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GUIDED BONE REGENERATION USING ULTRA-THIN TITANIUM MESH COMBINED WITH STICKY BONE AND SIMULTANEOUS IMPLANT PLACEMENT IN THE ANTERIOR MAXILLA: A PROSPECTIVE CLINICAL STUDY

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Abstract

Background: Reconstruction of deficient alveolar ridges in the anterior maxilla remains a major challenge in implant dentistry because of the functional and esthetic demands associated with this region. Following tooth loss, rapid and progressive bone resorption often results in insufficient bone volume for ideal implant placement. Guided bone regeneration (GBR) using titanium mesh has been widely applied to address such defects; however, clinical evidence regarding ultra-thin titanium mesh remains limited. Furthermore, the potential synergistic effect of combining ultra-thin titanium mesh with biologically active grafts such as sticky bone has not been sufficiently explored. Therefore, this study aimed to evaluate the clinical and radiographic outcomes of ultra-thin titanium mesh combined with sticky bone during simultaneous implant placement in the anterior maxilla. **Methods:** Eight patients presenting with horizontal or combined alveolar ridge deficiencies in the anterior maxilla were enrolled in this prospective clinical study. All patients underwent simultaneous implant placement and GBR using xenograft mixed with advanced platelet-rich fibrin (A-PRF) to form sticky bone. Ultra-thin titanium mesh was used for graft stabilization and space maintenance, followed by coverage with a collagen membrane. Clinical parameters, including implant stability and soft tissue conditions, were recorded. Radiographic assessment using Cone-beam computed tomography (CBCT) was performed preoperatively and after 6 months to evaluate changes in bone width, height and bone density. **Results:** All implants achieved successful osseointegration, with a 100% survival rate and no signs of mobility or infection at the 6-month follow-up. A statistically significant increase in bone density was observed, rising from 656.5 ± 52.8 HU preoperatively to 923.2 ± 126.5 HU at 6 months ($p < 0.001$), representing a mean increase of 40.7 ± 15.8%. Similarly, horizontal bone width increased significantly from 3.08 ± 0.3 mm preoperatively to 6.88 ± 0.5 mm at 6 months ($p < 0.001$), with a mean gain of 3.8 mm, while no significant difference was observed between immediate postoperative and 6-month measurements ($p = 0.49$). Bone height showed a slight, non-significant reduction from 14.8 ± 0.9 mm preoperatively to 13.9 ± 2.9 mm at 6 months ($p = 0.408$), with no significant percentage reduction over time ($p = 0.404$). Soft tissue parameters remained stable, with no statistically significant changes in gingival thickness ($p = 0.444$) or keratinized tissue width measured using digital scanning (2.05 ± 0.70 mm vs. 1.90 ± 0.73 mm; $p = 0.685$) and periodontal probe ($p = 0.374$). Mesh exposure occurred in 3 out of 8 cases (37.5%) but was successfully managed without compromising implant survival or final clinical outcomes,

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and postoperative pain scores showed a statistically significant reduction over time (p < 0.001). **Conclusions:** The combined use of ultra-thin titanium mesh and sticky bone demonstrated favorable clinical and radiographic outcomes for guided bone regeneration in the anterior maxilla with simultaneous implant placement. This approach provided predictable horizontal ridge augmentation, satisfactory implant stability, and acceptable soft tissue healing. Further studies of larger sample sizes and longer follow-up periods are recommended to confirm the long-term predictability of this technique.

Keywords: Titanium Mesh, Sticky Bone, Guided Bone Regeneration, Anterior Maxilla, Cone-Beam Computed Tomography.

INTRODUCTION

Implant rehabilitation in the anterior maxilla is considered one of the most technique-sensitive procedures in implant dentistry because of the demanding esthetic requirements and the frequent presence of insufficient alveolar bone volume. After tooth extraction, marked dimensional changes occur in the alveolar ridge, leading to progressive horizontal and vertical bone resorption. These alterations may compromise ideal implant positioning and often require augmentation procedures before or during implant placement. Studies have demonstrated that up to 50% of ridge width may be lost within the first year, with the most pronounced changes occurring during the initial healing phase (Jang et al., 2018; Buser et al., 2017). These dimensional changes often compromise ideal implant positioning and may necessitate additional augmentation procedures.

The quality and quantity of available bone play a critical role in determining implant success. The anterior maxilla is frequently characterized by low-density bone (Type IV), which presents challenges in achieving primary stability and predictable osseointegration (Misch, 1999; Alghamdi, 2018). Several classification systems, including those proposed by Cawood and Howell (1988) and Lekholm (1985), have emphasized the importance of evaluating ridge morphology and bone quality during treatment planning.

Guided bone regeneration (GBR) is considered a reliable and widely used approach for the reconstruction of deficient alveolar ridges. This technique is based on the application of barrier membranes that prevent the migration of soft tissue cells into the defect while permitting osteogenic cells to repopulate the area, thereby facilitating new bone formation (Elgali et al., 2017; Kim & Ku, 2020). Different types of membranes have been employed in GBR procedures, including resorbable collagen membranes as well as non-resorbable materials such as expanded polytetrafluoroethylene (e-PTFE) and titanium mesh (Bunyaratavej & Wang, 2001; Celletti et al., 1994).

Titanium mesh has been widely utilized in guided bone regeneration owing to its excellent mechanical strength, particularly its ability to provide rigid support and maintain adequate space for bone regeneration in large or non-contained defects (Briguglio et al., 2019; Xie et al., 2020). These characteristics make it particularly suitable for cases involving simultaneous implant placement, where maintaining graft stability is essential. However, conventional titanium mesh is associated with complications such as soft tissue dehiscence and exposure, which may negatively affect healing and compromise clinical outcomes (Hartmann et al., 2019; Cucchi et al., 2017). To overcome these limitations, ultra-thin titanium mesh has been introduced as a modification designed to improve

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adaptability, reduce soft tissue irritation, and potentially decrease exposure rates. Despite these theoretical advantages, clinical evidence supporting its use remains limited, and further investigation is required to validate its effectiveness in clinical practice. Besides mechanical stability, the biological environment is also essential for successful bone regeneration. Platelet-rich fibrin (PRF), considered a second-generation platelet concentrate, has been reported to promote wound healing and enhance bone regeneration through the continuous release of growth factors (Dohan et al., 2006; Kobayashi et al., 2016). When combined with particulate graft materials, PRF forms a cohesive matrix known as “sticky bone,” which improves graft stability, handling characteristics, and regenerative potential (Liu et al., 2019; Sareen et al., 2024).

While both titanium mesh and PRF-based grafting techniques have been extensively investigated independently, limited evidence exists regarding their combined use, particularly with ultra-thin titanium mesh in the anterior maxilla. This combined mechanical–biological approach may enhance graft stability, reduce complications, and improve regenerative outcomes. Therefore, the aim of this study was to evaluate the clinical and radiographic outcomes of using ultra-thin titanium mesh in combination with sticky bone for guided bone regeneration with simultaneous implant placement in the anterior maxilla.

PATIENTS AND METHODS

Study design and ethical considerations

This prospective in vivo clinical study was designed to assess the clinical and radiographic outcomes of guided bone regeneration (GBR) using ultra-thin titanium mesh combined with sticky bone for reconstruction of deficient anterior maxillary ridges during simultaneous implant placement. The study was designed as a two-phase clinical investigation. The first phase involved ridge augmentation with simultaneous implant placement, while the second phase, performed after a 6-month healing period, included surgical re-entry for titanium mesh removal and assessment of bone regeneration and implant osseointegration. All procedures were carried out at the outpatient clinic of the Faculty of Dentistry, Suez Canal University, Egypt. The study protocol was reviewed and approved by the institutional ethical committee, and all patients provided written informed consent after receiving a detailed explanation of the treatment plan, potential risks, and follow-up procedures.

Table 1: Demographic Data

Patient Number	Implant Number	Age	Gender	The area augmented	Implant Diameter	Implant Length
1	1	38	Female	Upper lateral	3.5	11.5
2	2	38	Female	Upper lateral	3.5	11.5
3	3	40	Female	Upper lateral	3.5	13
4	4	22	Female	Upper Central	3.5	13
5	5	45	Female	Upper lateral	3.5	11.5
6	6	34	Male	Upper Canine	3.5	13

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7	7	49	Male	Upper canine	3.5	13
8	8	43	Male	Upper lateral	3.5	11.5

Sample size calculation

The sample size was calculated according to the formula described by Daniel (1999) and Charan and Biswas (2013), using a standard normal variate (Zα) of 1.96 at a confidence level of 95%, a standard deviation (SD) of 2.88, and a precision level (d) of 2. Based on this calculation, the required sample size was 7.97, which was rounded to eight patients. Accordingly, eight patients were included in this pilot study.

Patient selection and baseline assessment

Patient selection was carried out according to predefined inclusion and exclusion criteria. Participants eligible for the study exhibited deficient anterior maxillary ridges with moderate to severe horizontal bone loss (ridge width < 4 mm), with or without associated vertical defects (height ≤ 5 mm). Only non-smoking patients with satisfactory oral hygiene and medically controlled systemic conditions were enrolled. Exclusion criteria included heavy smoking (>10 cigarettes/day), uncontrolled systemic disorders, inadequate oral hygiene, or a history of chemotherapy, radiotherapy, or immunosuppressive treatment within the previous five years.

The study included eight patients, comprising five females and three males, with ages ranging from 22 to 49 years. Implant placement was performed in the anterior maxillary esthetic region, involving central incisors, lateral incisors, and canines. All patients underwent a thorough preoperative evaluation that included detailed medical and dental histories, clinical examination, and standardized photographic records. Special consideration was given to the condition of the soft tissues, occlusal relationship, adjacent dentition, and oral hygiene level.

Radiographic evaluation was performed using cone-beam computed tomography (CBCT) with the SCANORA 3DX system (Soredex, Finland). Scans were obtained with a field of view of 5 × 10 cm, tube voltage of 90 kVp, current of 10 mA, and voxel size of 0.4 mm. The images were analyzed using OnDemand 3D software (Cybermed, Seoul, Korea). Preoperative CBCT analysis included assessment of bone density in Hounsfield Units (HU), measurement of ridge width and height, and evaluation of defect morphology to guide implant selection and surgical planning. (Fig. 1).

MATERIALS

All implants used in this study were tapered dental implants (Neo CMI Implant System, NeoBiotech, Korea) with a diameter of 3.5 mm and lengths of either 11.5 mm or 13 mm, selected according to the available bone height and prosthetic requirements. The implant system was chosen due to its ability to achieve high primary stability, particularly in low-density maxillary bone. A custom-made ultra-thin titanium mesh (CTi-Membrance RC9, NeoBiotech, Korea) was used for all cases. (Fig.2) The mesh had a thickness of 0.12 mm and dimensions of approximately 11–12 mm in width and 21 mm in length. It was designed with three fixation holes: one central hole to accommodate the implant cover

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screw and two additional holes for fixation using titanium micro-screws placed buccally and apically. (Fig 3a, 3b) This ultra-thin design allowed improved adaptability to the alveolar contour and reduced the risk of soft tissue irritation compared to conventional meshes.

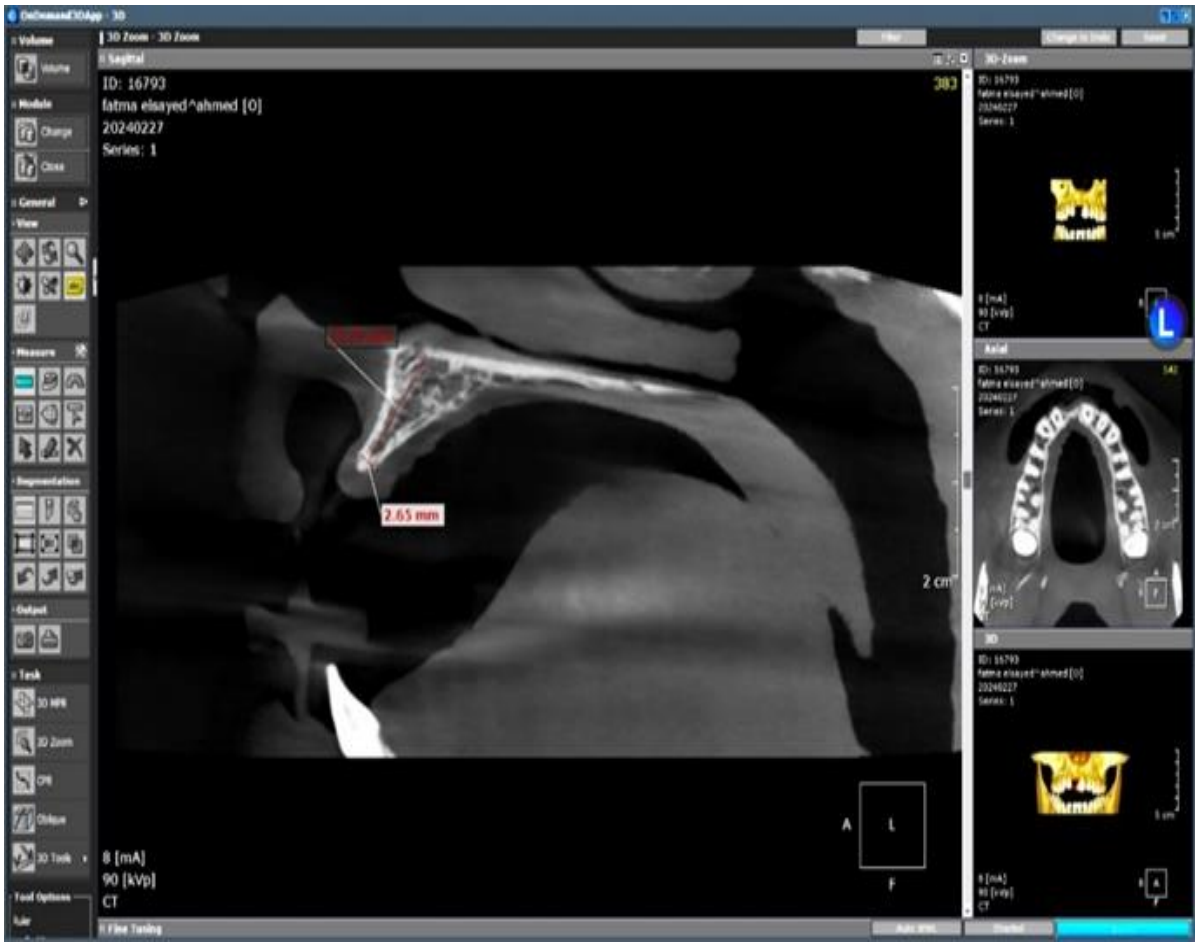

Figure 1: Preoperative CBCT scan

Figure 2: CTi-membrane RC9 supplied and sterilized

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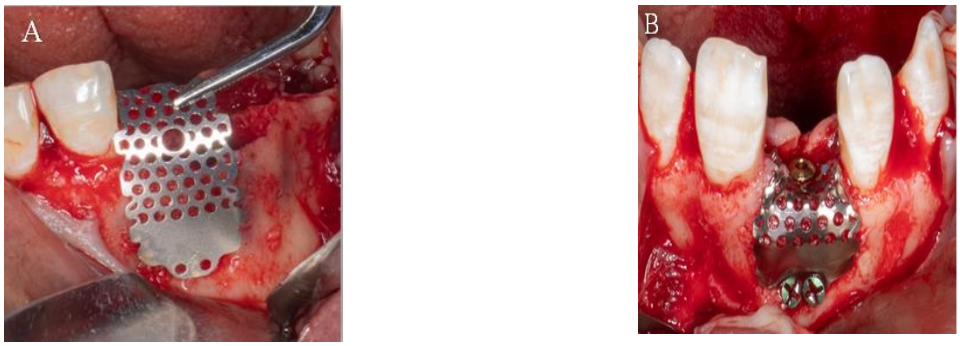

Figure 3: A. Intraoral photographs showing the titanium mesh before placement. B. Intraoral photograph showing titanium mesh placed and fixed with three screws (implant cover screw, two micro titanium screws)

Titanium micro-screws and their corresponding screwdriver (NeoBiotech, Korea) were used to secure the mesh in place. The grafting material consisted of a xenograft (Geistlich Bio-Oss®, Switzerland) with 10% collagen, supplied in sterile vials of 0.5 cc and 1 cc, selected according to the size of the defect.

Advanced platelet-rich fibrin (A-PRF) was prepared using an 80-1 desktop centrifuge (CGOLDENWALL, China) with a maximum rotational speed of 4000 rpm and a capacity of 6 × 20 mL tubes. Venous blood samples were centrifuged at 200 g for 8 minutes to produce the fibrin clot. A resorbable collagen membrane (ActyColl®, OverMed, Italy) composed of type I atelocollagen and measuring 15 × 20 × 0.2 mm was placed over the titanium mesh to provide additional coverage. Primary wound closure was achieved using 4-0 absorbable sutures (AssuCryl® PGA, Assut Sutures, Switzerland).

Surgical protocol

All surgical interventions were carried out under local anesthesia using 4% articaine hydrochloride with epinephrine 1:100,000. A rectangular full thickness mucoperiosteal flap was reflected to adequately expose the alveolar defect. (Fig. 4) Implant osteotomies were prepared through sequential drilling following the manufacturer's recommendations, and the implants were inserted approximately 1 mm below the crestal bone level to compensate for expected bone remodeling. (Fig. 5).

For preparation of Advanced Platelet-Rich Fibrin (A-PRF), venous blood was collected from the antecubital vein into sterile 10 mL glass tubes without anticoagulants and immediately centrifuged at 200 g for 8 minutes. After centrifugation, the PRF clot was separated from the red blood cell fraction, gently trimmed, and placed on dry sterile gauze to eliminate excess serum. The clot was then left undisturbed at room temperature for 10 minutes to allow stabilization. (Fig. 5). The A-PRF was subsequently mixed with the xenograft particles (0.5–1 cc) and gently stirred for approximately 15 seconds to form a cohesive mass known as sticky bone. Prior to graft placement, multiple cortical perforations were performed at the recipient site to enhance bleeding and vascularization. The sticky bone was then carefully adapted around the implant and over the deficient ridge. (Fig. 6).

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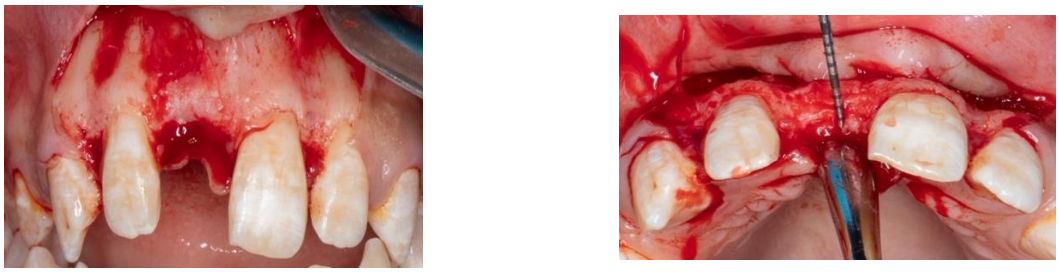

Figure 4: Intraoral photograph showing the reflection of full mucoperiosteal flap and measuring the ridge defect

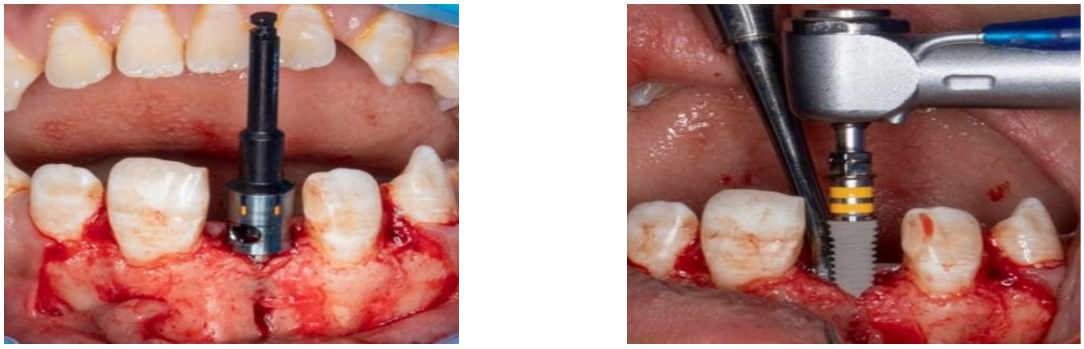

Figure 5: Initial drill for implant and implant placement in the osteotomy site

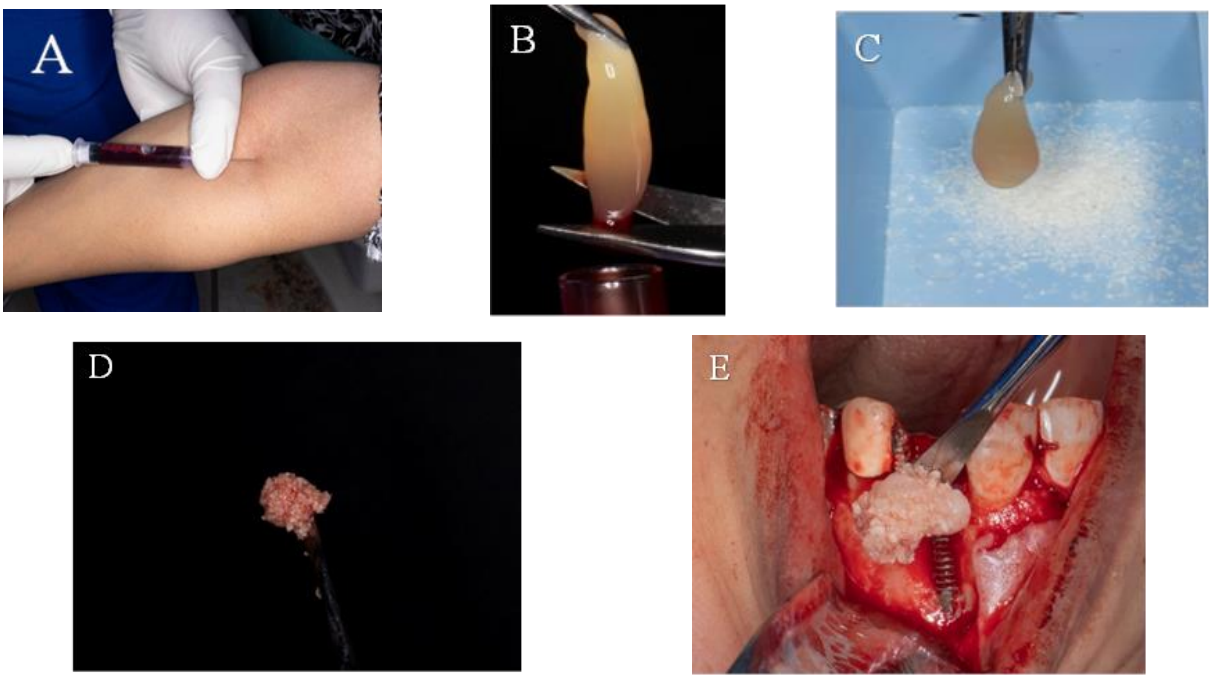

Figure 5: Steps of A-PRF and sticky bone preparation. A. blood withdrawal from the patient's antecubital vein. B. PRF separation with scissors. C. Applying A-PRF over the xenograft. D. Sticky bone formation. D. Application of sticky bone over the defect

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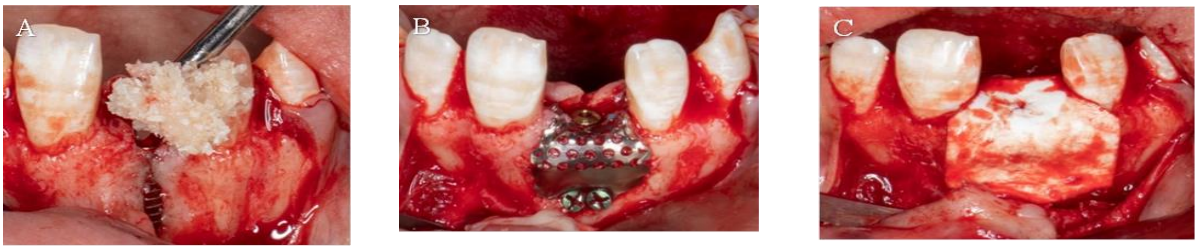

Figure 6: Intraoral photographs showing a. sticky bone graft before placement over the defect. B. The Ti-mesh was secured in place. C. Collagen membrane placed over the ti mesh

The ultra-thin titanium mesh was adapted over the augmented site and secured using two titanium micro-screws placed buccally and apically, in addition to the implant cover screw for occlusal stabilization. This fixation method ensured complete immobilization of the graft and maintenance of the regenerative space. A collagen membrane was then placed over the mesh to provide additional biological protection. Primary wound closure was achieved using a double-layer suturing technique with 4-0 resorbable sutures.

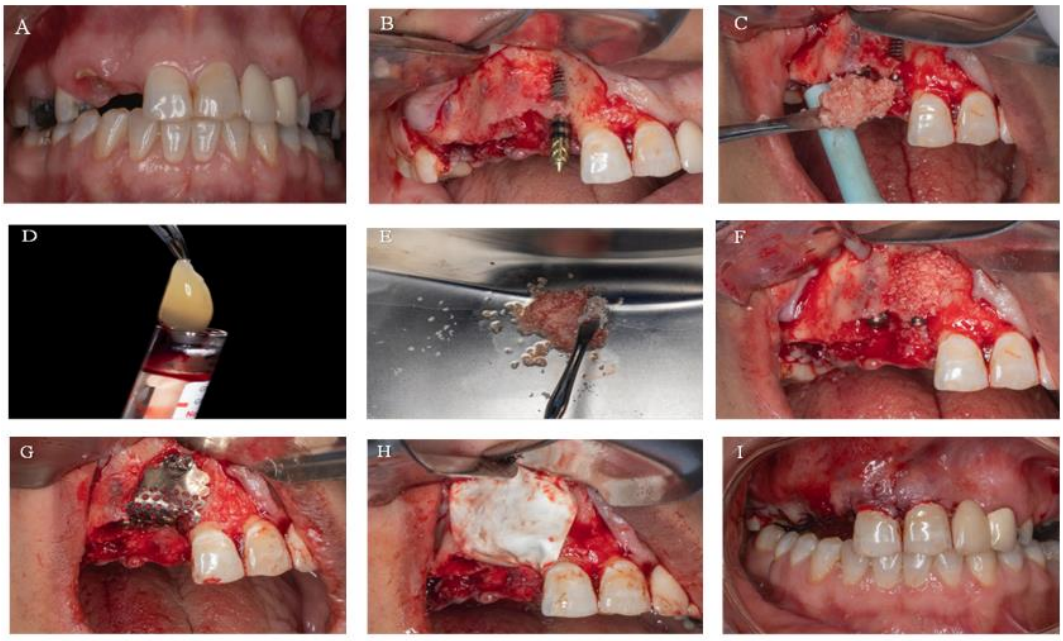

Figure 7: Intraoral photographs for case number 5 for ridge augmentation showing, A: occlusal view of the patient's maxillary teeth B: the reflection of full mucoperiosteal flap. C: sticky bone before application D: A-PRF before separation E: Xenograft mixed with A- PRF in a sterilized kidney dish F: sticky bone graft applied over the defect. G: ultra-thin titanium mesh fixated over the sticky bone. H: Collagen membrane applied over titanium mesh. I: Double layer closure of the flap

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Postoperative care and follow-up

All patients received standardized postoperative instructions, including the application of cold packs during the first 24 hours, avoidance of hot food and mechanical trauma, and maintenance of proper oral hygiene. Pharmacological management after ruling allergy included Hibiotec® 1 g (amoxicillin 875 mg and clavulanic acid 125 mg; Amoun Pharmaceutical Co., Egypt) administered twice daily for five days, ibuprofen 400 mg (Abbott Laboratories) taken three times daily for five days and thereafter as needed, and chlorhexidine mouthwash 0.12% (Hexitol®, Arab Drug Company, Egypt) used three times daily for one week. For cases with the titanium mesh exposure, management protocols followed Urban et al's 2017 recommendations. These included broad-spectrum antibiotics, thorough chlorhexidine irrigation, and strict oral hygiene measures using gauze moistened with 0.12% chlorhexidine to maintain cleanliness.

Patients were monitored clinically for 1 week, 1 month, 3 months, and 6 months following surgery. Postoperative pain intensity was evaluated using a Visual Analogue Scale (VAS) on postoperative days 1, 3, and 7. Soft tissue healing was evaluated using the modified Landry healing index at 1, 3, and 6 months. (Table 2.)

Table 2: Modified soft tissue healing Landry Index

Score	Clinical Finding
1 = Dehiscence	**Exposure of titanium mesh**
2 = Very Poor	• Tissue color: > 50% of gingiva red • Response to palpation: Bleeding • Granulation tissue: Present • Incision margin: Not epithelialized, with loss of epithelium beyond incision margin. • Suppuration
3 = Poor	• Tissue color: > 50% of gingiva red • Response to palpation: Bleeding • Granulation tissue: Present • Incision margin: not epithelialized, with connective tissue exposed.
4 = Good	• Tissue color: less than 50% of gingiva red • Response to palpation: no bleeding • Granulation tissue: none • Incision margin: no connective tissue.
5 = Very good	• Tissue color: less than 25% of gingiva red • Response to palpation: no bleeding • Granulation tissue: none • Incision margin: no connective tissue exposed.
6 = Excellent	• Tissue color: All tissue pink • Response to palpation: no bleeding • Granulation tissue: none • Incision margin: no connective tissue exposed.

Gingival thickness was measured preoperatively and at 6 months using a periodontal probe inserted perpendicularly to the mucosa. (Fig. 8) The width of keratinized mucosa was assessed both clinically using a UNC-15 periodontal probe and digitally using an

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intraoral scanner (Medit i700 wireless scanner, Seuol, South Korea) and analyzed with exocad software. (Darmstadt, Germany) (Fig. 9, 10).

Radiographic evaluation using CBCT was performed within one week postoperatively and at 6 months. Bone density was measured in Hounsfield Units, while bone width and height were assessed using standardized reference points. (Fig. 11, 12, 13).

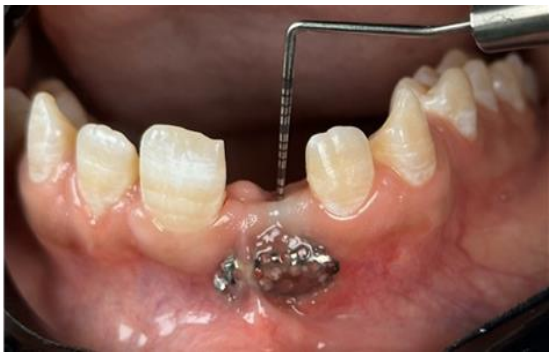

Figure 8: Intraoral photograph showing the measurement by the periodontal probe in the gingival sulcus

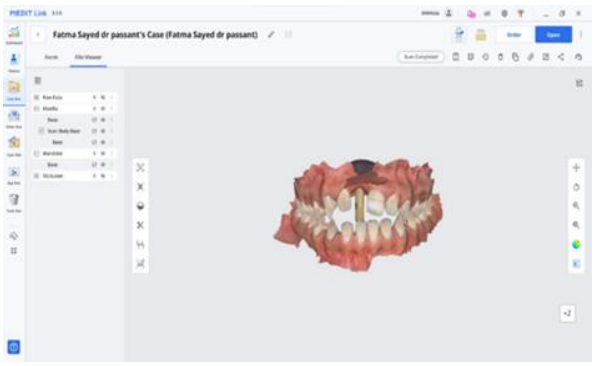

Figure 9: Image showing the interface of the Medit intraoral scanner after taking the scan

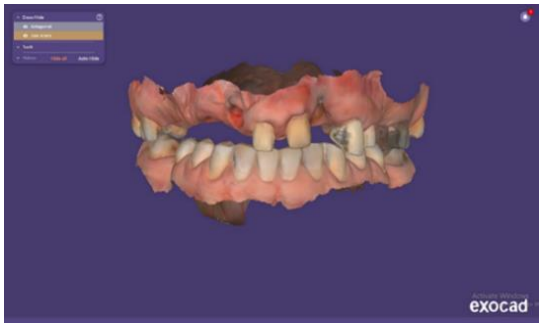

Figure 10: A. Image showing Exocad interface. A: showing the PLY file exported on Exocad. B: Color/texture tool feature in Exocad. C: Width of keratinized mucosa using "distance" measurement tool

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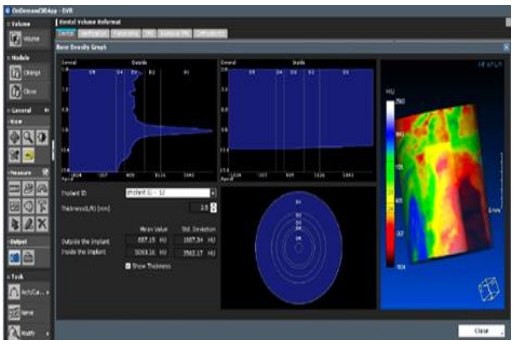

Figure 11: Photograph showing the bone density graph evaluation immediate postoperatively

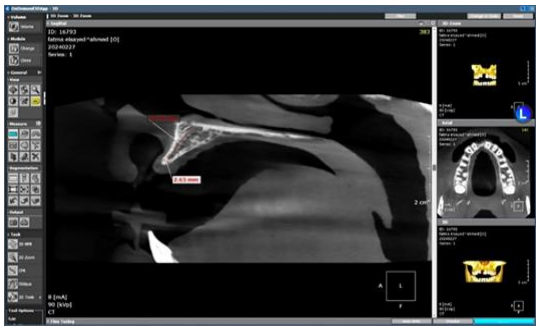

Figure 12: Preoperative CBCT measurement for both width and height for

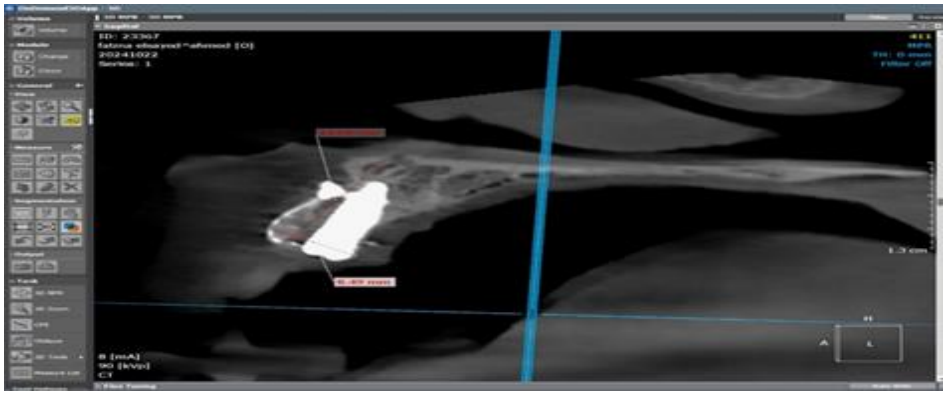

Figure 13: 6 months Postoperative CBCT measurement for both width and height for case number 3, width: 8.49mm, height: 14.69mm

Second-stage surgery and prosthetic rehabilitation

Following a 6-month healing period, a second-stage surgical procedure was carried out under local anesthesia for removal of the titanium mesh. A full-thickness flap was elevated, and in cases where soft tissue dehiscence was present, a para-crestal incision with flap scoring was performed to facilitate closure. Upon mesh removal, a dense connective tissue layer, referred to as a pseudo-periosteal layer, was observed covering the regenerated bone. (Fig 14)

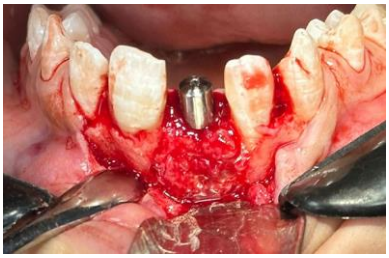

Figure 14: Intraoral photograph showing the pseudo-periosteal layer after it mesh removal

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All implants demonstrated successful osseointegration, with a 100% survival rate. Healing abutments were placed for two weeks, after which digital impressions were taken using scan bodies. Final prosthetic rehabilitation was completed using zirconia crowns cemented onto the implant fixtures.

RESULTS

Implant Survival

All eight implants placed in the anterior maxilla achieved successful osseointegration, resulting in a 100% survival rate at the 6-month follow-up, with no signs of mobility, infection, or peri-implant radiolucency.

Radiographic Outcomes

Bone Density

A statistically significant increase in bone density was observed over time. The mean bone density increased from 656.5 ± 52.8 HU preoperatively to 923.2 ± 126.5 HU at 6 months ($p < 0.001$). The percentage increase in bone density between immediate postoperative and 6-month measurements was 40.7 ± 15.8%. (Table 3) (Fig. 15)

Table 3: Bone Density data

	Bone density					% of change Bone density				
	Mean	**SD**	**Mdn**	**Min**	**Max**	**Mean**	**SD**	**Mdn**	**Min**	**Max**
Postoperative	656.5	52.8	667.5	572	735					
6 Months	923.3	126.5	934.5	687	1075	40.7	15.8	45.2	3.8	54.9
p-value	<0.001*									

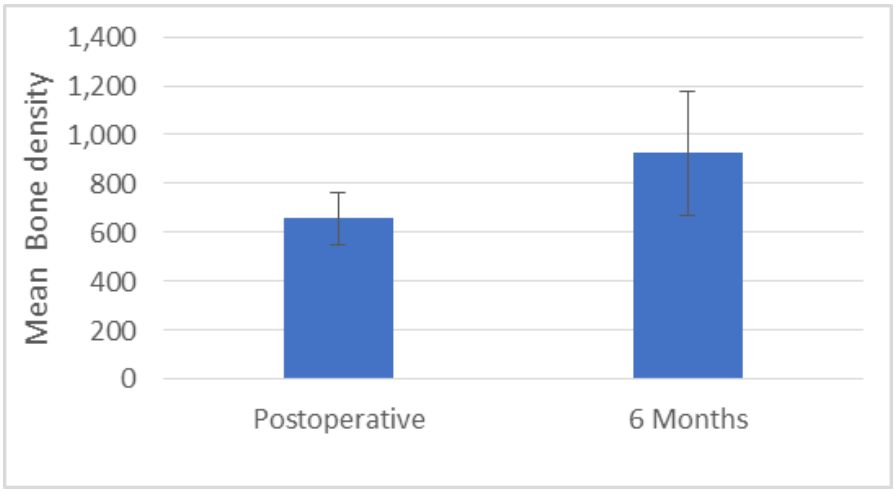

Figure 15: Bar chart showing the mean Bone Density

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Bone Width

A significant gain in horizontal ridge width was recorded, with mean values increasing from **3.08 ± 0.3 mm preoperatively to 6.88 ± 0.5 mm at 6 months** (**p < 0.001**), resulting in a mean bone width gain of **3.8 mm**. No statistically significant reduction in bone width was observed between immediate postoperative and 6-month measurements (**p = 0.49**), indicating stability of the augmented ridge. (Table 4) (Fig. 16)

Table 4: Bone Width data

	Bone Width					% of change Bone Width				
	Mean	**SD**	**Mdn**	**Min**	**Max**	**Mean**	**SD**	**Mdn**	**Min**	**Max**
Preoperative	3.08[a]	0.32	3.15	2.60	3.50					
Postoperative	7.26[b]	0.54	7.40	6.50	8.00	139.07	36.58	137.05	91.18	207.69
6 Months	6.88[b]	0.58	7.15	6.10	7.60	126.39	36.47	125.22	79.41	192.31
p-value	<0.001*					0.49 NS				

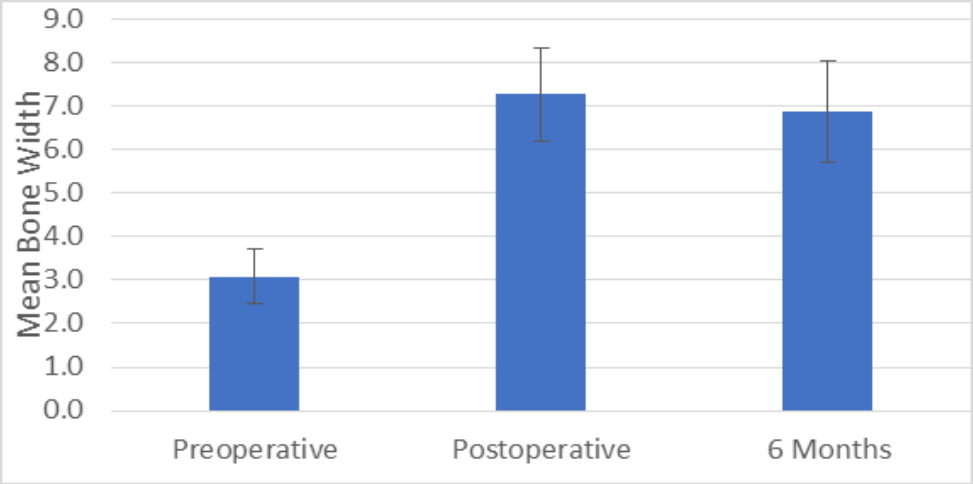

Figure 16: Bar chart showing the mean Bone Width

Bone Height

No statistically significant changes in vertical bone height were observed. The mean bone height was **14.8 ± 0.9 mm preoperatively and 13.9 ± 2.9 mm at 6 months** (**p = 0.408**). Additionally, the percentage reduction in bone height overtime was not statistically significant (**p = 0.404**). (Table 5) (Fig. 17)

Table 5: Bone Height data

	Bone Height					% of change Bone height				
	Mean	**SD**	**Mdn**	**Min**	**Max**	**Mean**	**SD**	**Mdn**	**Min**	**Max**
T1	14.8	0.9	14.5	13.7	16.3					
T3	15.1	1.0	14.7	13.9	16.7	1.8	0.5	1.8	1.3	2.5
T6	13.9	2.9	14.3	7.1	16.4	-5.3	22.9	0.4	-56.4	14.2
p-value	0.408 NS					0.404 NS				

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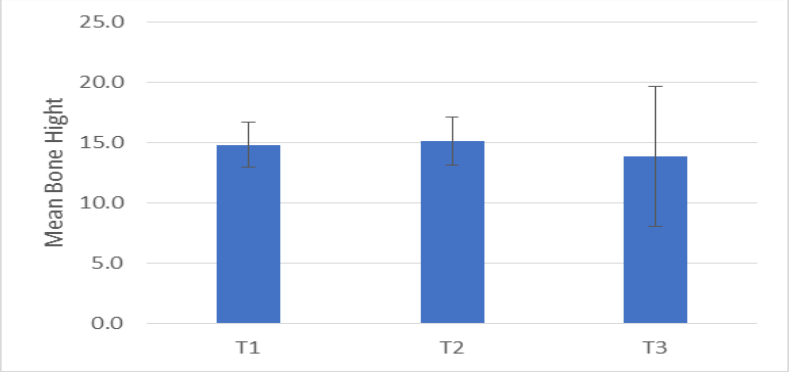

Figure 17: Bar chart showing the mean Bone Height

Clinical and Soft Tissue Outcomes

Postoperative Pain (VAS)

All patients reported mild to moderate postoperative pain, which decreased significantly over time. A statistically significant reduction in VAS scores was observed between Day 1, Day 3, and Day 7 ($p < 0.001$).

Soft Tissue Healing

Soft tissue healing progressed favorably in all cases, with most sites demonstrating good to excellent healing scores according to the modified Landry healing index at follow-up intervals. (Table 6) (Fig.18)

Table 6: Soft tissue Assessment using Landry Index

	Soft tissue Assessment using Landry Index				
	Mean	**SD**	**Mdn**	**Min**	**Max**
T1	5.0	0.9	5.0	4.0	6.0
T3	4.4	1.1	4.5	3.0	6.0
T6	3.9	1.9	4.5	1.0	6.0
p-value	0.274 NS				

Different letters indicate significant difference; *=significant, NS=non-significant

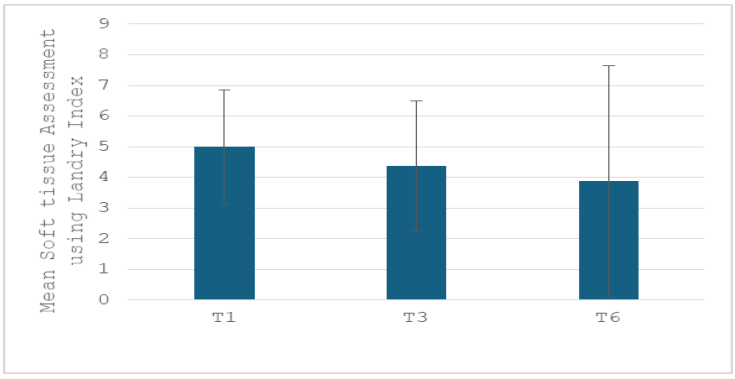

Figure 18: Bar chart showing the mean Landry Index

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Mesh Exposure

Titanium mesh exposure occurred in **three cases (37.5%)**, including one early exposure and two late exposures. All cases were managed conservatively without compromising implant survival or bone regeneration outcomes.

Gingival Thickness

No statistically significant difference in gingival thickness was observed between preoperative and 6-month postoperative measurements (**p = 0.444**). (Table 7) (Fig. 19)

Table 7: Soft tissue Assessment using Gingival thickness "periodontal probe"

	Gingival thickness "periodontal probe"					% of change Gingival thickness				
	Mean	SD	Mdn	Min	Max	Mean	SD	Mdn	Min	Max
Preoperative	1.6	0.4	1.5	1.2	2.0					
Postoperative	1.4	0.4	1.2	1.1	2.0	-9.3	11.5	-4.2	-26.7	0.0
p-value	0.444 NS									

Different letters indicate significant difference; *=significant, NS=non-significant

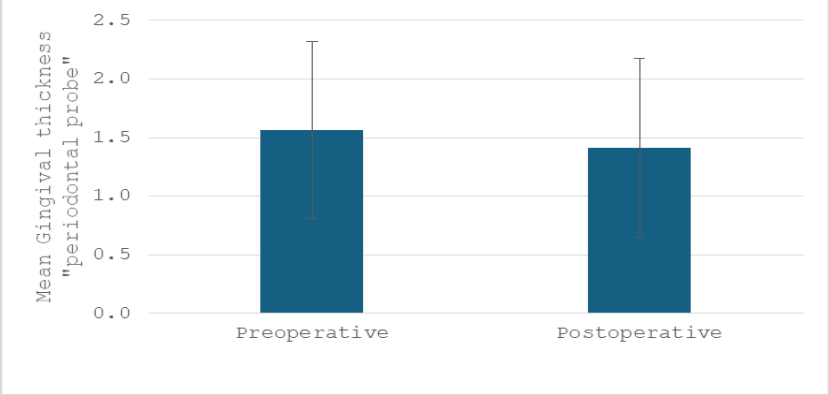

Figure 19: Bar chart showing the mean Gingival thickness "periodontal probe

Width of Keratinized Gingiva

No statistically significant difference was observed in the width of keratinized gingiva between preoperative and postoperative measurements, whether evaluated clinically (p = 0.374) or digitally. Nevertheless, a statistically significant variation was detected between the two measurement methods (p < 0.001). (Table 8) (Fig. 20)

Table 8: Soft tissue Assessment using Width of keratinized mucosa "periodontal probe"

	width of keratinized mucosa "periodontal probe"					% of change width of keratinized mucosa "periodontal probe"				
	Mean	SD	Mdn	Min	Max	Mean	SD	Mdn	Min	Max
Preoperative	2.9	0.6	2.9	2.0	4.0					
Postoperative	2.6	1.0	2.7	1.2	4.0	-14.1	21.4	-4.0	-50.0	0.0
p-value	0.374 NS									

Different letters indicate significant difference; *=significant, NS=non-significant

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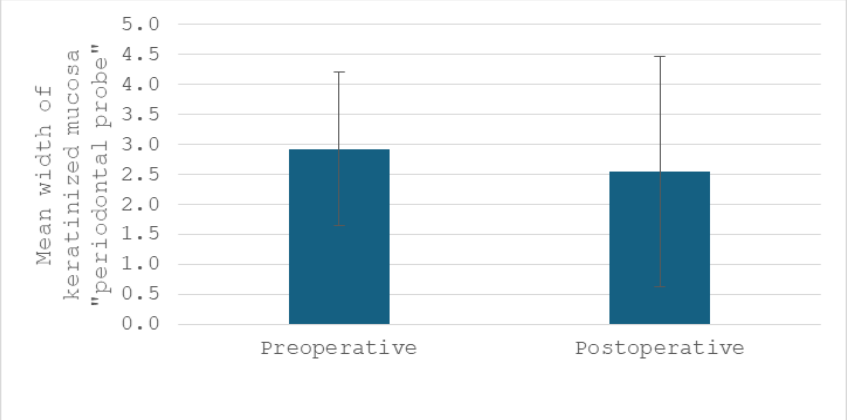

Figure 20: Bar chart showing the mean Width of keratinized mucosa "periodontal probe"

DISCUSSION

The present study evaluated the clinical and radiographic outcomes of using ultra-thin titanium mesh combined with sticky bone for guided bone regeneration in the anterior maxilla. The results demonstrated favorable hard and soft tissue outcomes, suggesting that this approach may be effective for the management of deficient alveolar ridges in esthetically demanding regions.

One of the key findings of the current study was the marked increase in horizontal ridge width observed at the 6-month evaluation period. This result is consistent with previously published studies demonstrating the effectiveness of titanium mesh in maintaining space and facilitating bone regeneration (Briguglio et al., 2019; Ricci et al., 2013). The rigidity of titanium mesh allows it to resist soft tissue pressure, which is essential for preserving the volume of the grafted area and promoting predictable bone formation.

In addition to dimensional changes, a notable increase in bone density was observed. This finding suggests successful maturation and mineralization of the regenerated bone, which is critical for long-term implant stability. Similar improvements in bone density have been reported in studies utilizing GBR techniques with particulate grafts and barrier membranes (Urban et al., 2019).

A key aspect of the present study is the use of ultra-thin titanium mesh, which represents a modification of conventional mesh designs. Traditional titanium meshes, while effective, are often associated with handling difficulties and a relatively high incidence of soft tissue complications, particularly mesh exposure (Hartmann et al., 2019; Cucchi et al., 2017). In contrast, ultra-thin meshes are designed to improve adaptability and reduce mechanical irritation of the overlying soft tissues.

Although mesh exposure occurred in three cases in the present study, it is important to note that these exposures did not compromise the final outcomes as they were considered to be a late exposure occurance. This finding agrees with previous studies

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reporting that titanium mesh exposure does not inevitably result in graft failure when appropriately managed (Ghensi et al., 2017; Abu-Mostafa et al., 2022). The absence of infection or implant failure in these cases further supports the resilience of this technique.

Soft tissue outcomes were also assessed and demonstrated favorable healing. No statistically significant changes were observed in gingival thickness or width of keratinized mucosa, indicating that the procedure maintained soft tissue stability without adverse effects. These results are in accordance with previous studies indicating that GBR procedures mainly affect hard tissue regeneration while producing minimal changes in soft tissue dimensions (Pieri et al., 2008).

The incorporation of sticky bone represents another important component of the present protocol. Platelet-rich fibrin has been widely investigated for its regenerative potential, with studies demonstrating its ability to enhance angiogenesis, promote cell proliferation, and support osteogenic differentiation (Dohan et al., 2006; Ghanaati et al., 2014). When combined with particulate grafts, PRF improves the cohesion and stability of the graft material, reducing the risk of particle migration and enhancing overall handling (Liu et al., 2019; Sareen et al., 2024).

Another important consideration is the decision to perform simultaneous implant placement. This approach provides several benefits, including shortening the overall treatment duration and minimizing the number of surgical procedures required. However, it requires careful case selection and adequate primary stability, as emphasized in previous studies (Konstantinidis et al., 2015). In the present study, all implants achieved primary stability and remained stable throughout the follow-up period.

The favorable outcomes observed in the present study may be attributed to the synergistic effect of combining a mechanically stable scaffold, provided by titanium mesh, with a biologically active graft in the form of sticky bone. This dual approach fulfills both the structural requirements for space maintenance and the biological conditions necessary for angiogenesis and bone regeneration, in accordance with established GBR principles (Boyapati & Wang, 2006; Dohan et al., 2006; Ghanaati et al., 2014; Briguglio et al., 2019; Urban et al., 2019).

Despite the favorable outcomes observed in the present study, certain limitations should be considered. The relatively small sample size may limit the generalizability of the findings. In addition, the lack of a control group restricts direct comparison with other guided bone regeneration techniques and grafting materials. Furthermore, the short follow-up duration does not allow evaluation of long-term outcomes, including implant survival and marginal bone stability over time.

Future investigations should include larger patient populations, extended follow-up periods, and comparative study groups to further assess the clinical performance of ultra-thin titanium mesh compared with conventional regenerative approaches. Randomized controlled clinical trials would provide stronger evidence regarding the effectiveness and long-term predictability of this technique

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CONCLUSION

Within the limitations of this prospective clinical study, the combined use of ultra-thin titanium mesh and sticky bone demonstrated favorable outcomes for guided bone regeneration in the anterior maxilla. The technique resulted in significant horizontal bone gain, increased bone density, successful implant osseointegration (100% implant survival rate), and stable peri-implant soft tissue conditions. In addition, the enhanced adaptability of ultra-thin titanium mesh together with the biological advantages of platelet-rich fibrin-enriched grafts appeared to provide a favorable environment for bone regeneration.

Although titanium mesh exposure occurred in a limited number of cases, it was successfully managed without negatively affecting the final regenerative or implant outcomes. This combined mechanical and biologically enhanced regenerative approach may therefore serve as a predictable treatment modality for simultaneous implant placement in deficient anterior maxillary ridges.

Further controlled clinical studies with larger sample sizes and longer follow-up periods are necessary to validate these findings and assess long-term clinical stability.

Ethics approval and consent to participate

The study was carried out in accordance with the principles of the Declaration of Helsinki and received approval from the Ethical Committee of the Faculty of Dentistry, Suez Canal University, Egypt. All participants were fully informed about the study objectives, potential benefits, and possible risks, and written informed consent was obtained before participation.

Consent for publication

Written informed consent for publication of clinical data and accompanying images was obtained from all participants.

Availability of data and materials

The datasets generated and analyzed during the present study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Abbreviations

A-PRF: Advanced Platelet-Rich Fibrin

CBCT: Cone Beam Computed Tomography

GBR: Guided Bone Regeneration

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HU: Hounsfield Units

PRF: Platelet-Rich Fibrin

VAS: Visual Analogue Scale

WKG: Width of Keratinized Gingiva

WAG: Width of Attached Gingiva

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