Clinical and Radiographic Evaluation of Maxillary Sinus Augmentation using Apatite Carbonate with or without Platelet Rich Fibrin with Simultaneous Dental Implant Placement: A Randomised Study

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Abstract

Background: The absence of posterior maxillary teeth can cause alveolar bone resorption and maxillary sinus pneumatization, bone height reduction, and implant placement difficulty. Maxillary sinus floor augmentation (MSFA) using lateral approach is an effective technique for the regeneration of vertical bone height. Due to its osteoconductive potential and stark chemical resemblance to natural bone, Carbonate apatite (CO_3Ap) has emerged as an excellent alloplastic graft substitute. Platelet-Rich Fibrin (PRF), an advanced autologous platelet concentrate, fosters bone regeneration, soft tissue restoration, and blood vessel formation. The aim of the present study is to evaluate clinically and radiographically sinus augmentation using apatite carbonate graft and simultaneous implant placement with or without the addition of PRF to enhance bone formation around the dental implants.

Methods: The present study was designed as a randomized controlled split-mouth clinical study and included eight systemically healthy edentulous patients in the posterior maxilla. Group I (Control group): Comprised eight implants placed in the edentulous posterior maxilla with simultaneous sinus augmentation (lateral approach) using carbonate apatite alone, without the addition of PRF. Group II (Study – PRF group): Comprised eight implants placed in the contra-lateral edentulous posterior maxilla with simultaneous sinus augmentation (lateral approach) using carbonate apatite combined with autologous PRF. Clinical evaluations recorded included: surgical time factor, pain, edema, and post operative complications assessed on the first, third and seventh day postoperatively, additionally, implant stability was measured immediately after implant placement, then, six months postoperatively. Along with relative bone density, vertical bone gain in the maxillary sinus floor was radiographically evaluated at baseline and six months postoperatively using CBCT.

Results: Both groups showed significant reductions in pain and swelling postoperatively ($P < 0.05$). The study group demonstrated significantly greater bone density ($P = 0.017$) and implant stability after six months ($P = 0.002$). Vertical bone gain, although slightly greater in the PRF group, showed no statistically significant difference ($P = 0.161$).

Conclusions: Apatite carbonate bone graft is a promising material for bone grafting especially in maxillary sinus augmentation. PRF is a simple, autologous, and cost-effective adjunct that can be safely integrated with synthetic grafts such as apatite carbonate. The addition of PRF to apatite carbonate in maxillary sinus augmentation with simultaneous implant placement result in improved osseointegration and promotes bone healing around dental implants.

Trial Registration: PACTR202509825697094 (Registration date: September 9, 2025), Retrospectively registered.

Keywords: Carbonate apatite, Platelet-Rich Fibrin, sinus augmentation, bone density and implant stability are the main keywords.

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Background

The absence of posterior maxillary teeth often leads to alveolar ridge resorption and increased pneumatization of the maxillary sinus, diminishing remaining bone height and constraining the viability of implant implantation without augmentation [1]. Maxillary sinus floor augmentation (MSFA) is a reliable surgical procedure designed to restore vertical bone volume, facilitating the placement of implants with sufficient primary stability. Two primary methodologies are employed: the lateral window technique, favored for significant augmentation, and the trans-crestal (osteotome) technique for minor enhancements when residual bone height is enough. [2]

Autogenous bone has traditionally been regarded as the benchmark graft material owing to its osteogenic, osteo-inductive, and osteoconductive characteristics. Nonetheless, its drawbacks, such as donor site morbidity, restricted volume, and unpredictable resorption, have prompted the adoption of bone substitutes [3]. Among alloplastic alternatives, carbonate apatite (CO_3Ap) closely mimics the mineral composition of human bone, exhibits significant osteo-conductivity, and experiences progressive resorption followed by substitution with new bone. Histological and clinical investigations indicate that CO_3Ap ensures constant graft volume, predicted osseous development, and advantageous integration in both staged and simultaneous sinus augmentation techniques [4].

In addition to scaffold selection, physiologically active adjuncts have been explored to improve healing. Platelet-Rich Fibrin (PRF) is a second-generation platelet concentrate obtained from the centrifugation of autologous blood devoid of anticoagulants. It comprises a fibrin network that ensnares platelets, leukocytes, and various growth factors released gradually during the healing process, facilitating angiogenesis, soft tissue repair, and initial osteogenesis [5].

Numerous clinical trials have investigated the use of PRF in sinus augmentation, either as the exclusive filler material or in conjunction with bone grafts. PRF has been documented to expedite bone maturation, augment early radiographic density, and bolster initial implant durability. Meta-analyses indicate that PRF may additionally enhance soft tissue healing and augment bone density in the initial phases; nevertheless, the evidence for substantial long-term benefits regarding new bone volume, vertical bone gain, or implant survival remains equivocal [6].

Considering CO_3Ap's scaffold potential and PRF's biological activity, assessing their combined application in sinus augmentation is clinically pertinent. This study aims to compare the clinical and radiographic outcomes of simultaneous implant insertion and sinus augmentation using CO_3Ap, with or without PRF, by evaluating bone density, vertical bone gain, implant stability, and postoperative recovery over a six-month period.

Materials and Methods

Study design and settings

The design of present study was interventional prospective clinical randomized controlled study. The study was conducted on eight patients seeking implant placement to restore their missing bilateral maxillary posterior teeth. Patients were selected from those attending the outpatient clinic of the Oral and Maxillofacial Department, Faculty of Dentistry, Suez Canal University after the approval of the Research Ethics Committee (REC) of the Faculty of Dentistry, Suez Canal University with approval number (828/2024). The trial was registered on PACTR registry number: **PACTR202509825697094**.

Ethical Consideration

The techniques and follow-up assessments were explained to the patients, who signed an informed consent after the approval of the Research Ethics Committee (REC) of Suez canal university number: 828/2024 following the guidelines of the Declaration of Helsinki (1975, revised 2013).

Sample Size Calculation:

Sample size calculation was performed using G*Power version 3.1.9.2. [7] The effect size conventions (d) were 1.80 (large) based on mean difference of sample size calculation was based on mean difference of retrieved from previous research by Kudoh et al. ([8] using alpha (α) level of 0.05 and Beta (β) level of 0.05, i.e., power = 80%; the estimated sample size (n) should be 16 implants and will be divided equally 8 implants in each group.

Eligibility criteria

Patients participating in this study were chosen to fulfill the following criteria [9-11]:

Inclusion criteria

Both genders, patients who agreed to follow all study procedures and provided written consent, aged between 30 to 55 years, healthy patients with type I American Society of Anesthesiologists (ASA) classification, patients with partial edentulism in the posterior region of the maxilla bilaterally and the edentulous sites consist of native non augmented bone, with horizontal ridge dimension minimum of 5mm, vertical ridge dimension less than 5mm, bone quality of D2 or D3 (as revealed form pre-operative CBCT) and enough inter-arch distance [12].

Exclusion criteria

Exclusion criteria included heavy smoking (>10 cigarettes/day), history of alcohol abuse, uncooperative patients, patients with active acute infection or residual lesion related to the edentulous sites, patients with maxillary sinus pathosis, patients with remaining root dislodged in the maxillary sinus, patients that lack a stable occlusion or has parafunctional habits and patients with poor oral

hygiene that are not amenable to motivation and improvement [4].

Patient Grouping

A total of 16 dental implants were placed, with one implant inserted in each maxillary quadrant. The side allocation for each treatment modality was determined by simple randomization using a computer-generated random sequence from www.randomizer.org. The implants were divided as follows:

Group I (Control group): Comprised eight implants placed in the edentulous posterior maxilla with simultaneous sinus augmentation (lateral approach) using carbonate apatite alone, without the addition of PRF.

Group II (Study – PRF group): Comprised eight implants placed in the contralateral edentulous posterior maxilla with simultaneous sinus augmentation (lateral approach) using carbonate apatite combined with autologous PRF.

Both procedures were performed under standardized surgical protocols by the same surgical team to ensure consistency in technique and minimize operator-related bias. Postoperative care, follow-up schedules, and evaluation methods were identical for both groups to allow valid comparison of clinical and radiographic outcomes.

Methods

Presurgical phase:

A comprehensive clinical and radiographic examination was conducted for each patient, including detailed recording of personal, medical, and dental history. The surgical procedures, possible complications, and the need for photographs and CBCT follow-ups were thoroughly explained to all participants. Preoperative CBCT scans of the maxillary sinus and maxillary arch were obtained using the Scanora 3D imaging system (Sordex, Finland) at DentSCAN center in Ismailia, with standardized exposure parameters (10 mA, 90 kVp, 0.5 mm focal spot, 14 s scan time, 3.2 s effective exposure, FOV 14 × 16.5 cm). The acquired DICOM data were reconstructed and analyzed using On-Demand software (Cybermed, Korea) to assess bone quantity, quality, and anatomical relationships, ensuring implant site eligibility and detecting any carious or pathological conditions requiring treatment. Impressions were also taken to fabricate study casts for treatment planning and to replicate natural dentition.

Surgical phase:

All surgical procedures for both groups were conducted under local anesthesia and strict aseptic conditions at the Oral and Maxillofacial Surgery outpatient clinic, Faculty of Dentistry, Suez Canal University, by the same surgeon and surgical team to ensure consistency of the surgical technique. Patients rinsed with 0.1% chlorhexidine and had the perioral area disinfected with 10% povidone-iodine before surgery. Local anesthesia was achieved using 4% articaine with 1:100,000 epinephrine via buccal, palatal, and infraorbital nerve infiltration. A crestal incision with a distal vertical release allowed elevation of a full-thickness flap for optimal visibility and access to the alveolar ridge and lateral sinus wall [9]. A lateral window osteotomy was prepared using a DASK #5 drill, and the sinus membrane was carefully elevated without perforation. Apatite carbonate bone graft mixed with saline was condensed along the sinus walls, followed by placement of an implant of appropriate dimensions determined by preoperative CBCT [10]. **Figure (1,2)**

The remaining sinus space was filled with bone graft around the implant, and the flap was sutured using 3-0 silk sutures. **Figure (3)**

The total surgical time was recorded from the start of anesthesia to the end of suturing using a stopwatch [11].

For the study group, platelet-rich fibrin (PRF) was prepared by collecting 10 mL of venous blood from each patient into two sterile glass-coated vacutainer tubes without anticoagulants to allow natural coagulation. The tubes were centrifuged at 4000 rpm for 6 minutes at the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Suez Canal University. This process separated the blood into three layers: a red lower layer of red blood cells, an upper straw-colored plasma layer, and a middle fibrin clot layer. The upper plasma was discarded, and the middle PRF layer was collected approximately 2 mm above the red cell layer [12]. **Figure (4)**

The surgical steps were identical to those of the control group; however, in the study group, the bone graft granules were hydrated with saline, mixed with the PRF, and condensed in the sinus cavity, followed by the placement of PRF over the graft to cover the lateral window before suturing. **Figure (5,6)**

Similarly, the total surgical time, from anesthesia induction to end of suturing, was recorded using a stopwatch [13].

Post-operative phase:

Postoperative care included informing all patients about possible facial swelling, pain, and trismus, and providing detailed instructions to promote healing. Patients were advised to bite on sterile gauze for one hour, avoid rinsing or spitting for 24 hours, and if bleeding persisted, to bite on fresh gauze for an additional two hours. They were also instructed to avoid hot or hard foods and smoking, with sutures scheduled for removal after seven days. Postoperative medications for both groups included Amoxicillin with Clavulanic acid (1 g every 12 hours for 7 days), Metronidazole (500 mg every 8 hours for 7 days), Acetaminophen as needed for pain, and 0.12% Chlorhexidine mouthwash (15 mL twice daily starting 8 hours after surgery for 7 days).

Methods of Post-operative Evaluations

Clinical and radiographic assessments were conducted to evaluate postoperative outcomes. Clinically, all patients were recalled after 7 days for suture removal and at 1-, 3-, and 7-days post-surgery to assess: 1) Pain: using a Visual Analog Scale (VAS) from 0 (no pain) to 10 (severe pain). 2) Edema: was graded visually from 1 (none) to 4 (severe). 3) Intra- and postoperative complications, including Schneiderian membrane perforation, bleeding, epistaxis, sinusitis, and peri-implantitis, were recorded. 4) Surgical time was measured from start of anesthesia injection to the end of final suture. 5) Implant stability was evaluated immediately after placement then after 6 months using Osstell device. Radiographically, all patients underwent CBCT 6 months postoperatively to assess: 1) Bone density: analyzed around each implant 0.5 mm distal to the threads using OnDemand3D™ software, comparing pre- and postoperative values through fusion of both images. 2) Vertical bone height gain in the maxillary sinus floor was determined by superimposing the preoperative and postoperative CBCT scans using images with the same voxel size and orientation parameters. Measurements were taken from the alveolar bone crest to the most elevated point of the augmented sinus floor adjacent to the implant site, on both buccal and palatal aspects, and the difference between the pre- and postoperative values represented the gained bone height **Figures (7,8)** [14].

Statistical analysis

All data was sorted and structured in tabular forms which was then used for statistical analysis on SPSS version 26.0 (IBM Corp, Armonk, NY). The normality of the data set was evaluated by calculating the Shapiro-Wilk test. All quantitative measurements were the descriptive statistical data expressed as mean and standard deviation (SD) and the range (maximum-minimum). For the qualitative variables, values were dished out as frequencies and percentages. For the independent comparative analysis of the two groups, the student's t-test was used for the data which followed a normal distribution, and the Mann-Whitney test for data which did not follow normal distribution. Any p-value of lower than 0.05 was considered to be statistically significant.

Results

Results of the present study are presented as:

Demographic data:

Demographic data of the patients participating in the study showed that the study sample included 8 patients, 7 males (87.5%) and 1 female (12.5%) with a mean age of 45 ±5.2 years, and a minimum of 39 and a maximum of 53 years old.

Results of clinical assessment:

Pain measurements by (VAS) score:

Table 1 represents changes in pain (VAS) scores within each group and comparison between both groups throughout follow-up period. In both the control group and the study group, a statistically significant reduction in mean pain scores was observed over the postoperative assessment period (P= 0.024*and 0.004*in the study and control groups respectively). However, at all evaluated time intervals; day 1, day 3, and day 7, there was no statistically significant difference in mean VAS scores between the control and study groups.

Comparison of the edema score at different times

Table 2 represent changes in edema scale within each group and comparison between both groups throughout the assessment period. In both groups, there was a statistically significant reduction in edema scores postoperatively (P = 0.001). At all assessment points; day 1, day 3, and day 7, there was no statistically significant differences in mean edema scores between the control and study groups.

Surgical Time Factor:

The mean surgical time was 43.25 ± 3.10 minutes in the control group and 52.63 ± 2.85 minutes in the study group. The difference in mean surgical time between groups was statistically significant (P = 0.004).

Comparison of the implant stability at different times

In the control group, implant stability values (ISQ scores) showed a slight increase after six months compared to immediate postoperative measurements; however, this change was not statistically significant (P = 0.157). While in the study group, implant stability demonstrated a statistically significant improvement after six months (P = 0.027), indicating progressive osseointegration over the follow-up period. At both assessment time-points, immediately postoperatively and after six months, the study group exhibited statistically significantly higher implant stability compared to the control group. (**Table 3)**

Results of radiographic assessment

Bone density:

Table 4 represent the changes in bone density values within each group at the radiographic assessment times and comparison between both groups. In both groups, bone density values demonstrated a statistically significant increase after six months compared to preoperative measurements (P = 0.012 for both groups). Preoperatively, there was no statistically significant difference in bone density between the two groups (P = 0.069). However, after six months, the study group exhibited statistically significantly higher mean bone density compared to the control group (P = 0.017).

Vertical bone height gained in maxillary sinus floor:

Table 5 represents the vertical bone gain in maxillary sinus floor after six months and comparison between both groups. Bone height gain was calculated as the difference between bone height measurements at base line and after six months. Although vertical bone gain after six

months was slightly greater in the PRF group (3.04 mm) in comparison to the control group (2 mm); however, this difference was not statistically significant (P = 0.161).

Discussion

Sinus augmentation in the atrophic posterior maxilla remains challenging due to reduced bone height and limited ideal graft materials. Carbonate apatite offers bone-like properties and controlled resorption, while PRF may enhance early healing and bone formation. Yet, evidence on their combined use during simultaneous sinus augmentation and implant placement is still limited. This study therefore aimed to compare clinical and radiographic outcomes of sinus augmentation using CO_3Ap with or without PRF addition, focusing on assessment of bone density changes, vertical bone gain in in the maxillary sinus floor and implant stability over a period of six months.

To reduce inter-patient variability while allocating precise intra-patient comparison, this study employed an interventional split-mouth design with eight patients who had bilateral missing maxillary posterior teeth receiving a total of sixteen dental implants. As in Nizam et al. [15], Barbu et al. [16], and Pichotano et al. [17], this design allowed to study the impact of PRF on sinus augmentation outcomes without individual variations in healing. Systemically healthy patients with good oral hygiene and no history of smoking were selected which is in agreement with the inclusion criteria set forth in the research conducted by Heitz-Mayfield et al. [18] to serve as 'control'. The use of CBCT allowed for the visualization of the sinus anatomy and the bone quality which provided clarity for the preoperative assessment and the surgical plan. For reproducible and quantitative data, the OnDemand3D™ software was used to objectively evaluate the changes in bone density around the implant and bone gain in in the maxillary sinus floor after implant insertion.

Ostell employs a non-invasive procedure in assessing post-insertion stability of dental implants based on resonance frequency analysis (RFA). It provides a unit value of the ISQ which assists the clinician in determining the osseointegration, strategic evaluation, and timing of the load to the implant that can be utilized [17-19].

Results of the present study revealed significant improvement and decrease of postoperative pain and edema throughout the follow up period in both groups, however the difference between both groups was statistically insignificant. These findings are concomitant with those of Gurler & DelilbaSi [16], who found that while PRF provided gradual improvements in patients discomfort after sinus lifting, these differences were not statistically significant in comparison to their control group.

On the other hand, several studies partially disagreed with these results. Of these studies, Malcangi et al., [11] who reported that PRF significantly reduced inflammation and postoperative pain. These divergent findings may be contributed to the influence of variations in surgical techniques, individual pain thresholds, and subjective reporting.

Regarding intra or post operative complications, no major complications were recorded in both groups except one case in study group of Schneiderian membrane perforation that was successfully managed. In agreement with our results, several studies have reported minimal or no intra or postoperative complications, specifically membrane perforations during sinus lift procedures involving PRF. Nizam et al. [15], Barbu et al. [16], and Karagah et al. [20] emphasized PRF's role in sealing and reinforcing the sinus membrane, enhancing surgical outcomes.

Importantly, no cases of intraoperative bleeding, postoperative epistaxis, or sinusitis were observed, whereas previous studies have documented intraoperative vascular bleeding as mentioned by Hong & Mun [21] and postoperative sinusitis reported by Fischer et al. [22] as occasional complications following sinus augmentation, particularly in patients with pre-existing sinus disease.

Similarly, peri-implantitis was not detected in our short-term follow-up, although recent reviews suggest a potential association between implant-related infections and sinus membrane pathology in augmented sinuses as reported by Iușan et al. [23].

The surgical time in the present study was significantly longer in the study group compared to the control group, a finding attributable to the additional steps required for PRF preparation and application. Similar observations have been reported in a previous clinical study by Liu et al. [24] where adjunctive biologic materials were incorporated into sinus augmentation protocols, resulting in modest increases in operative duration without adversely affecting outcomes. However, Karagah et al. [20] stated that the potential biological benefits of PRF, such as improved soft tissue healing and accelerated bone maturation, may outweigh the minor increase in operative time.

A significant finding of this study was the improved implant stability (higher ISQ values) in the PRF group. This observation is in agreement with the results of Karagah et al. [20] and Babich et al. [25], who reported statistically higher ISQ values in PRF-treated sites at multiple time points.

The higher immediate post-operative implant stability (ISQ) values in the study group could be explained by the fact that PRF when tightly packed into the graft, it filled all the spaces between the graft and the implant acting as a mesh, therefore it increased the volume of the graft and induced resistance around the implant part inside the sinus

cavity, affecting the ISQ and increasing its value [26-29].

In contrast, Pichotano et al. [17] found no statistically significant differences in ISQ between PRF and non PRF groups when added to allogenous bone graft for direct sinus lifting through a lateral window. These variation in outcomes may be due to differences in the implant system, measurement protocols, or PRF quality and handling.

Implant stability was assessed using resonance frequency analysis (RFA), which provides quantitative Implant Stability Quotient (ISQ) values reflecting the stiffness of the bone–implant interface and the degree of osseointegration. RFA has been validated as a reliable, non-invasive method for monitoring both primary and secondary implant stability over time, with higher ISQ values indicating greater stability and improved bone–implant contact. Meredith et al. [30] demonstrated that ISQ measurements correlate strongly with implant anchorage and peri-implant bone quality, making them suitable for longitudinal evaluation following sinus augmentation procedures. Furthermore, Sennerby and Meredith [31] emphasized that changes in ISQ values during healing reflect biological events at the implant interface rather than mere mechanical fixation, supporting their use in assessing treatment-related differences such as the adjunctive application of biologic materials. Consequently, ISQ values are widely accepted as an objective clinical parameter for comparing implant stability outcomes in sinus floor augmentation with simultaneous implant placement.

The present study demonstrated statistically significant increase in bone density at six months in both the control and the PRF group with the study group (PRF group) exhibiting more pronounced increase in bone density compared to the control group ($p = 0.012$). This finding agreed with previous studies such as Ghanaati et al. [26] who reported enhanced bone density when PRF was combined with deproteinized bovine bone. Similarly, Francisco et al. [27] observed a significant improvement in the percentage of mineralized tissue in the PRF-treated group compared to the controls.

In contrast, Liu et al. [24] and Meng et al. [28] presented opposing results. Their meta-analyses concluded that autologous platelet concentrates (APCs) provided no statistically significant benefit in bone density or new bone formation when used with grafting materials. The discrepancy may stem from the heterogeneity of included graft materials, PRF protocols, and evaluation periods in these analyses.

Regarding vertical bone height, although both groups showed increased bone height in maxillary sinus floor with time, confirming that both grafting approaches effectively enhanced vertical bone gain in augmented sinus, the difference between the two groups was insignificant. This result is concomitant with findings from Nizam et al. [15] and Pichotano et al. [17], who similarly reported no significant difference regarding augmented bone height or volume between their study groups, despite observing some histological benefits in the PRF groups. In agreement, our results indicated comparable final postoperative outcomes in terms of vertical bone gain.

On the other hand, Francisco et al. [29] reported significantly increased mineralized tissue in the PRF group, which could be interpreted as an indirect indicator of vertical gain. Nonetheless, the current consensus in many CBCT-based studies supports our finding that PRF's influence on vertical bone height may be limited in the short term. [29]

Study limitations

Despite the lack of statistically significant differences in several parameters, the trends observed support the clinical usefulness of PRF in sinus augmentation. The increase in bone density and ISQ in the PRF group suggests improved osseointegration, potentially allowing for earlier or more predictable implant loading. However, the small sample size, short follow-up duration, and lack of histological evaluation are key limitations of the present study.

Conclusions

Apatite carbonate bone graft is a promising material for bone grafting, especially in maxillary sinus augmentation. PRF is a simple, autologous, and cost-effective adjunct that can be safely integrated with synthetic grafts such as apatite carbonate. The addition of platelet-rich fibrin (PRF) to apatite carbonate in maxillary sinus augmentation with simultaneous implant placement results in improved osseointegration and promotes bone healing around dental implants, which may lead to earlier implant loading and restoration of function and esthetics therefore, improving patient satisfaction and contentment.

Declarations:

Human Ethics and Consent to Participate

The techniques and follow-up assessments were explained to the patients, who signed an informed consent after the approval of the Research Ethics Committee (REC) of Suez Canal University number: 828/2024 following the guidelines of the Declaration of Helsinki (1975, revised 2013).

Ethics Approval declaration

Approval of the Research Ethics Committee (REC) of Suez Canal University number: **828/2024**.

Consent for publication: Not applicable.

Availability of data and materials

The datasets generated or analyzed during this study are not publicly accessible but can be obtained from the corresponding author upon request.

Declaration of Competing Interest

The authors declare no known financial or personal conflicts of interest that could have affected the research described in this study.

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Authors' contribution:

All authors contributed to the study conception and design. Material preparation were performed by Ahmed Younis.The first draft of the manuscript was written by Mostafa Qamar and all authors commented on previous versions of the manuscript.

Patient selection: Mohamed Hamed.

Surgical procedures: Ahmed Younis, Mostafa Qamar.

Clinical assessment: Mostafa Qamar.

Radiographic analysis: Gihan El-desouky, Mostafa Qamar.

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Table 1: Changes in pain (VAS) scores within each group and comparison between both groups

Time	Study (n= 8)		Control (n = 8)		P-value	Effect size (d)
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
1 day	1.5 (1, 4) [A]	2 (1.31)	2 (1, 5) [A]	2.5 (1.41)	0.157	0.5
3 days	1 (1, 2) [B]	1.25 (0.46)	1 (1, 3) [B]	1.63 (0.92)	0.180	0.474
7 days	1 (1, 1) [B]	1 (0)	1 (1, 2) [B]	1.25 (0.46)	0.157	0.5
P-value	**0.024***		**0.004***			
Effect size (w)	0.464		0.696			

*: Significant at P ≤ 0.05, Different superscripts within the same column indicate statistically significant change by time

Table 2: Changes in edema scale within each group and comparison between both groups

Time	Study (n= 8)		Control (n = 8)		P-value	Effect size (d)
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
1 day	2 (2, 3) [A]	2.13 (0.35)	2.5 (2, 3) [A]	2.5 (0.53)	0.083	0.612
3 days	1 (1, 2) [B]	1.25 (0.46)	2 (1, 2) [B]	1.63 (0.52)	0.083	0.612
7 days	1 (1, 1) [B]	1 (0)	1 (1, 2) [B]	1.13 (0.35)	0.317	0.354
P-value	**0.001***		**0.001***			
Effect size (w)	0.875		0.875			

*: Significant at $P \leq 0.0$

Table 3: Changes within each group regarding implant stability (ISQ scores) and comparison between both groups

Time	Study (n= 8)		Control (n = 8)		P-value	Effect size (Partial Eta squared)
	Mean	SD	Mean	SD		
Immediate post-operative	82.6	14.6	72	14.8	**0.030***	0.512
6 months	87.5	9.2	82.4	9.1	**0.002***	0.775
P-value	0.157		**0.027***			
Effect size (Partial Eta squared)	0.264		0.527			

*: Significant at P ≤ 0.0

Table 4: Changes in bone density values within each group at the radiographic assessment times and comparison between both groups

Time	Study (n = 8)		Control (n = 8)		P-value	Effect size (d)
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Pre-operative	161 (30.9, 359.3)	176.8 (115.6)	93.2 (68.1, 156)	101.1 (34)	0.069	0.643
6 months	379.7 (180.5, 711.9)	381.8 (160.9)	269.8 (177.4, 713.3)	319.1 (179.5)	**0.017***	0.841
P-value	**0.012***		**0.012***			
Effect size (d)	0.891		0.891			

*: Significant at P ≤ 0.0

Table 5: Vertical bone gain after six months (mm) and comparison between both two groups

	Study (n = 8)		Control (n = 8)		P-value	Effect size (d)
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Vertical bone Gain	2.95 (1.88, 5.24)	3.04 (1.04)	1.8 (0.42, 5.02)	2 (1.45)	0.161	0.495

: Significant at P ≤ 0.0

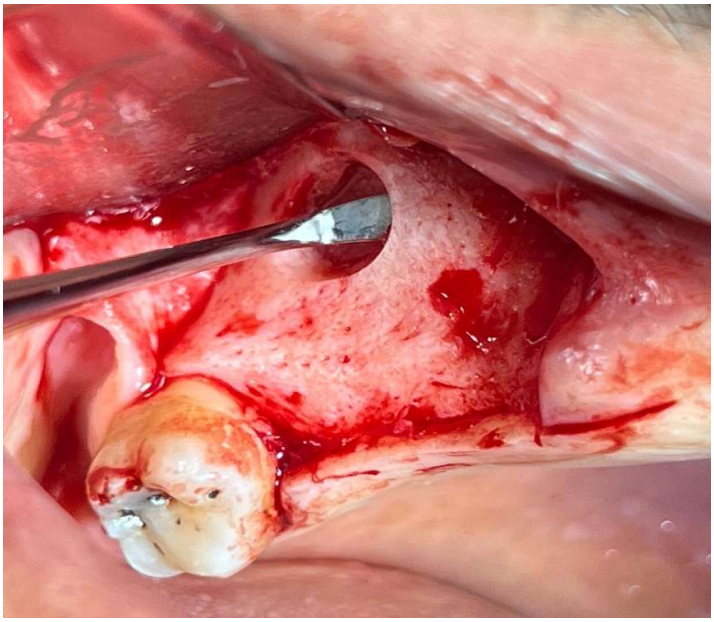


Figure 1: Elevation of Schneiderian membrane.

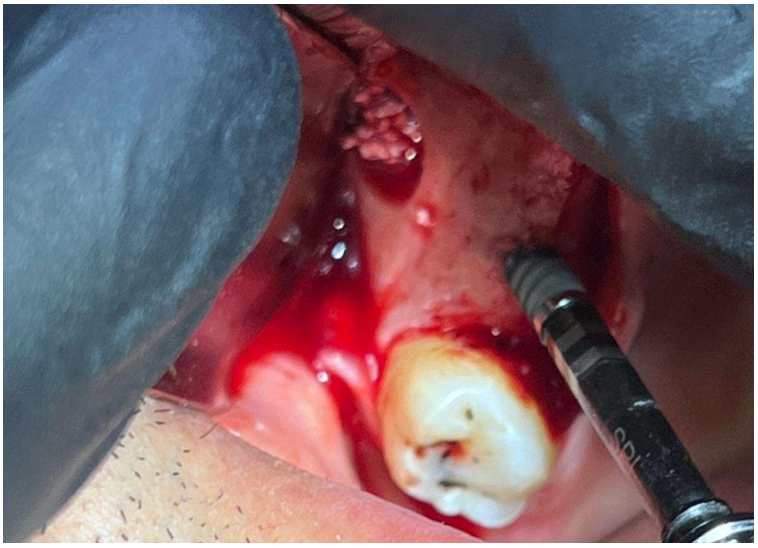


Figure 2: Implant placement and bone graft condensation.

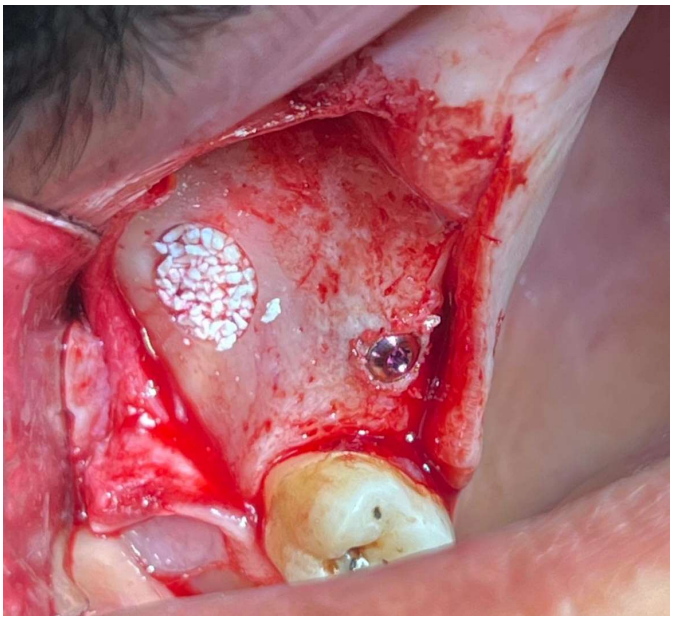


Figure 3: Condensation of bone graft till the lateral window.

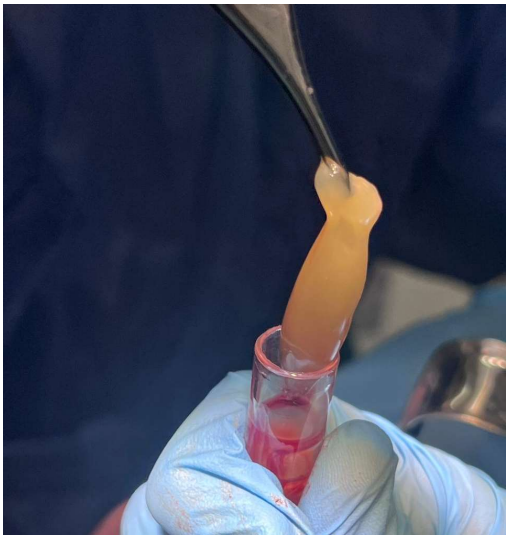


Figure 4: Isolated Platelet-rich fibrin obtained by separating the middle fraction from the centrifuged blood, 2 mm below the lower dividing line.

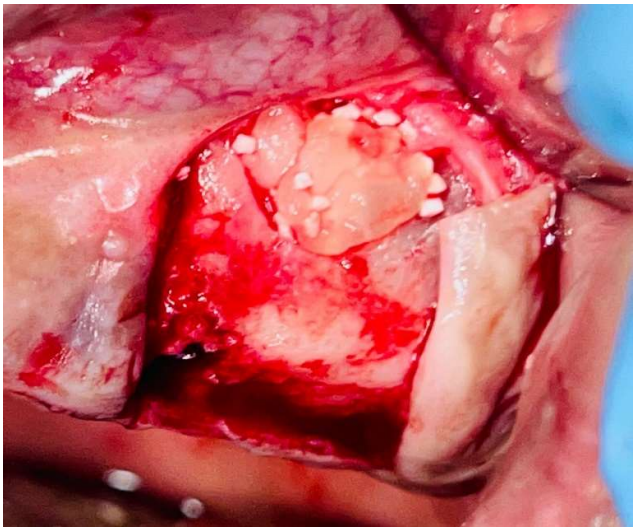
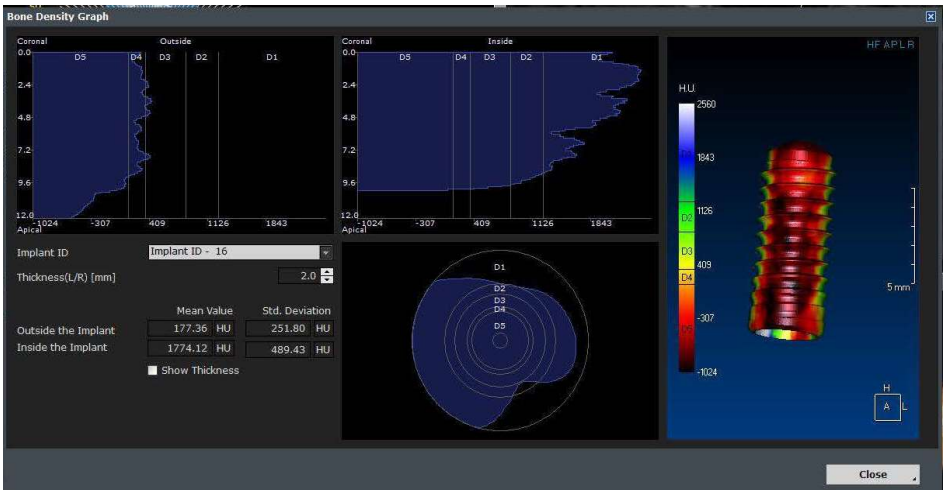


Figure 5: Bone graft filled sinus cavity with subsequent placement of PRF

Figure 6: Suturing of the flap.



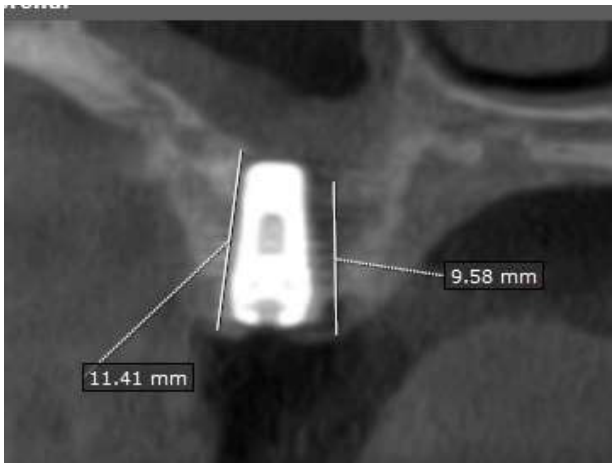


Figure 7: evaluation of bone density using OnDemand3D™ software

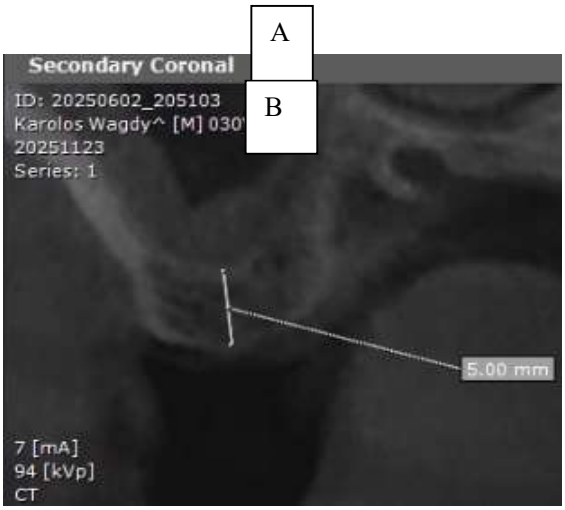
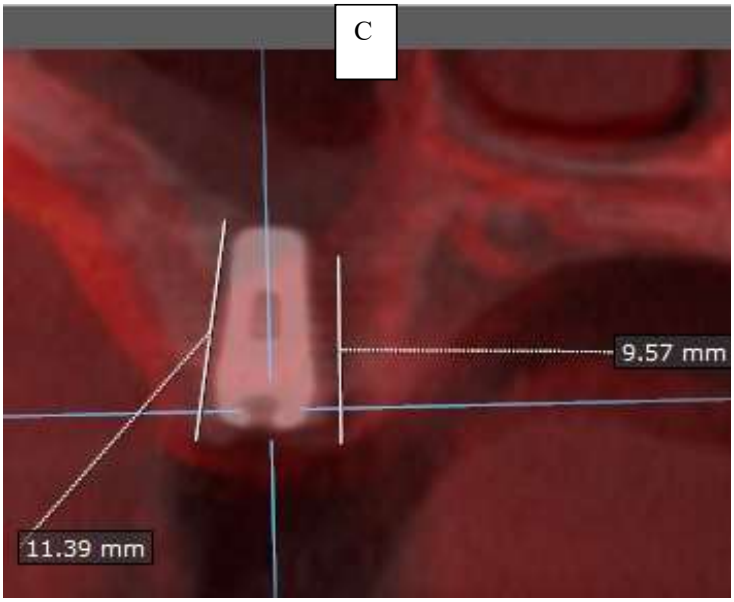


Figure 8: Measurement of vertical bone height preoperative (A) and 6 months postoperative (B).



Fusion of the preoperative and postoperative CBCT for measuring the vertical bone height gain (C)