4,6	28′ 00″	0	1
2	2	27	9,1	6,3	33′ 30″	1	2
3	3	15	8,7	3,6	27′ 00″	0	0
4	4	27	8,4	6,6	35′ 30″	0	1
5	5	25	8,8	5,3	31′ 00″	0	2
6	5	26	9,3	4,4	24′ 30″	/	/
7	6	17	8,2	6,0	29′ 00″	0	3
8	7	16	9,1	5,6	25′ 30″	2	4
9	8	16	9,8	5,8	27′ 00″	0	1
10	8	17	9,5	5,7	26′ 00″	/	/
11	9	25	8,7	3,6	21′ 30″	1	1
12	10	14	10,0	4,0	28′ 00″	0	3
13	11	26	8,4	5,9	31′ 00″	1	2
14	12	26	9,3	6,3	28′ 30″	1	0
15	13	17	8,5	7,0	34′ 00″	0	0
16	14	15	8,9	5,6	22′ 30″	2	2
17	14	16	9,1	4,7	19′ 30″	/	/
18	14	26	10,2	7,5	23′ 30″	/	/
19	15	27	8,6	6,8	29′ 30″	1	2
20	16	25	9,6	4,9	25′ 00″	0	0
21	17	24	8,4	3,0	19′ 30″	0	3
22	18	15	9,1	5,7	26′ 30″	0	1
23	18	17	8,6	6,0	25′ 00″	/	/
24	19	26	8,7	7,5	38′ 30″	3	2
25	20	16	8,8	5,1	24′ 00″	0	0
26	21	27	8,9	4,8	26′ 30″	0	3
27	22	15	9,3	5,6	22′ 30″	1	2
28	22	16	7,4	5,3	28′ 00″	/	/
29	23	17	9,0	5,5	30′ 30″	2	2
30	24	15	9,5	4,8	22′ 30″	0	0
31	24	25	10,1	6,6	24′ 00″	/	/
32	25	27	9,2	6,7	30′ 00″	0	1
33	26	16	8,8	5,4	23′ 00″	1	2
34	27	25	10,4	5,6	24′ 30″	0	0
35	27	27	9,2	3,6	20′ 30″	/	/
36	28	26	8,4	6,1	28′ 30″	0	2
37	29	16	9,4	5,8	25′ 00″	3	3
38	30	17	9,0	4,2	18′ 00″	1	2
39	31	15	9,9	5,0	27′ 30″	0	2
40	32	26	8,7	6,1	20′ 00″	0	0
41	33	26	8,6	6,7	22′ 00″	0	0

Tab. 4

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