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Original Article

Vertical Bone Gain and Implant Survival Following Crestal Hydraulic Sinus Elevation with CAS Kit: Retrospective Case Series

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ABSTRACT

This study examined the outcomes of using the Crestal Approach Sinus (CAS) kit alongside tissue-level implants for sinus augmentation in patients with limited bone height. It also evaluated the bone thickness above the implant tip to determine safety and effectiveness of this minimally invasive technique. Data from 15 patients (20 implants) treated between September 2021 and October 2024 were analyzed. All cases had at least 2 mm of residual bone in the posterior maxilla. Preoperative CBCT scans assessed initial bone conditions, and panoramic X-rays tracked changes at the time of implant placement and nine months post-procedure. Primary measures included implant survival and complications, while secondary measures focused on vertical bone gain and bone coverage over the implant apex. Wilcoxon signed-rank tests were used for statistical comparisons with a 0.05 significance threshold.

All implants integrated successfully, with no failures or complications reported. Initial bone height averaged 4.2 ± 1.4 mm, increasing to 13.8 ± 1.8 mm after sinus elevation. At nine months, membrane elevation slightly decreased to 13.0 ± 1.6 mm, yielding an average bone gain of 9.6 ± 2.4 mm. Bone above the implant tip reduced from 3.4 ± 1.7 mm to 3.0 ± 1.2 mm ($p = 0.007$). The CAS kit combined with tissue-level implants appears to be a safe and effective minimally invasive approach for sinus lifts, producing reliable bone gain and excellent implant survival. These findings support its use in patients with limited residual bone, although larger studies with longer follow-up are recommended.

Keywords: Crestal sinus lift, Minimally invasive sinus augmentation, Tissue-level implants, Vertical bone gain

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Introduction

Sinus augmentation has been an integral part of dental implantology for over five decades, with its first formal description by Tatum Jr. in 1986 [1]. These procedures are particularly important for patients with limited vertical bone height in the posterior maxilla, often caused by alveolar bone resorption and sinus pneumatization. By increasing bone volume, sinus augmentation improves implant stability and contributes to long-term success [2, 3].

Two main approaches are used to elevate the maxillary sinus membrane: the lateral window technique and the alveolar crestal approach. The lateral window method, developed by Tatum, involves creating an opening on the lateral wall of the sinus to lift the Schneiderian membrane. This approach allows the insertion of a bone graft beneath the membrane to encourage new bone formation and implant support. Although effective, it carries risks such as membrane perforation, postoperative discomfort, and longer recovery times [4, 5].

In contrast, the crestal approach, introduced by Summers in 1994 [6], is a less invasive technique that accesses the sinus floor via the alveolar crest using

osteotomes to carefully fracture the sinus floor and elevate the membrane. Bone grafts are often added to enhance regeneration. Over time, the crestal method has evolved with innovations including piezoelectric tools, balloon-assisted elevation, and hydraulic systems designed to reduce trauma and improve outcomes [7–10]. A randomized trial by Xhanari *et al*. [7] comparing lateral and crestal techniques showed that both methods achieved successful results, though the crestal approach required less surgical time and was preferred by patients due to its minimally invasive nature and reduced postoperative discomfort.

Further innovations have included hydraulic-assisted sinus elevation, where controlled pressure is used to lift the Schneiderian membrane while simultaneously placing a flowable bone substitute [8–10]. This method reduces the risk of membrane perforation and simplifies the procedure, though it requires specialized implants and surgical experience. Recent comparisons by Yassin Alsabbagh *et al*. [11] between balloon-assisted techniques and the CAS kit approach demonstrated that both approaches outperform conventional osteotome methods in safety and effectiveness [11], with additional studies validating the CAS kit with bone-level implants [12–14].

The crestal approach is generally indicated when moderate sinus floor augmentation (≥3 mm) is needed [15]. Contraindications include severe sinus pathology (e.g., chronic sinusitis), very limited residual bone (<3 mm), uncontrolled systemic conditions, active periodontal disease, poor oral hygiene, previous sinus surgeries, or anatomical variations such as thin sinus membranes [16, 17].

Despite advances, challenges remain in achieving predictable membrane elevation, graft stability, and long-term implant success. Current research focuses on optimizing graft materials, refining surgical protocols, and developing novel tools to improve safety and clinical outcomes. Standardized protocols and long-term data are needed to support evidence-based practice in sinus augmentation.

This retrospective study aims to evaluate vertical bone gain following sinus lift using the CAS kit in combination with tissue-level implants and to measure the bone height between the implant apex and Schneiderian membrane. The manuscript follows the STROBE guidelines for observational studies.

Materials and Methods

Study design and ethical considerations

This research was conducted as a retrospective case series at San Pietro Hospital, Fatebenefratelli, Rome. All participants were fully informed about the procedures and provided written consent prior to treatment. Patient information was anonymized to ensure confidentiality. Since the study involved standard clinical care without experimental interventions, formal ethical approval was not required under European (Directive 2001/20/EC) [18] and Italian regulations (Artt. 10 e 320 cod.civ.; artt. 96 e 97 legge 22.4.1941, n. 633). All clinical and prosthetic procedures were performed by two experienced clinicians (FMC and AM) following the ethical guidelines of the Declaration of Helsinki, updated in October 2024.

Inclusion and exclusion criteria

The study included partially edentulous patients aged 18 or older, treated in the posterior maxilla (premolars and molars) with tissue-level implants combined with crestal sinus lifts from September 2021 to October 2024. A minimum residual bone height (RBH) of 2 mm was required. Patients were excluded if they had symptomatic sinus disease or maxillary ostium obstruction, received immediate implants (<4 months post-extraction), smoked heavily (≥10 cigarettes/day), had untreated periodontitis, poor oral hygiene (full-mouth bleeding or plaque index ≥25%), systemic contraindications to surgery (ASA III–IV), prior head/neck irradiation within five years, psychiatric disorders, substance abuse, pregnancy or lactation, or were on medications affecting bone metabolism such as steroids or bisphosphonates.

Surgical protocol

Preoperative CBCT scans were used to assess bone anatomy and plan implant placement. Under local anesthesia, a full-thickness flap was raised to expose the alveolar ridge. The CAS kit system (Osstem Implant CO., LTD., Seoul, Korea) was used according to manufacturer guidelines. The procedural steps included:

- *Site preparation:* Cortical bone was marked using a guide drill (2.0/2.7 mm) with a 2 mm stopper at 1,000–1,500 rpm.
- *Twist drilling:* A 2.2 mm twist drill was used with a stopper set 1 mm shorter than the planned depth at 1,000–1,500 rpm. The depth was defined as the distance from the alveolar crest to the sinus floor. For RBH of 2–3 mm, this step was omitted.
- *CAS drilling:* Specialized drills with rounded tips were used to reach the sinus floor while minimizing membrane trauma, at 400–800 rpm with stoppers.
- *Hydraulic elevation:* Sterile saline was slowly injected using a hydraulic lifter to separate the Schneiderian membrane. The volume injected

was adjusted to the planned lift height, delivered in 0.5 cc increments up to 1–1.5 cc.

Table 1. Amount of bone graft and saline according to the sinus anatomy.

Lift Height (mm)	Bone Graft (cc)	Saline (cc)
3	0.36	0.5–1
4	0.5	1
5	0.7	1–1.5
6	0.9	1.5–2

- CAS drills were employed to expand the osteotomy according to the final diameter of the planned implants and the bone quality: a 2.8 mm drill for 3.8 mm implants and a 3.1 mm drill for 4.25 mm implants. This step also provided access to the sinus for graft placement. Anorganic bovine bone (Bio-Oss, granules 0.25–1 mm, Geistlich Pharma AG, Wolhusen, Switzerland) was used to fill the sinus at the implant site, with the graft volume adjusted according to the desired lift height **(Table 1)**.
- Subsequently, self-tapping implants (PRAMA, Sweden and Martina) were placed. These implants featured a 2.8 mm convergent neck with a microtextured UTM surface and a Zirconium Titanium (ZirTi) body, designed to support the biologically oriented preparation technique (BOPT). Implants were inserted with a minimum torque of 25 Ncm. Healing abutments were placed immediately, and the flap was sutured without tension. Postoperative care included standard instructions, analgesics (Ibuprofen 600 mg as needed, up to three times daily), and antibiotics (Amoxicillin 1 g twice daily for six days).
- Six months post-implantation, conventional impressions were taken, and single screw-retained porcelain-fused-to-metal crowns were delivered 3–4 weeks later. Patients were included in a maintenance program with periodic checks of the restoration and radiographic evaluations.

Outcome measures

- Primary outcomes included implant and prosthetic survival and the occurrence of biological or technical complications. Implant failure was defined as mobility, infection requiring removal, fracture, or other mechanical issues compromising function. Prosthetic failure was defined as the need for replacement. Biological complications included pain, swelling, suppuration, or mobility, whereas technical issues included abutment or veneer fracture, or screw loosening/fracture.
- Secondary outcomes were measured as the total effective vertical height (residual bone + implant + graft) immediately after placement and the final sinus elevation at crown delivery, approximately nine months postoperatively. All postoperative measurements were obtained from panoramic radiographs.

Statistical analysis

Data were compiled using Numbers for MacOS Sequoia (Version 14.2). A pre-defined analysis plan was implemented under the supervision of a dental biostatistician. Descriptive statistics included mean ± standard deviation, median, and 95% confidence intervals. Changes in outcomes over time were assessed using the non-parametric Wilcoxon signed-rank test. Each implant was treated as a statistical unit. Statistical significance was set at $p < 0.05$.

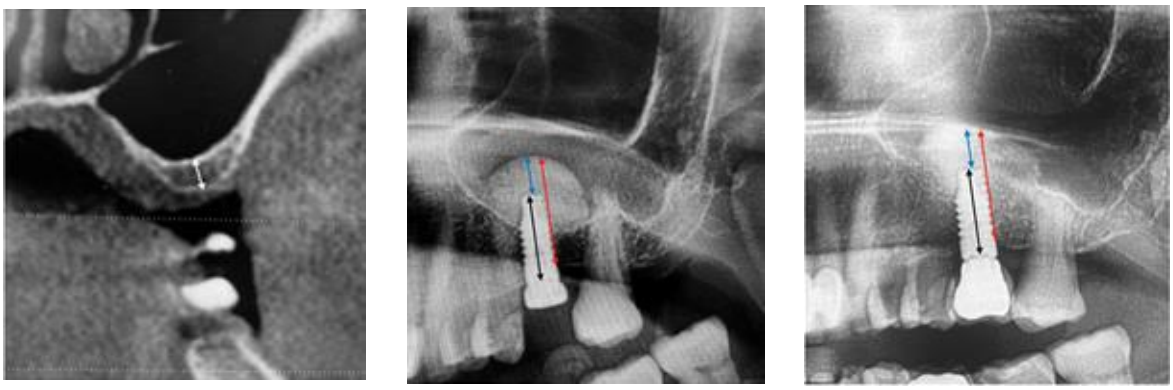
Results and Discussion

From the initial pool of 36 potential candidates, 15 patients meeting all inclusion and exclusion criteria were included in this analysis, comprising a total of 20 tissue-level implants. Exclusions (n = 21) were primarily due to missing postoperative panoramic radiographs (n = 16), relocation before final crown delivery (n = 3), or significant health events (n = 2). All included patients underwent radiographic evaluation nine months after implant placement, with a mean follow-up duration of 19.5 ± 6.4 months (range: 9–30 months). No implant or prosthetic failures were observed, and no biological or technical complications were reported throughout the study period.

Baseline residual bone height (RBH) at the implant sites averaged 4.2 ± 1.4 mm (range: 2.0–6.7 mm). Immediate postoperative measurements indicated a mean sinus membrane elevation of 13.8 ± 1.8 mm (range: 10.9–17.8 mm), resulting in an average vertical bone gain of 9.6 ± 2.4 mm (range: 5.7–14.3 mm; $p < 0.001$). The thickness of bone above the implant apex at placement was 3.4 ± 1.7 mm (range: 1.3–7.9 mm).

At the nine-month follow-up, the average sinus elevation slightly decreased to 13.0 ± 1.6 mm (range: 10.4–16.1 mm), representing a minor reduction of 0.8 ± 0.7 mm from the immediate postoperative measurement (range: 0.0–2.6 mm; $p < 0.001$). Similarly, bone thickness above the implant tip decreased slightly to 3.0 ± 1.2 mm (range: 1.3–5.7 mm), corresponding to a mean reduction of 0.4 ± 0.6 mm (range: 0.0–2.3 mm; $p = 0.007$).

Overall, these findings demonstrate substantial vertical bone gain using the crestal approach sinus lift with the CAS kit in combination with tissue-level implants. Representative cases and detailed measurements are provided in **Figure 1** and **Tables 2a and 2b**.



a) b) c)

Figure 1. Sequential radiographic overview of the surgical sites. From left to right: preoperative condition, immediate postoperative implant placement with sinus lift, and follow-up at nine months. White line indicates residual bone height (RBH); black line represents the implant length; red line denotes the overall amount of bone (OAB); blue line shows the bone thickness above the implant apex (BAI).

Table 2. (a) Radiographic outcome measures in mm. (b) Descriptive statistics.

(a)

Implants' Characteristics				Implant Placement				9 Months Follow-Up			
Case N°	Site	Diameter (mm)	Length (mm)	RBH (mm)	OAB (mm)	Difference (mm)	BAI (mm)	OAB (mm)	Difference (mm)	BAI (mm)	Last FU (Months)
1	26	4.25	10	4.6	13.66	9.06	2.31	13.21	0.45	2.13	9
2	15	4.25	10	3.29	13.99	10.7	3.10	13.14	0.85	3.05	11
3	25	3.8	10	4.94	13.90	8.96	2.69	13.84	0.06	2.7	11
4	26	4.25	10	3.38	13.29	9.91	2.73	12.34	0.95	2.45	11
5	25	3.8	10	6.6	14.84	8.24	3.04	13.44	1.4	2.78	14
6	16	4.25	10	3.28	11.8	8.52	1.37	11.05	0.75	1.28	15
7	26	4.25	10	4.27	14.25	9.98	4.42	13.65	0.6	3.45	16
8	15	4.25	10	4.72	13.02	8.3	3.04	12.25	0.77	2.89	16
9	26	4.25	10	2.43	16.69	14.26	6.14	14.11	2.58	4.15	19
10	26	4.25	10	4.88	11.08	6.2	1.61	10.78	0.3	1.45	19
11	25	3.8	10	6.17	15.67	9.5	4.11	15.60	0.07	3.98	21
12	26	3.8	10	3.66	15.45	11.79	4.49	15.03	0.42	3.90	21
13	16	4.25	10	3.78	17.77	13.99	7.94	16.09	1.68	5.66	22
14	17	4.25	8,5	2.45	13.81	11.36	4.44	13.13	0.68	4.15	22
15	15	4.25	10	4.57	15.19	10.62	3.56	14.67	0.52	3.11	24
16	27	4.25	10	2.0	12.03	10.03	2.36	11.42	0.61	2.09	25
17	16	3.8	10	4.11	10.87	6.76	1.46	10.37	0.5	1.44	27
18	17	3.8	10	5.59	11.27	5.68	1.31	11.17	0.1	1.35	27
19	26	4.25	10	6.72	13.24	6.52	3.89	13.20	0.04	3.77	29
20	16	4.25	10	2.0	13.97	11.97	4.53	12.02	1.95	4.23	30

(b)

Implants (n = 20)	Implant Placement				9 Months Follow-Up			
	RBH (mm)	OAB (mm)	Difference (mm)	BAI (mm)	OAB (mm)	Difference (mm)	BAI (mm)	Last FU (Months)
Mean (mm) and SD (mm)	4.2 (1.4)	13.8 (1.8)	9.6 (2.4)	3.4 (1.7)	13.0 (1.6)	0.8 (0.7)	3 (1.2)	19 (6)
Confidence interval (mm)	0.6	0.8	1	0.7	0.7	0.3	0.5	2.8
Min (mm)/Max (mm)	2.0–6.7	10.9–17.8	5.7–14.3	1.3–7.9	10.4–16.1	0.0–2.6	1.3–5.7	9–30
p Value			0.000			0.000		

RBH = residual bone height; OAB = overall amount of bone; BAI = bone above the implant tip; FU = Follow-up; SD = standard deviation.

This retrospective case series investigated the outcomes of sinus floor elevation in the posterior maxilla using the CAS kit combined with tissue-level implants. The results demonstrated a substantial gain in vertical bone height, with a mean membrane lift of 13.8 ± 1.8 mm at implant placement, which slightly decreased to 13.0 ± 1.6 mm at the nine-month follow-up. No implants or prosthetic components failed during the observation period, and no biological or mechanical complications were observed, indicating that this technique is both safe and predictable.

These findings are consistent with previous research evaluating minimally invasive sinus augmentation approaches. Studies by Yassin Alsabbagh *et al*. [11] have highlighted that the CAS kit improves procedural safety and effectiveness compared to conventional osteotome techniques, mainly due to controlled hydraulic elevation that reduces the risk of Schneiderian membrane trauma. The current study corroborates these advantages, demonstrating that the CAS kit permits significant vertical bone gain while minimizing intraoperative risks. The use of tissue-level implants may further contribute to stability and peri-implant tissue health, reducing the likelihood of inflammation or peri-implantitis [19].

Compared with the traditional lateral window approach, which carries a higher risk of complications such as membrane perforation and postoperative discomfort, the crestal CAS kit approach provides several clinical advantages. Consistent with findings by Xhanari *et al*. [7], the less invasive nature of the crestal approach results in shorter surgical time and greater patient satisfaction. The CAS kit system allows gradual and controlled membrane elevation using hydraulic pressure, with protective drills and stoppers minimizing the risk of perforation. Saline is incrementally injected to lift the membrane, achieving the desired height safely and efficiently [10].

The decision to use graft material in sinus lifts remains debated. Silva *et al*. [20] suggested that sinus augmentation, with or without bone grafting, yields safe and predictable outcomes. Gatti *et al*. [14] reported that grafting with anorganic bovine bone reduces resorption and helps maintain vertical bone height during healing. In the present series, grafting was performed according to residual bone height, ensuring predictable augmentation and radiographic monitoring. Overall, the CAS kit combined with tissue-level implants proved to be an effective and reliable approach for posterior maxillary sinus augmentation. The technique enabled consistent vertical bone gain, remained stable over a nine-month period, and demonstrated high survival rates for both implants and prosthetic restorations, with no reported complications.

Despite its advantages, the crestal approach has inherent limitations. Membrane perforation remains a potential risk, particularly in patients with thin or irregular sinus floors. Limited visual and tactile feedback may also challenge membrane integrity. Future studies should address these limitations by including larger, multicenter populations with long-term follow-up. Additionally, comparative studies assessing the CAS kit against other modern sinus elevation techniques, such as balloon-assisted or piezoelectric methods, are necessary to determine the most appropriate approach for different clinical scenarios [21–24].

The study's limitations include its retrospective design, small sample size, and the use of panoramic radiography rather than cone-beam CT, which may have limited measurement accuracy. Future investigations should incorporate CBCT imaging and control groups to allow for more precise evaluation and comparison of outcomes.

Conclusion

The CAS kit technique, in combination with tissue-level implants, is a safe and effective method for sinus augmentation in patients with limited residual bone height. The procedure achieved significant vertical bone gain and maintained stability over nine months, with no implant or prosthetic failures reported. Further research involving larger cohorts and extended follow-up periods is warranted to confirm these findings and

support standardized clinical protocols for maxillary sinus augmentation.

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