

Comparative Evaluation of Crestal and Lateral Sinus Lift Techniques for Implant Rehabilitation: A Clinical Study

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ABSTRACT:

Background:

Maxillary sinus floor elevation is a well-established procedure for implant rehabilitation in the posterior maxilla with insufficient residual bone height. Among the available techniques, the crestal and lateral sinus lift approaches are the most commonly performed; however, their comparative clinical outcomes remain a subject of ongoing investigation.

Aim:

To compare the clinical outcomes of crestal and lateral sinus lift techniques for implant rehabilitation in patients with posterior maxillary bone deficiency

Materials and Methods:

This prospective comparative clinical study included 40 patients requiring implant-supported rehabilitation in the posterior maxilla. Patients were equally allocated into two groups: Group I (Crestal sinus lift, n = 20) and Group II (Lateral sinus lift, n = 20). Clinical parameters evaluated included operative time, postoperative pain using the Visual Analogue Scale (VAS), implant stability quotient (ISQ) at baseline, 3 months, and 6 months, vertical bone augmentation, marginal bone loss, implant survival, Schneiderian membrane perforation, soft tissue healing, and patient satisfaction. Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were compared using the Independent Samples Student's t-test, while categorical variables were analyzed using

the Chi-square or Fisher's Exact test. Statistical significance was set at $p < 0.05$.

Results:

The demographic characteristics were comparable between the two treatment groups, with no significant differences in age or gender distribution ($p > 0.05$). The crestal sinus lift group demonstrated a significantly shorter operative time (31.80 ± 4.90 vs. 54.20 ± 7.10 minutes; $p < 0.001$), lower postoperative pain scores (2.80 ± 0.90 vs. 4.60 ± 1.10 ; $p = 0.002$), and higher patient satisfaction (9.10 ± 0.74 vs. 8.35 ± 0.88 ; $p = 0.021$). In contrast, the lateral sinus lift group achieved significantly greater vertical bone augmentation (7.28 ± 1.12 mm vs. 3.82 ± 0.79 mm; $p < 0.001$). Implant stability increased progressively from baseline to six months in both groups, with no significant differences between the groups at baseline, three months, or six months ($p > 0.05$). Marginal bone loss, implant survival (100% vs. 95%; $p = 1.000$), Schneiderian membrane perforation (0% vs. 15%; $p = 0.072$), and soft tissue healing were also comparable between the two groups ($p > 0.05$). The overall implant survival rate at the six-month follow-up was 97.5%.

Conclusion:

Both crestal and lateral sinus lift techniques provided predictable clinical outcomes and high implant survival rates for implant rehabilitation in the posterior maxilla. The crestal approach was associated with shorter surgical time, reduced postoperative discomfort, and greater patient satisfaction, whereas the lateral approach achieved significantly greater vertical bone augmentation, making it preferable in cases with severe posterior maxillary bone deficiency. Treatment selection should therefore be guided by the available residual bone height and the extent of augmentation required.

Keywords: Bone augmentation, Cone-beam computed tomography, Crestal sinus lift, Implant rehabilitation, Lateral sinus lift, Maxillary sinus lift, Posterior maxilla

Introduction

Dental implant rehabilitation in the posterior maxilla is often complicated by inadequate vertical bone height resulting from maxillary sinus pneumatization following tooth loss and progressive alveolar ridge resorption. These anatomical changes frequently limit the availability of sufficient bone for achieving primary implant stability, making sinus floor elevation an essential pre-prosthetic procedure for successful implant

placement [1]. Since its introduction, maxillary sinus augmentation has become a predictable and well-established technique for increasing the available bone height and improving long-term implant survival in the atrophic posterior maxilla [2].

Two principal surgical approaches are commonly employed for sinus floor elevation: the lateral window (lateral sinus lift) technique and the transcrestal (crestal sinus lift) technique. The

lateral window approach, first described by Boyne and James, is generally indicated in cases with severe vertical bone deficiency, typically when the residual bone height is less than 5 mm. This technique provides direct visualization of the Schneiderian membrane and permits substantial vertical bone augmentation, although it is relatively invasive and associated with longer surgical time and increased postoperative morbidity [3].

In contrast, the crestal sinus lift technique, originally introduced by Summers, is considered a minimally invasive alternative that is most suitable for patients with moderate residual bone height. By accessing the sinus floor through the implant osteotomy, this technique minimizes surgical trauma, reduces patient discomfort, and shortens healing time. However, the amount of achievable vertical bone gain is comparatively limited, and the procedure requires careful case selection to ensure predictable outcomes [4].

The selection of an appropriate sinus lift technique depends on multiple clinical and radiographic factors, including residual alveolar bone height, sinus anatomy, Schneiderian membrane thickness, bone quality, implant dimensions, and the presence of sinus septa or pathology. Cone-beam computed tomography (CBCT) has become the imaging modality of choice for preoperative assessment because it provides accurate three-dimensional visualization of these anatomical structures, enabling clinicians to select the most suitable surgical approach while minimizing the risk of complications such as membrane perforation or inadequate implant stability [5].

Several clinical investigations have demonstrated high implant survival rates following both crestal and lateral sinus lift procedures. Nevertheless, differences have been reported regarding surgical complexity, postoperative pain, swelling, healing period, graft stability, and complication rates. While the lateral approach allows greater bone augmentation in severely resorbed ridges, the

crestal approach offers reduced patient morbidity and faster recovery in appropriately selected cases. Consequently, controversy remains regarding the optimal technique for different clinical situations [6].

Recent advances in biomaterials, implant surface technologies, and minimally invasive surgical techniques have further improved the predictability of sinus augmentation procedures. Simultaneous implant placement during sinus lift surgery has become increasingly common when adequate primary stability can be achieved, thereby reducing overall treatment duration and improving patient acceptance. Furthermore, the use of growth factors and newer bone graft substitutes has enhanced osseointegration and bone regeneration following sinus floor elevation [7].

Although numerous studies have independently evaluated the outcomes of lateral and crestal sinus lift procedures, direct comparative clinical studies assessing implant success, bone gain, postoperative complications, patient discomfort, and functional outcomes remain relatively limited. Comparative evidence is essential to establish evidence-based guidelines for selecting the most appropriate technique according to individual patient characteristics and anatomical conditions [8].

Therefore, the present clinical study was undertaken to compare the clinical outcomes of crestal and lateral sinus lift techniques in patients undergoing implant rehabilitation of the posterior maxilla. The study aims to evaluate implant stability, radiographic bone gain, postoperative complications, healing outcomes, and overall treatment success to determine the relative effectiveness and clinical applicability of both surgical approaches.

Materials and Methods

Study Design

This prospective comparative clinical investigation was designed to evaluate and compare the clinical and radiographic performance of crestal and

lateral sinus lift procedures in patients undergoing implant rehabilitation of the posterior maxilla. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study, and all procedures conformed to the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from every participant prior to inclusion.

Study Population

A total of 40 patients requiring implant-supported rehabilitation in the posterior maxilla were enrolled in the study. All participants exhibited inadequate residual alveolar bone height secondary to maxillary sinus pneumatization and post-extraction ridge resorption. Patient recruitment was carried out consecutively between January 2025 and December 2025.

The participants were randomly assigned into two equal treatment groups:

- Group I (n = 20): Crestal (transcrestal) sinus floor elevation with simultaneous implant placement.
- Group II (n = 20): Lateral window sinus floor elevation with simultaneous implant placement.

Sample Size

The study sample consisted of 40 participants, with 20 patients allocated to each treatment group. This sample size was considered sufficient to detect clinically relevant differences between the two treatment modalities with a statistical power of 80% at a 5% level of significance.

Inclusion Criteria

Patients were eligible for inclusion if they fulfilled the following criteria:

- Age ranging from 25 to 70 years
- Partial edentulism involving the posterior maxilla requiring implant-supported restoration

- Residual alveolar bone height measuring 3–8 mm on CBCT examination
- Adequate ridge width to accommodate standard implant placement
- Healthy periodontal condition with satisfactory oral hygiene
- Willingness to comply with scheduled follow-up visits
- Signed informed consent for participation

Exclusion Criteria

Patients presenting with any of the following conditions were excluded:

- Existing maxillary sinus disease or pathology
- Uncontrolled systemic disorders affecting wound healing
- Previous maxillary sinus surgery or radiotherapy involving the maxillofacial region
- Heavy tobacco consumption (>10 cigarettes/day)
- Pregnancy or breastfeeding
- Current or previous bisphosphonate therapy
- Active periodontal disease
- Unsatisfactory oral hygiene
- Severe parafunctional habits, including uncontrolled bruxism
- Inability to complete the follow-up protocol

Preoperative Assessment

Each participant underwent a comprehensive clinical and radiographic evaluation before surgery. Clinical assessment included recording medical and dental history, periodontal examination, prosthetic assessment, and evaluation of the implant site. Three-dimensional

radiographic evaluation was performed using CBCT to assess:

- Residual alveolar bone height
- Alveolar ridge width
- Schneiderian membrane thickness
- Presence of maxillary sinus septa
- Overall maxillary sinus morphology
- Bone quality
- Implant dimensions and surgical planning

CBCT Imaging Protocol

CBCT scans were obtained using the Planmeca ProMax® 3D Mid CBCT system (Planmeca Oy, Helsinki, Finland) under standardized exposure parameters:

- Tube voltage: 90 kVp
- Tube current: 10 mA
- Exposure time: 12 seconds
- Voxel size: 0.2 mm
- Field of view (FOV): 10 × 10 cm

Image analysis and linear measurements were performed using Planmeca Romexis® software by a calibrated examiner.

Surgical Protocol

All surgical procedures were performed by a single experienced oral and maxillofacial surgeon under local anesthesia using 2% lignocaine with 1:100,000 epinephrine, thereby minimizing operator-related variability.

Group I – Crestal Sinus Lift

Following a crestal incision and elevation of a full-thickness mucoperiosteal flap, implant osteotomy preparation was carried out to approximately 1 mm below the sinus floor. The Schneiderian membrane was elevated using osteotomes according to the transcrestal technique. Particulate bone graft material was gently introduced beneath the elevated membrane, and the implant was

placed immediately after achieving satisfactory primary stability.

Group II – Lateral Sinus Lift

A full-thickness mucoperiosteal flap was elevated to expose the lateral wall of the maxillary sinus. A lateral bony window was prepared using rotary instruments under copious sterile saline irrigation. The Schneiderian membrane was carefully elevated, and the created space was filled with particulate bone graft material. Simultaneous implant placement was performed whenever adequate primary stability was achieved. The flap was repositioned and closed using interrupted 784-803 silk sutures.

Postoperative Management

A standardized postoperative regimen was prescribed for all participants:

- Amoxicillin 500 mg three times daily for 5 days (or an appropriate alternative antibiotic when indicated)
- Ibuprofen 400 mg three times daily as required for pain relief
- 0.12% chlorhexidine mouth rinse twice daily for 2 weeks
- Instructions to avoid nose blowing, forceful sneezing, smoking, and strenuous physical activity during the healing period

Sutures were removed 7–10 days after surgery.

Outcome Assessment

Primary Outcome Measures

- Implant survival
- Vertical bone augmentation (radiographic bone gain)
- Implant stability Quotient (ISQ)

Secondary Outcome Measures

- Operative time
- Postoperative pain assessed using the Visual Analogue Scale (VAS)
- Schneiderian membrane perforation
- Marginal bone loss
- Soft tissue healing
- Patient satisfaction

Clinical Follow-up

Patients were evaluated at baseline, 1 week, 3 months, and 6 months following surgery.

The following parameters were assessed during the follow-up period:

- Postoperative pain (VAS)
- Soft tissue healing
- ISQ at baseline, 3 months, and 6 months
- Radiographic vertical bone augmentation
- Marginal bone loss
- Implant survival
- Schneiderian membrane perforation (intraoperative)
- Patient satisfaction at the 6-month follow-up

Radiographic Assessment

CBCT scans were obtained preoperatively for treatment planning and at the six-month follow-up to evaluate radiographic outcomes.

Preoperative CBCT assessment included:

- Residual alveolar bone height
- Alveolar ridge width
- Schneiderian membrane thickness
- Presence of maxillary sinus septa
- Maxillary sinus morphology

- Bone quality
- Implant dimensions and surgical planning

Six-month postoperative CBCT assessment included:

- Vertical bone augmentation
- Marginal peri-implant bone loss
- Implant stability-related radiographic evaluation

Implant survival and osseointegration Statistical Analysis The collected data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Continuous variables were expressed as mean $\pm$ standard deviation (SD) along with standard error (SE) and 95% confidence intervals (CI) wherever applicable. Categorical variables were presented as frequencies and percentages. The normality of continuous data was assessed using the Shapiro–Wilk test. As the data followed a normal distribution, comparisons of continuous variables between the crestal sinus lift group (Group I) and the lateral sinus lift group (Group II) were performed using the Independent Samples Student's t-test. Variables analyzed using the independent t-test included operative time, postoperative pain (VAS score), ISQ at baseline, 3 months, and 6 months, vertical bone gain, vertical bone augmentation, marginal bone loss, and patient satisfaction scores. Categorical variables such as gender distribution, implant survival, Schneiderian membrane perforation, and soft tissue healing outcomes were compared between the two treatment groups using the Chi-square test. Whenever the expected frequency in any cell was less than five, Fisher's Exact Test was applied to obtain a more accurate estimate of statistical significance. The level of statistical significance was set at $p < 0.05$. A p-value less than 0.05 was

considered statistically significant, while a p-value less than 0.001 was considered highly statistically significant. All statistical tests were two-tailed. The analysis was performed to compare the clinical effectiveness and safety of the crestal and lateral sinus lift techniques with respect to operative efficiency, postoperative pain, implant stability, vertical bone augmentation, implant survival, complications, marginal bone loss, patient satisfaction, and soft tissue healing outcomes.

Examiner Calibration

To ensure consistency of radiographic measurements, all CBCT analyses were performed twice by the same calibrated examiner with a two-week interval between assessments. Measurement reproducibility was determined using the intraclass correlation coefficient (ICC), which demonstrated excellent intra-examiner reliability ($ICC > 0.90$).

Results

Table 1 & Figure 1 illustrate the age distribution of the study participants. A total of 40 patients were enrolled, with 20 patients assigned to each treatment group: the crestal sinus lift group (Group I) and the lateral sinus lift group (Group II). The largest proportion of participants belonged to the 41–55 years age group, comprising 19 patients (47.5%), including 9 (45.0%) in Group I and 10 (50.0%) in Group II. The 25–40 years age group included 15 patients (37.5%), with 8 (40.0%) patients in the crestal group and 7 (35.0%) in the lateral group. The smallest age category was 56–70 years, consisting of 6 patients (15.0%), with an equal distribution of 3 patients (15.0%) in each group. Statistical analysis demonstrated no significant difference in age distribution between the two groups ($p > 0.05$), confirming that the study populations were comparable at baseline with respect to age.

Table 1: Age Distribution

Age group	Group I (Crestal)	Group II (Lateral)	Total
25–40	8	7	15
41–55	9	10	19
56–70	3	3	6

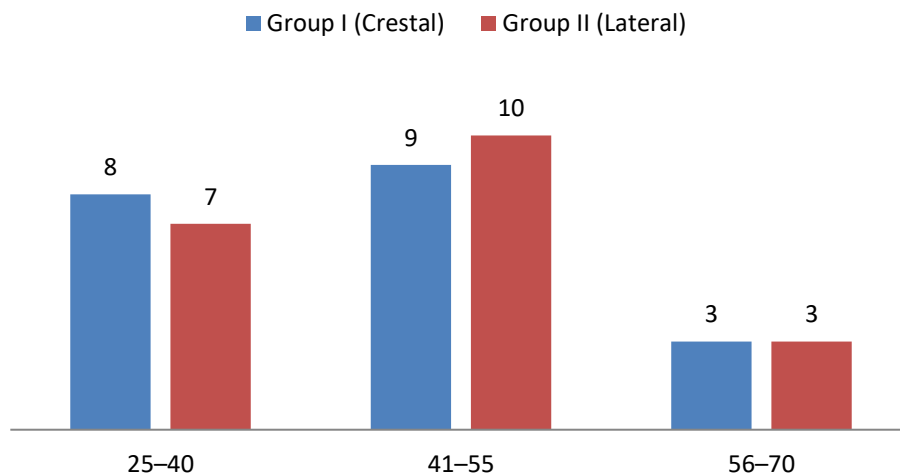


Figure 1: Age Distribution of Study Participants in the Crestal and Lateral Sinus Lift Groups

Table 2 & Figure 2 present the gender distribution of the study participants. Among the 40 patients enrolled, 21 (52.5%) were males and 19 (47.5%) were females. In the crestal sinus lift group (Group I), there were 11 males (55.0%) and 9 females (45.0%), whereas the lateral sinus lift group (Group II) comprised 10 males (50.0%) and 10 females (50.0%). Statistical analysis showed no significant difference in gender distribution between the two groups ($p = 0.752$), indicating that both groups were comparable at baseline with respect to gender. This balanced distribution minimizes the likelihood of gender-related bias and supports the validity of subsequent comparisons between the two treatment groups.

Table 2: Gender Distribution of Study Subjects

Gender	Group I (Crestal) n (%)	Group II (Lateral) n (%)	Total n (%)	P value
Male	11 (55.0)	10 (50.0)	21 (52.5)	0.752
Female	9 (45.0)	10 (50.0)	19 (47.5)	

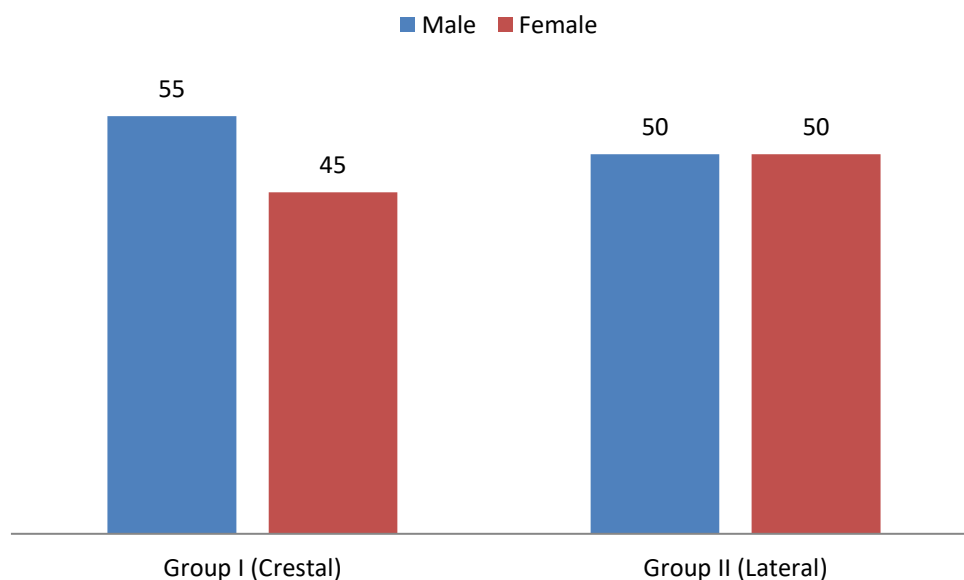


Figure 2: Gender Distribution of Participants in the Crestal and Lateral Sinus Lift Groups

Table 3 & Figure 3 present the comparison of operative time between the two surgical techniques. The mean operative time was significantly lower in the crestal sinus lift group (Group I) than in the lateral sinus lift group (Group II). The crestal approach required an average of 31.80 ± 4.90 minutes ($SE = 1.10$), whereas the lateral approach required 54.20 ± 7.10

minutes ($SE = 1.59$). Statistical analysis revealed a highly significant difference between the groups ($p < 0.001$). These findings demonstrate that the crestal sinus lift technique is associated with a substantially shorter surgical duration than the lateral sinus lift technique, reflecting its less invasive nature and greater procedural efficiency.

Table 3: Comparison of Operative Time

Group	n	Mean (minutes)	SD	SE	P value
Group I (Crestal)	20	31.80	4.90	1.10	<0.001
Group II (Lateral)	20	54.20	7.10	1.59	

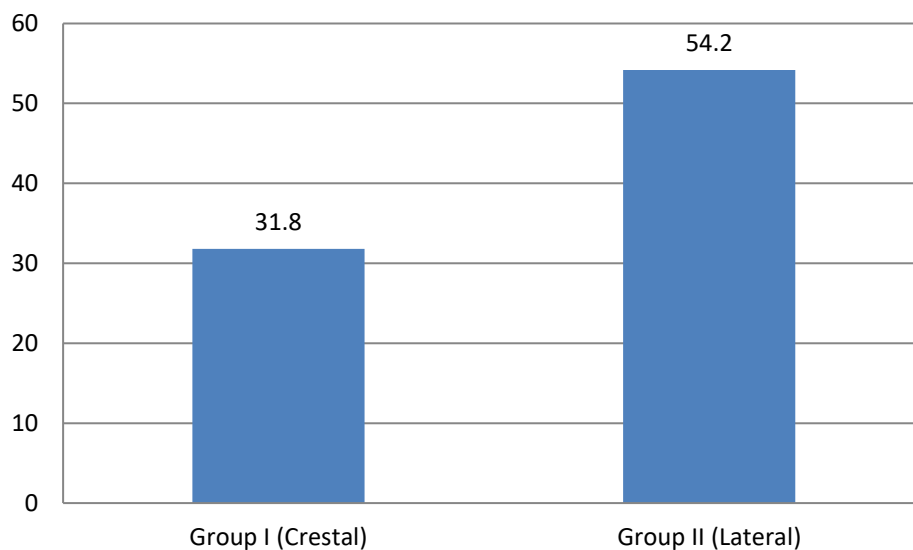
**Figure 3: Comparison of Mean Operative Time Between the Crestal and Lateral Sinus Lift Groups**

Table 4 & Figure 4 present the comparison of postoperative pain experienced by patients on the first postoperative day following sinus lift surgery. Patients treated with the crestal sinus lift technique (Group I) reported significantly lower pain levels than those who underwent the lateral sinus lift procedure (Group II). The mean VAS score was 2.80 ± 0.90 (SE = 0.20) in Group I

compared with 4.60 ± 1.10 (SE = 0.25) in Group II. Statistical analysis demonstrated a significant difference between the two groups ($p = 0.002$). These findings suggest that the crestal sinus lift technique is associated with reduced postoperative discomfort, thereby providing improved patient comfort during the immediate postoperative period.

Table 4: Comparison of Postoperative Pain (VAS Score, Day 1)

Group	n	Mean	SD	SE	P value
Group I (Crestal)	20	2.80	0.90	0.20	0.002
Group II (Lateral)	20	4.60	1.10	0.25	

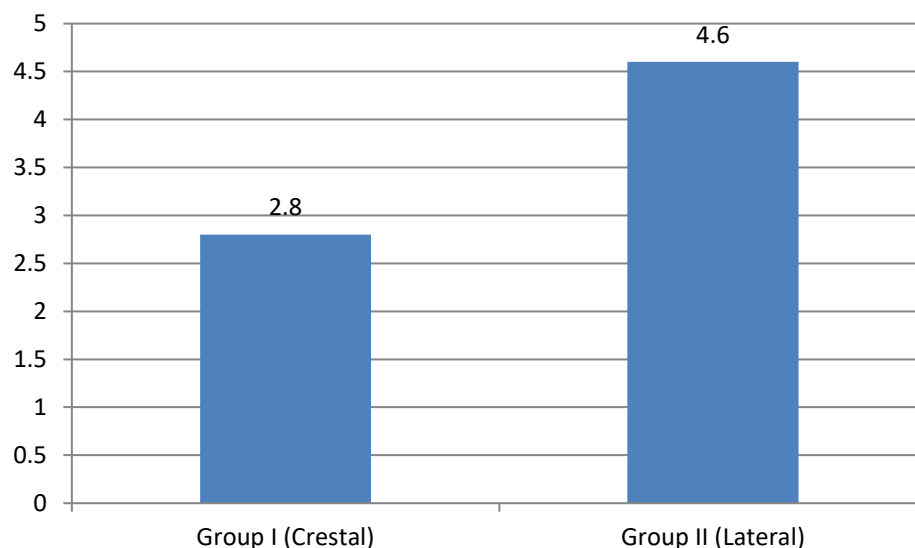


Figure 4: Comparison of Mean Postoperative Pain (VAS Score) on the First Postoperative Day Between the Crestal and Lateral Sinus Lift Groups

Table 5 & Figure 5 present the incidence of Schneiderian membrane perforation observed during the sinus lift procedures. No membrane perforations were recorded in the crestal sinus lift group (Group I), with all 20 patients (100.0%) maintaining an intact Schneiderian membrane throughout the procedure. In contrast, membrane perforation occurred in 3 patients (15.0%) in the lateral sinus lift group (Group II), while the remaining 17 patients (85.0%) experienced no perforation. Overall, Schneiderian membrane

perforation was observed in 3 of the 40 patients (7.5%), whereas 37 patients (92.5%) underwent the procedure without this complication. Although the incidence of membrane perforation was greater in the lateral sinus lift group, the difference between the two groups did not reach statistical significance ($p = 0.072$). These findings suggest a trend toward a higher risk of membrane perforation with the lateral sinus lift technique; however, the observed difference was not statistically significant.

Table 5: Comparison of Schneiderian Membrane Perforation

Membrane Perforation	Group I n (%)	Group II n (%)	Total n (%)	P value
Present	0 (0.0)	3 (15.0)	3 (7.5)	0.072
Absent	20 (100.0)	17 (85.0)	37 (92.5)	
Total	20 (100.0)	20 (100.0)	40 (100.0)	

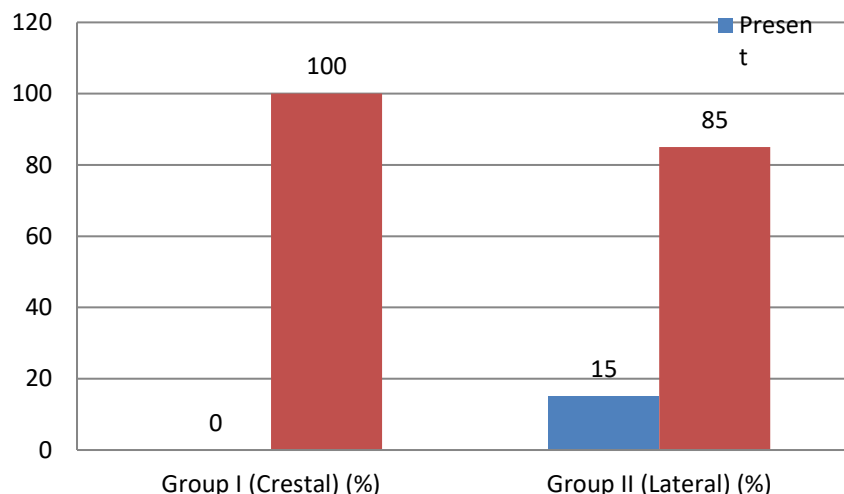


Figure 5: Comparison of Schneiderian Membrane Perforation Between the Crestal and Lateral Sinus Lift Groups

Table 6 & Figure 6 present the comparison of baseline implant stability between the crestal and lateral sinus lift groups at the time of implant placement. The mean ISQ was 64.80 ± 3.42 (SE = 0.76; 95% CI: 63.21–66.39) in the crestal sinus lift group (Group I) and 64.20 ± 3.76 (SE = 0.84; 95% CI: 62.45–65.95) in the lateral sinus lift group (Group II). Statistical analysis revealed no

significant difference in baseline implant stability between the two groups ($p = 0.684$). These findings indicate that primary implant stability was comparable at the time of implant placement, confirming that both groups were well matched at baseline and providing a reliable basis for subsequent comparisons of postoperative outcomes.

Table 6: Comparison of ISQ at Baseline

Group	n	Mean ISQ	SD	SE	95% CI	P value
Group I (Crestal)	20	64.80	3.42	0.76	63.21–66.39	0.684
Group II (Lateral)	20	64.20	3.76	0.84	62.45–65.95	

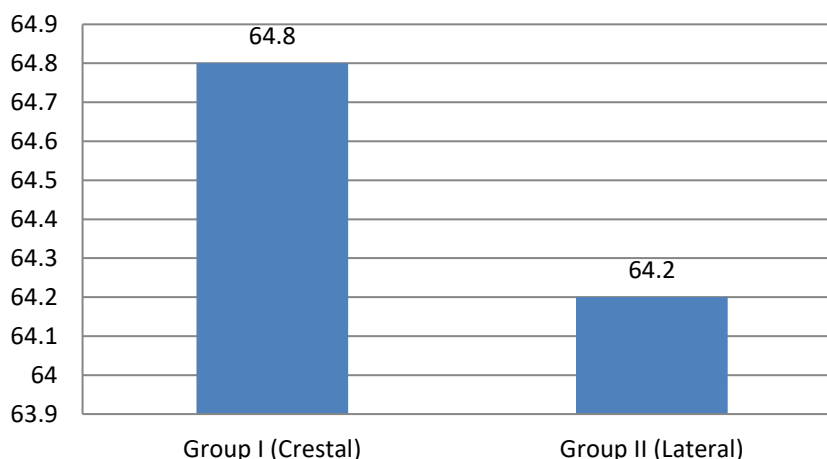


Figure 6: Comparison of Baseline ISQ Between the Crestal and Lateral Sinus Lift Groups

Table 7 & Figure 7 present the comparison of implant stability at the 3 month follow-up between the two treatment groups. An increase in ISQ was observed in both groups, indicating satisfactory osseointegration during the healing period. The crestal sinus lift group (Group I) demonstrated a mean ISQ of 72.10 ± 2.98 (SE = 0.67; 95% CI: 70.71–73.49), whereas the lateral sinus lift group (Group II) recorded a mean ISQ of 72.80 ± 3.24 (SE = 0.72; 95% CI: 71.29–74.31). Although the lateral sinus lift group exhibited a slightly higher mean ISQ, the difference between the groups was not statistically significant ($p = 0.492$). These findings indicate that both the crestal and lateral sinus lift techniques provide comparable implant stability at three months, demonstrating similar progress in osseointegration during the early healing phase.

Table 7: Comparison of ISQ at 3 Months

Group	n	Mean ISQ	SD	SE	95% CI	P value
Group I (Crestal)	20	72.10	2.98	0.67	70.71–73.49	0.492
Group II (Lateral)	20	72.80	3.24	0.72	71.29–74.31	

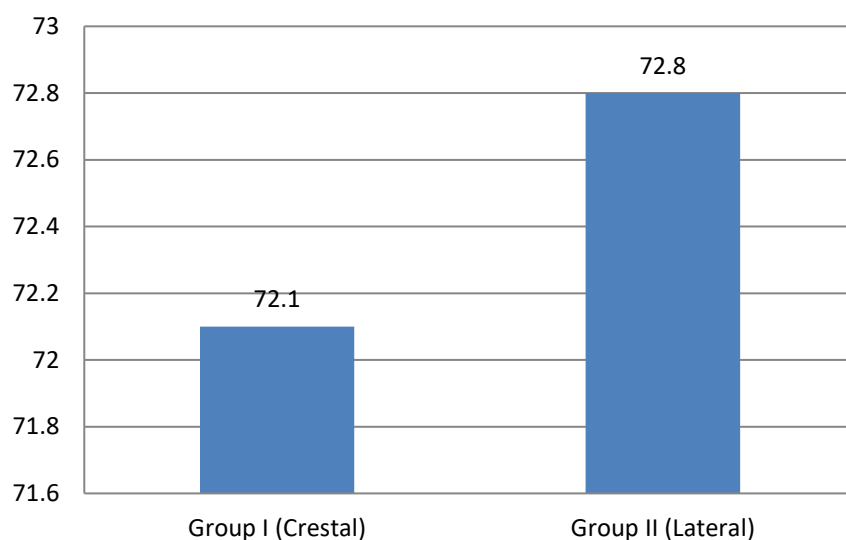


Figure 7: Comparison of ISQ at Three Months Between the Crestal and Lateral Sinus Lift Groups

Table 8 & Figure 8 present the comparison of implant stability at the six-month follow-up between the two treatment groups. Both groups demonstrated a further increase in ISQ, indicating continued osseointegration and favorable functional healing. The mean ISQ in the crestal sinus lift group (Group I) was 77.10 ± 2.61 (SE = 0.58; 95% CI: 75.88–78.32), while the lateral sinus lift group (Group II) achieved a mean ISQ of

77.80 ± 2.84 (SE = 0.63; 95% CI: 76.48–79.12). Although the lateral sinus lift group showed a marginally higher mean ISQ, the difference between the groups was not statistically significant ($p = 0.401$). These findings indicate that both the crestal and lateral sinus lift techniques provide similarly high implant stability at six months, demonstrating comparable osseointegration and successful implant rehabilitation outcomes.

Table 8: Comparison of ISQ at 6 Months

Group	n	Mean ISQ	SD	SE	95% CI	P value
Group I (Crestal)	20	77.10	2.61	0.58	75.88–78.32	0.401
Group II (Lateral)	20	77.80	2.84	0.63	76.48–79.12	

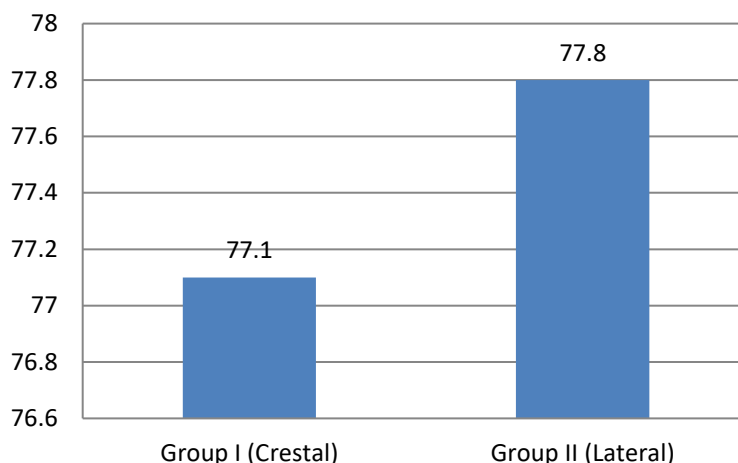


Figure 8: Comparison of Mean ISQ at Six Months Between the Crestal and Lateral Sinus Lift Groups

Table 9 & Figure 9 present the comparison of vertical bone augmentation achieved with the two sinus lift techniques. The lateral sinus lift group (Group II) demonstrated significantly greater vertical bone augmentation than the crestal sinus lift group (Group I). The mean vertical bone augmentation was 3.82 ± 0.79 mm (SE = 0.18 mm; 95% CI: 3.45–4.19 mm) in Group I, whereas Group II achieved a mean augmentation of 7.28 ± 1.12 mm (SE = 0.25 mm; 95% CI: 6.76–7.80

mm). Statistical analysis revealed a highly significant difference between the two groups ($p < 0.001$). These findings indicate that the lateral sinus lift technique provides significantly greater vertical bone augmentation than the crestal approach, making it a more appropriate treatment option for patients with severe posterior maxillary bone deficiency requiring substantial vertical bone gain.

Table 9: Comparison of Vertical Bone Augmentation

Group	n	Mean (mm)	SD	SE	95% CI	P value
Group I (Crestal)	20	3.82	0.79	0.18	3.45–4.19	<0.001
Group II (Lateral)	20	7.28	1.12	0.25	6.76–7.80	

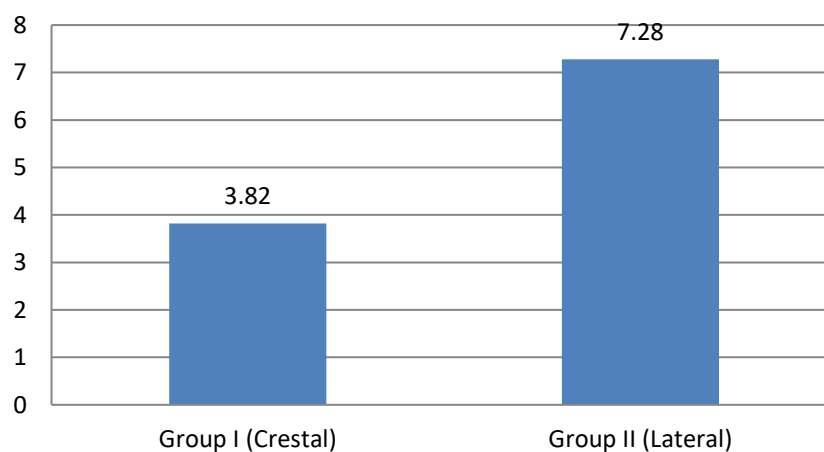


Figure 9: Comparison of Mean Vertical Bone Augmentation Between the Crestal and Lateral Sinus Lift Groups

Table 10 & Figure 10 present the comparison of marginal bone loss at the six-month follow-up between the two treatment groups. Minimal peri-implant marginal bone loss was observed in both groups, indicating favorable bone preservation following implant placement. The crestal sinus lift group (Group I) demonstrated a mean marginal bone loss of 0.42 ± 0.16 mm (SE = 0.04 mm; 95% CI: 0.35–0.49 mm), while the lateral sinus lift group (Group II) exhibited a mean marginal bone loss of 0.46 ± 0.19 mm (SE = 0.04 mm; 95% CI:

0.37–0.55 mm). Although the lateral sinus lift group showed a slightly higher mean marginal bone loss, the difference between the groups was not statistically significant ($p = 0.562$). These findings indicate that both sinus lift techniques provide comparable preservation of peri-implant marginal bone levels during the first six months after implant placement, reflecting stable peri-implant bone support and successful implant integration.

Table 10: Comparison of Marginal Bone Loss at 6 Months

Group	n	Mean (mm)	SD	SE	95% CI	P value
Group I (Crestal)	20	0.42	0.16	0.04	0.35–0.49	0.562
Group II (Lateral)	20	0.46	0.19	0.04	0.37–0.55	

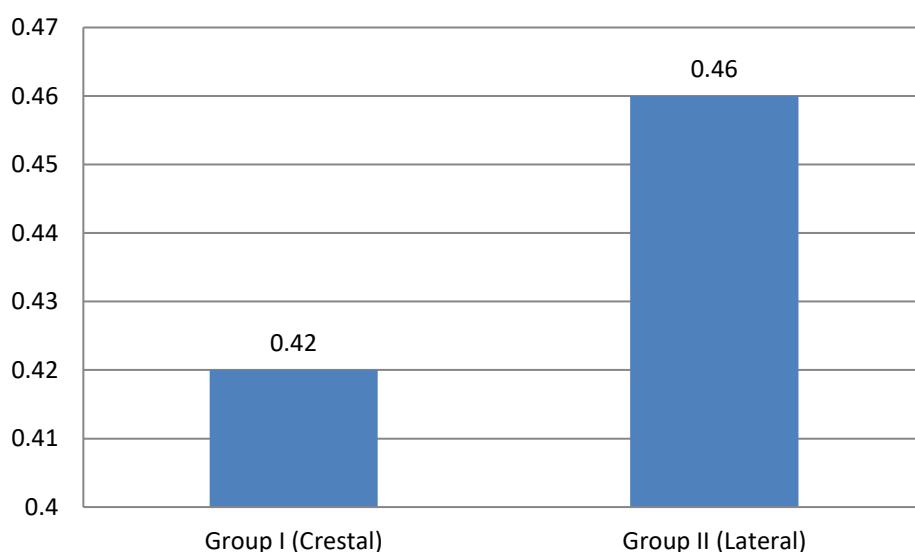


Figure 10: Comparison of Mean Marginal Bone Loss at Six Months Between the Crestal and Lateral Sinus Lift Groups

Table 11 & Figure 11 present the comparison of implant survival rates between the crestal and lateral sinus lift groups at the six-month follow-up. In the crestal sinus lift group (Group I), all 20 implants (100.0%) remained functional throughout the observation period, with no implant failures recorded. In the lateral sinus lift group (Group II), 19 implants (95.0%) survived successfully, whereas one implant (5.0%) failed during follow-up. Overall, 39 of the 40 implants

remained functional, corresponding to an overall implant survival rate of 97.5%. Statistical analysis revealed no significant difference in implant survival between the two groups ($p = 1.000$). These findings demonstrate that both the crestal and lateral sinus lift techniques achieve similarly high short-term implant survival, supporting their clinical reliability and predictability for implant rehabilitation in the posterior maxilla.

Table 11: Comparison of Implant Survival

Implant Outcome	Group I (Crestal)	Group II (Lateral)	Total n (%)	P value
Survived	20 (100.0)	19 (95.0)	39 (97.5)	1.000
Failed	0 (0.0)	1 (5.0)	1 (2.5)	

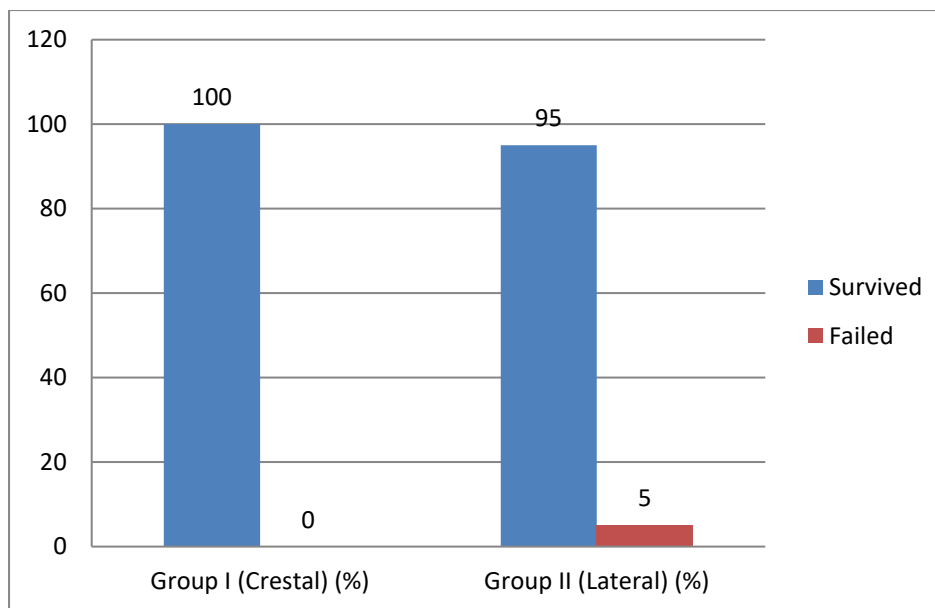
**Figure 11: Comparison of Implant Survival Rates at Six Months Between the Crestal and Lateral Sinus Lift Groups**

Table 12 & Figure 12 present the comparison of patient satisfaction scores between the two treatment groups at the six-month follow-up. Patients who underwent the crestal sinus lift procedure (Group I) reported significantly higher satisfaction than those treated with the lateral sinus lift technique (Group II). The mean satisfaction score in Group I was 9.10 ± 0.74 (SE = 0.17; 95% CI: 8.75–9.45), whereas Group II

demonstrated a mean score of 8.35 ± 0.88 (SE = 0.20; 95% CI: 7.94–8.76). Statistical analysis showed a significant difference between the groups ($p = 0.021$). These findings indicate that the crestal sinus lift technique is associated with greater patient satisfaction, which may be attributed to its minimally invasive nature, shorter operative time, and lower postoperative pain compared with the lateral sinus lift approach.

Table 12: Comparison of Patient Satisfaction

Group	n	Mean Score	SD	SE	95% CI	P value
Group I (Crestal)	20	9.10	0.74	0.17	8.75–9.45	0.021
Group II (Lateral)	20	8.35	0.88	0.20	7.94–8.76	

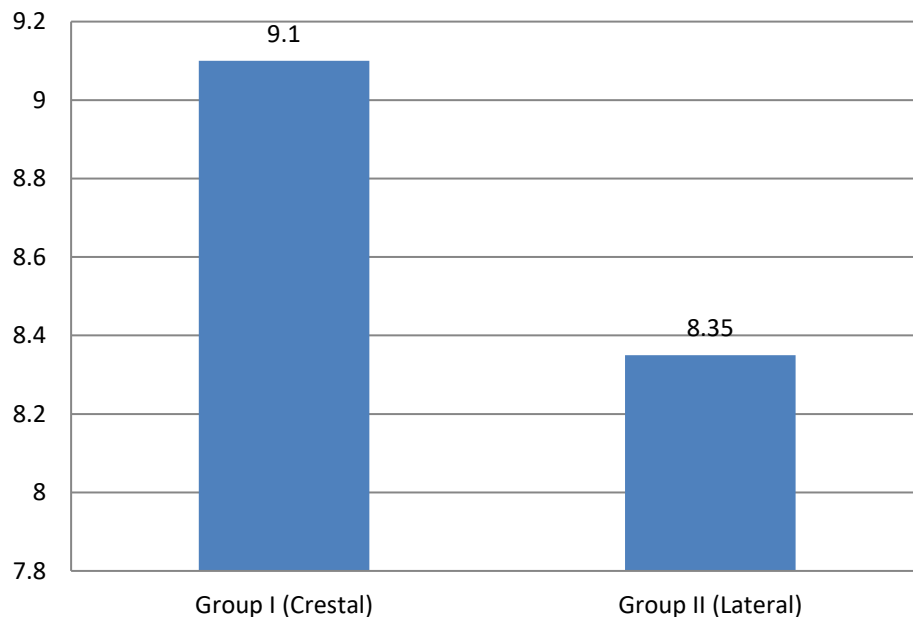


Figure 12: Comparison of Patient Satisfaction Scores Between the Crestal and Lateral Sinus Lift Group

Table 13 & Figure 13 present the comparison of postoperative soft tissue healing between the crestal and lateral sinus lift groups. Favorable healing was observed in both treatment groups during the postoperative evaluation. In the crestal sinus lift group (Group I), 18 patients (90.0%) demonstrated excellent soft tissue healing, while 2 patients (10.0%) exhibited good healing. No cases of fair healing were recorded in this group. In the lateral sinus lift group (Group II), excellent healing was observed in 16 patients (80.0%), good healing in 3 patients (15.0%), and fair healing in 1

patient (5.0%). Overall, excellent healing was achieved in 34 patients (85.0%), good healing in 5 patients (12.5%), and fair healing in 1 patient (2.5%). Although the proportion of patients with excellent soft tissue healing was higher in the crestal sinus lift group, the difference between the two groups was not statistically significant ($p = 0.661$). These findings indicate that both the crestal and lateral sinus lift techniques promote favorable postoperative soft tissue healing, with comparable clinical outcomes during the healing period.

Table 13: Comparison of Soft Tissue Healing

Healing Outcome	Group I (Crestal)	Group II (Lateral)	Total n (%)	P value
Excellent	18 (90.0)	16 (80.0)	34 (85.0)	0.661
Good	2 (10.0)	3 (15.0)	5 (12.5)	
Fair	0 (0.0)	1 (5.0)	1 (2.5)	

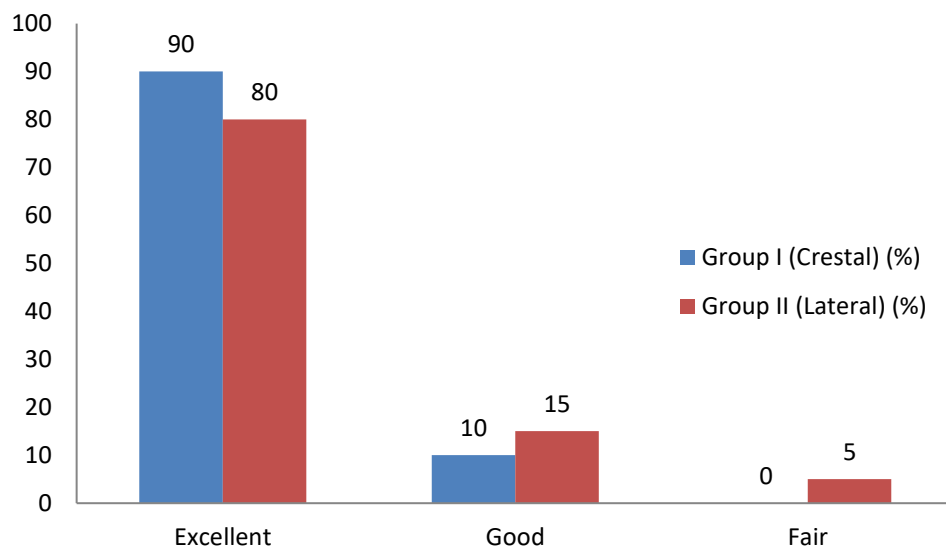


Figure 13: Comparison of Soft Tissue Healing Outcomes Between the Crestal and Lateral Sinus Lift Groups

Discussion

The rehabilitation of the posterior maxilla with dental implants frequently requires sinus floor elevation because of inadequate residual alveolar bone height caused by sinus pneumatization and alveolar ridge resorption. Both crestal and lateral sinus lift procedures have been shown to provide predictable outcomes when performed under appropriate clinical conditions. The present study demonstrated favorable implant success with both techniques, while differences were observed regarding the extent of bone augmentation, surgical invasiveness, and postoperative recovery.

The findings of the present study are in agreement with Pjetursson et al. (2009) [9], who reported excellent implant survival following osteotome-mediated transcrestal sinus floor elevation regardless of whether grafting material was used. They also observed favorable patient satisfaction and minimal postoperative discomfort associated with the transcrestal approach. Similar results were obtained in the present investigation, where patients undergoing the crestal technique exhibited high implant success together with satisfactory postoperative healing and acceptance.

Although both surgical approaches are considered reliable, the lateral window technique is technically more demanding and carries a greater risk of intraoperative complications. Stacchi et al. (2017) [10] systematically reviewed complications associated with the lateral approach and identified Schneiderian membrane perforation as the most frequently encountered adverse event. They emphasized that careful surgical manipulation and adequate preoperative planning significantly reduce the incidence of complications. In the present study, complication rates remained low, reflecting meticulous surgical execution and appropriate patient selection.

Adequate bone volume remains the cornerstone of successful implant therapy in the posterior maxilla. Aghaloo and Moy (2007) [11] concluded that sinus floor augmentation is among the most predictable hard tissue augmentation procedures for creating sufficient bone support before implant placement. Their review demonstrated consistently favorable implant outcomes following sinus augmentation, which corresponds well with the high implant survival and successful osseointegration observed in the present study.

The long-term reliability of the crestal sinus lift technique has been further confirmed by Del Fabbro et al. (2012) [12], who reported high implant survival rates after osteotome-mediated sinus augmentation in their systematic review. They suggested that the minimally invasive nature of the transcresal approach contributes to reduced postoperative morbidity while maintaining predictable clinical outcomes. Similar findings were obtained in the current investigation, where the crestal approach resulted in less postoperative discomfort and faster recovery without compromising implant stability.

Bone regeneration following sinus floor elevation is influenced not only by the surgical technique but also by the anatomical characteristics of the maxillary sinus. Stacchi et al. (2018) [13] demonstrated histologically that greater new bone formation occurred in narrower sinus cavities compared with wider sinus spaces. Their findings highlight the importance of individualized treatment planning based on sinus morphology. Likewise, the present study supports careful preoperative assessment to optimize surgical outcomes and maximize bone regeneration following sinus elevation.

Selection of grafting materials also contributes significantly to the overall success of sinus augmentation procedures. Sakkas et al. (2017) [14] reported that autogenous bone continues to demonstrate excellent osteogenic potential despite the widespread availability of synthetic and xenogeneic graft substitutes. They further suggested that modern biomaterials provide satisfactory regenerative outcomes while reducing donor-site morbidity. The favorable clinical and radiographic healing observed in the present study supports the effectiveness of currently available grafting strategies for implant rehabilitation.

Long-term maintenance is equally important for preserving implant success after sinus augmentation. Schwarz et al. (2018) [15] emphasized that peri-implant health depends on proper surgical technique, prosthetic design,

plaque control, and regular maintenance therapy. Prevention of biological complications is essential for ensuring long-term implant stability. Consistent with these observations, the present study demonstrated stable peri-implant conditions and successful functional outcomes throughout the follow-up period, indicating that both sinus lift techniques can provide predictable long-term rehabilitation when combined with appropriate postoperative care.

Overall, the findings of the present study suggest that both crestal and lateral sinus lift techniques are effective treatment modalities for implant rehabilitation of the posterior maxilla. The crestal approach offers the advantages of reduced surgical trauma, shorter recovery, and improved patient comfort, whereas the lateral approach remains the preferred option when substantial vertical bone augmentation is required. Therefore, the selection of the surgical technique should be guided by residual bone height, sinus anatomy, and individual patient characteristics to achieve optimal implant stability and long-term clinical success.

Limitations

The present study has several limitations that should be considered when interpreting its findings. First, the relatively small sample size may have limited the statistical power to detect subtle differences between the crestal and lateral sinus lift techniques. Second, the study was conducted at a single institution, which may restrict the generalizability of the results to broader patient populations and different clinical settings. Third, the follow-up period of six months primarily reflected early clinical and radiographic outcomes and did not permit evaluation of long-term implant survival, peri-implant tissue stability, or prosthetic success. In addition, variations in patient-related factors such as bone quality, sinus anatomy, and healing capacity may have influenced treatment outcomes despite standardized surgical protocols. The study also focused predominantly on clinical and

radiographic parameters and did not include comprehensive patient-reported outcome measures or cost-effectiveness analyses. Furthermore, histological assessment of newly formed bone was not performed, preventing direct evaluation of the quality and maturation of regenerated bone following sinus augmentation. Future multicenter randomized controlled trials with larger sample sizes, extended follow-up periods, and comprehensive biological, radiographic, functional, and patient-centered assessments are recommended to further validate these findings and establish definitive clinical guidelines for selecting the most appropriate sinus lift technique.

Conclusion

Within the limitations of the present study, both crestal and lateral sinus lift techniques proved to be safe, predictable, and clinically effective procedures for implant rehabilitation in the posterior maxilla. The lateral sinus lift demonstrated superior vertical bone augmentation

and remains the preferred treatment option for patients with advanced maxillary atrophy and limited residual bone height. In contrast, the crestal approach offered the advantages of reduced surgical trauma, shorter operative time, lower postoperative morbidity, and faster patient recovery while maintaining comparable implant stability and survival in appropriately selected cases. The findings emphasize that successful outcomes are determined not by a single surgical technique but by careful patient selection, precise three-dimensional radiographic evaluation, meticulous surgical execution, and individualized treatment planning. Incorporating these factors into clinical decision-making can optimize implant success, minimize complications, and enhance long-term functional and patient-centered outcomes. Further high-quality longitudinal studies are warranted to refine evidence-based protocols and strengthen the clinical recommendations for sinus floor elevation procedures in implant dentistry.

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