Immediate Implant Placement Simultaneously with Ridge Augmentation in the Maxillary Esthetic Region Using Allograft Bone Ring versus Titanium Mesh Guided Bone Regeneration

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Abstract:

Objective: To assess ridge augmentation with an allograft bone ring versus GBR with titanium mesh, and immediate implant placement (IIP) in the maxillary esthetic zone. **Materials and Methods:** The 12 patients with 14 defective sockets were randomly divided into two groups: three females and four males in the control group (Titanium mesh-GBR), and three females and two males in the study group (Allograft bone ring). Patients had post-operative clinical examinations each day for the first week, then once a month for the next six months. **Results: :** At 6 months post-surgery, all cases in the control group healed well and showed relative bone gain (7.09±1.56mm^2), and even though four of them had wound dehiscence, only one of them completely healed during the follow-up period. In the study group, at 6 months following surgery, the relative bone gain was (2.76±1.06^2). All cases healed well, with no dehiscence or infection except for two cases of allograft ring failure due to early exposure within two weeks after surgery which did not respond to local measures or disinfected applications. **Conclusions:** Those certain two simultaneous procedures achieved promising and advantageous results; therefore they could be used as an alternative treatment to other graft techniques, in particular for defective sockets in the maxillary aesthetic region.

Introduction:

After tooth extractions, bone remodelling leads to ridge insufficiency, which makes it challenging to insert dental implants, as well as a limitation of underlying soft tissues, creating a substantial reconstructive problem. The decreased bone volume harms long-term prognosis and implant survival, as well as aesthetics.[1]

Dental implants may now be placed immediately after tooth extraction owing to advances in design and surface treatments. This is a variant of the traditional osseointegration protocol established by Branemark.[2] Immediate implantation shortens the time necessary for osseointegration[3, 4], compared to using the conventional protocol which normally takes 3–6 months.[5] The new method significantly reduces bone resorption by preserving periodontal architecture and produces superior aesthetic outcomes, especially when the anterior teeth are missing.[6]

In the aesthetic area, simultaneous guided bone regeneration (GBR) treatments involving bone grafts and barrier membranes are often required to treat peri-implant deficiencies and/or enhance surrounding tissues. This technique may also produce great treatment outcomes with high predictability and a low risk of complications, both functionally and aesthetically.[7] Horizontal defects may be repaired with predictable clinical outcomes.
However, vertical defects might be difficult to restore.[8] Vertical bone augmentation is a complex operation that's still mostly performed in the anterior aesthetic zone. Many techniques for vertical bone augmentation have been described, including the use of particulate bone substitutes and GBR procedure, autogenous or allogenic block grafts, and distraction osteogenesis.[9-14] The basic principle of GBR consists of placing a mechanical barrier to protect the blood clot and separating the bony defect from the surrounding connective tissue. This permits the osteoblasts to enter an isolated space intended for bone regeneration.[6]

GBR membranes have the potential to effectively restore moderate to severe osseous defects.[15] Titanium meshes have a long record of getting predictable bone regeneration due to their rigidity, ability to conform to the size and shape of the defect, and ability to preserve their shape over time.[16] Soft-tissue dehiscence and membrane or graft exposure are well-known drawbacks of GBR approaches, specifically when using non-resorbable membranes.[17, 18]

However, many augmentation procedures, such as alveolar osteogenesis distraction or bone block reconstruction, require a phased approach, which results in increased morbidity and a longer treatment period.[19, 20] To overcome this disadvantage, the bone ring technique (BRT) has been characterized as a one-

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stage technique for vertical ridge augmentation.[21]
The bone ring technique (BRT) is a one-stage vertical augmentation treatment in which an autogenous or allogeneic cortico-cancellous bone block graft is stabilized with a dental implant placed simultaneously.[21] Additionally, as autogenous grafts exhibit osteoinductive, osteoconductive, and osteogenic characteristics, clinicians typically use autogenous bone blocks to reconstruct alveolar defects in this approach.[22]

Nevertheless, autogenous bone harvesting frequently necessitates an additional surgical site, which may intensify intraoperative suffering and prolong operation time, as well as increase risks and donor site morbidity.[23] Allogeneic bone ring grafts are the most predictable alternative to autogenous ring bone, with approximately similar clinical outcomes.[24] According to several studies, even processed freeze-dried bone allograft (FDBA) is comparable to autogenous bone blocks as regards volumetric graft remodeling rates for restoring single tooth defects.[25]
This research compared two simultaneous bone augmentation procedures in defective sockets in the maxillary aesthetic region: titanium mesh GBR and a custom-made allograft bone ring with immediate implant placement.

Material and Methods:

A randomized clinical trial was conducted on 14 cases who were seeking implant rehabilitation of a partially edentulous atrophic ridge in the Maxillary esthetic zone. The patients were selected from the Out-Patient Clinic of the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Mansoura University. The patients in this study were chosen according to the following criteria: inclusion criteria; age range:18-45 years, good oral hygiene, a freshly extracted socket of single-rooted teeth in the maxillary esthetic zone, and inadequate ridge width and height that needed 3D bone augmentation, while exclusion criteria; active infection, patients on chemotherapy or radiotherapy, alcohol or drug abuse, patients with calcium deficiency or any systemic disorder that contraindicates implant placement surgery, smokers, pregnancy. Written informed consent was taken from all patients. The patients were informed about the benefits, risks, complications, and follow-up times before treatment. This study was approved by the Ethical Committee of the Faculty of Dentistry, Mansoura University with No. (A01040521).
Sample Size: Sample size calculation was based on G*power version 3.0.10 to calculate sample size based on the effect size of 1.34, 2-tailed test, α error =0.05, and power 80.0% then total sample size will be 7 cases at least in each group.[26]
Methods: The patients were randomly and equally divided into two groups:
Group I (control group): involved 7 patients where a titanium mesh-guided bone regeneration was used for ridge augmentation with simultaneous immediate implant placement.
Group II (study group): involved 7 patients where an allogeneic bone ring was used for ridge augmentation with simultaneous immediate implant placement.

A. Preoperative phase: Personal data, medical and dental history: The personal data was taken and recorded in full detail, including the patient's name, age, gender, occupation, residence, and phone number, as well as the medical and dental histories, which were taken from each patient
Clinical Examination: Inspection and palpation of both intraoral and extraoral tissues were done carefully for all cases.
Preoperative preparation:
-Clinical evaluation of the surgical site to rule out any infections or pathological abnormalities.
-CBCT radiographic examination of the recipient site for evaluation of the quantity and quality of the residual bone, measurement of buccal bone volume, as well as bone density.
-Study cast: was made for each patient to evaluate occlusion and inter-arch space.

B. Operative phase:
Surgical procedure: Before surgery, both groups were administered a prophylactic antibiotic (Augmentin, GSK, Hungry) 1g tablet one-hour pre-operative, also mouth-wash (Hexitol 0.12%, ADC, Cairo, Egypt) was used 1 minute immediately before surgery. after the elevation of a rectangular full-thickness mucoperiosteal flap under local anesthesia, the unrestorable tooth was extracted.
For the control group: The titanium mesh was trimmed according to the aluminum foil template, which was used to outline the size and morphology of the defect. After that, the implant site preparation was carried out using the manufacturer's surgical drills to prepare at least 3 mm of residual apical bone to get implant primary stability, Figure 1A. Then, the primary implant stability was determined using Resonance Frequency Analysis Device (Osstell).

An adequate amount of allograft material was wetted in saline in a sterilized dish before being applied to the defect site, Figure 1B. After that, the trimmed Ti-mesh was fitted over the allograft and secured by bone tacks and its applicator in the mesial and distal areas of the buccal wall as well as on the palatal wall to achieve total immobilization of the Ti-mesh, Figure 1C. Finally, Tension-free primary closure was achieved via a horizontal releasing incision on the base of the flap using 4/0 polypropylene with interrupted sutures.
For the Study group: Prepared the recipient site by trephine bur NO 7 the allogenic bone ring (8mm) diameter was inserted and immobilized by friction into the prepared recipient site (7mm) and positioned 1–2 mm above the adjacent socket walls to compensate for any anticipated bone resorption ,Figure 2A, After that, the implant drills were sequentially inserted through

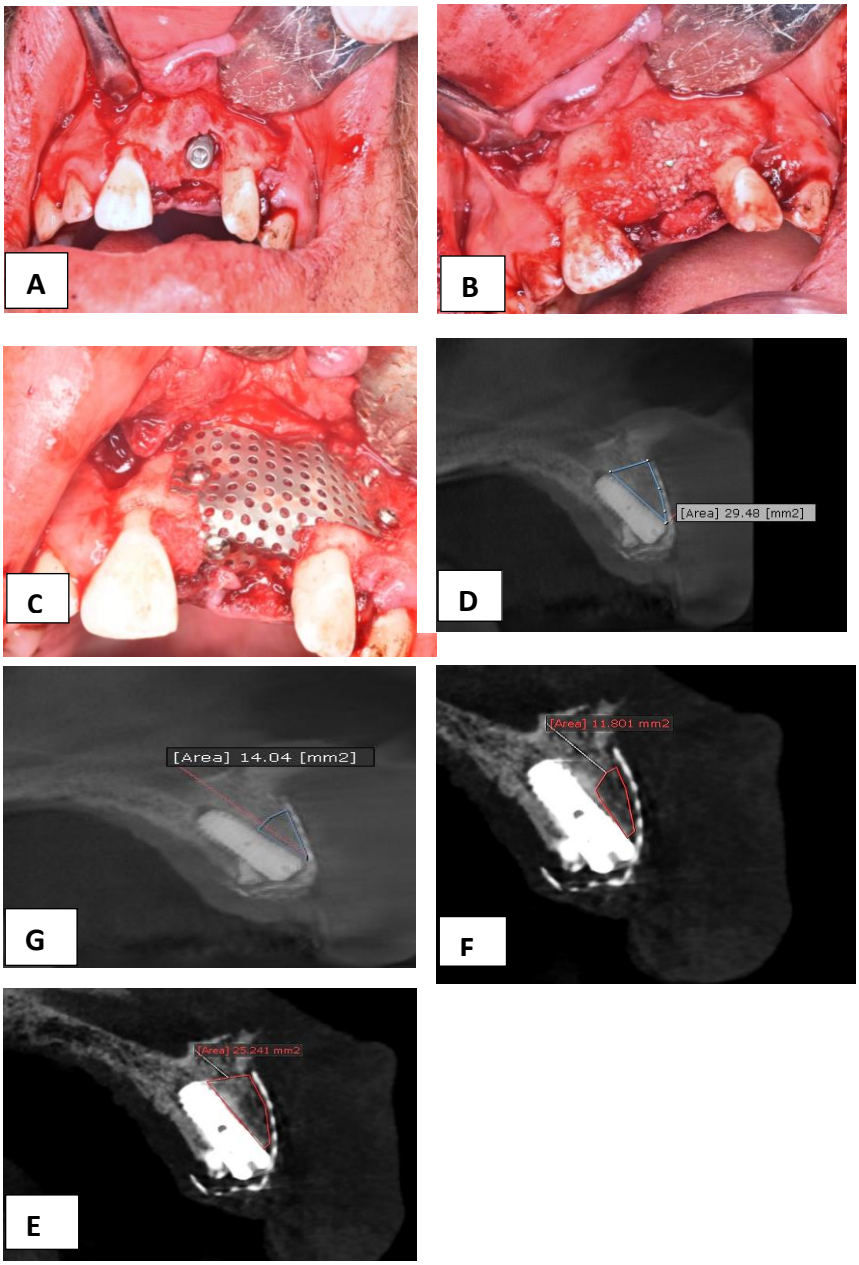

Figure 1: A photograph showing immediate implant placement (A), Applied allograft material (B), Ti-mesh stabilization (C), Cross sectional CBCT view showing immediate post-operative of the relative buccal bone volume (residual bone and bone graft) (D), Cross sectional CBCT view showing immediate post-operative of the relative buccal bone gain (bone graft only) (E), Cross sectional CBCT view showing the relative buccal bone volume at 6 months post-surgery (F), Cross sectional CBCT view showing the relative buccal bone gain at 6 months post-surgery (G).

the central osteotomy of the bone ring to prepare a least least 3 mm of residual apical bone to get implant primary stability, Figure 2B, then , the implant drills were sequentially inserted through the central osteotomy of the bone ring to prepare at least 3mm of residual apical bone to get implant primary stability,, Figure 2B, then the primary implant

C. Postoperative phase: stability was determined using Resonance Frequency Analysis Device (Osstell).

Finally, all flaps were primarily sutured using 4/0 polypropylene with interrupted sutures.

Postoperative Instructions: All patients received: Antibiotic (Augmentin 1g tablet) for 7 days, twice daily, and a non-steroidal anti- inflammatory analgesic drug (Cataflam, Novartis, Switzerland) 50 mg tablet, 2 times daily for 5 days, as well as mouthwash(Hexitol 0.12%)3 times /day.

Follow-up phase: All patients were scheduled for for immediate post-surgery within 1 week (T0) and at 1 month (T1), 3 months (T3), and 6 months (T6) postoperatively. For all cases, the sutures were removed after 2 weeks. Also, the healing process or any signs of infection or dehiscence were detected and assessed.

Second-stage surgery:

For the control group: After six months, a full mucoperiosteal flap was elevated under local

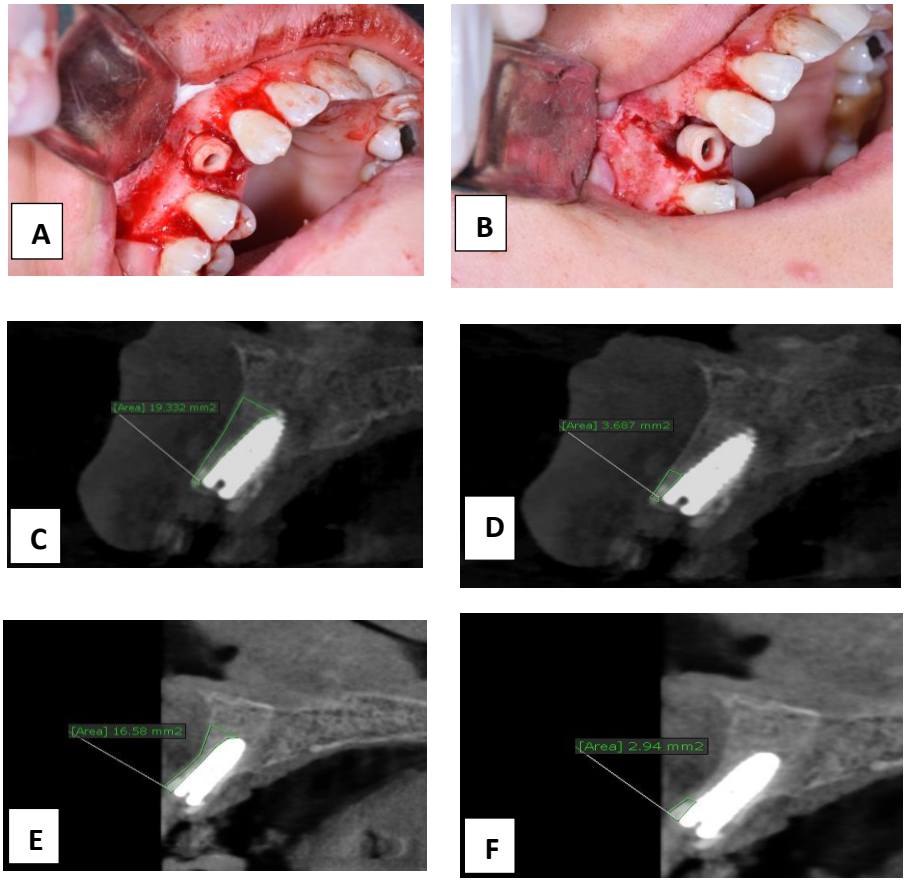

Figure 2: A photograph showing allograft ring placement after socket prepared by trephine NO.7 (A), Immediate Implant placement 1 mm below bone ring (B), Cross sectional CBCT view showing immediate post-operative of the relative buccal bone volume of ring placement (C), Cross sectional CBCT view showing immediate post-operative of the relative buccal bone gain (D), Cross sectional CBCT view showing the relative buccal bone volume at 6 months post-surgery (E), Cross sectional CBCT view showing the relative buccal bone gain at 6 months post-surgery (F).

anesthesia to expose the titanium mesh and to de-attach it. Any soft tissue below the mesh was removed, and stability was recorded for all fixtures using osstell ISQ. After that, the healing abutment was installed, and the gingival flap was sutured to restore the natural gingival profile. The healing abutment was removed after 15 days, and the transfer abutment was placed.

For the Study group: Local anesthesia was performed after 6 months, and the cover screw was exposed through a minor crestal incision, stability was recorded for all fixtures using osstell ISQ and placed on a healing abutment for 10-14 days.

Prosthetic phase: The healing abutment was replaced by the functional abutment, and the impression was taken with the help of an impression post and a laboratory analog before fabricating the working cast. The final porcelain fused to metal restoration was temporarily cemented.

Clinical Evaluation:

Implant stability: The implant stability was measured at (T0) and (T6) using the Osstell device (ISQ).

Soft tissue healing: was assisted by using the soft tissue healing index of Landry et.al. [27] at T1, T3, and T6, Table.

Radiographic Evaluation (CBCT): was taken for each patient at T0 ,Figure 1D, Figure 1E & Figure 2C, Figure 2D, and T6 ,Figure 1F, Figure 1G & Figure 2E, Figure 2F,to assess:

Relative buccal bone volume (RBV): at T0 and T6.The area button was passed to select the area to be measured, Figure 3 A. The measurements included:

1- The residual buccal bone at T0, Figure 3 B.
2- The buccal bone at T0, Figure 3 C.
3- Bone gain at T0 = Buccal bone at T0 (2) - Residual buccal bone (1).
4 -The buccal bone at T6, Figure 3 D.
5- Bone gain at T6 = Buccal bone at T6 (4) - Residual buccal bone (1).
6- Bone loss at T6 = Buccal bone at T0 (2) - Buccal bone at T6 (4).

For standardization, this step was repeated at the middle, mesial, and distal ends of each implant. The RBV was calculated from the mean of these measurements.

Table**:** Soft tissue healing Landry index

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

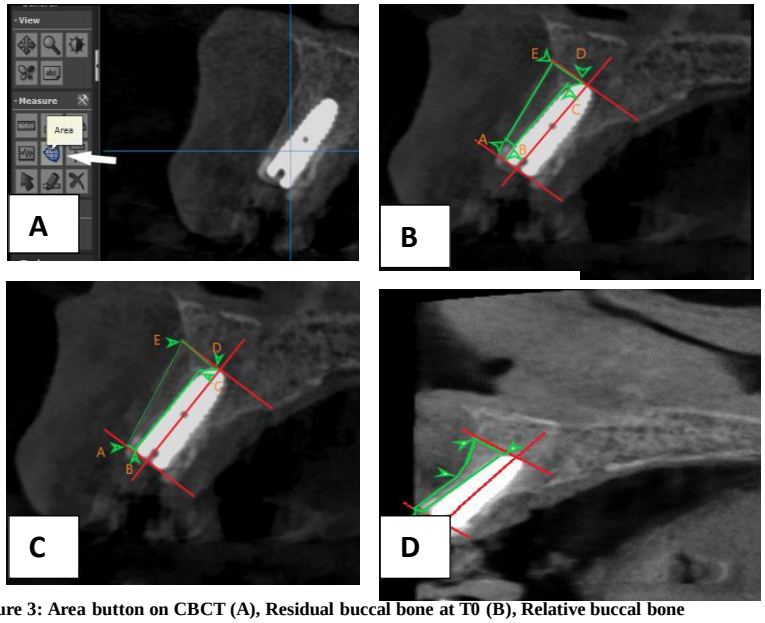

Figure 3: Area button on CBCT (A), Residual buccal bone at T0 (B), Relative buccal bone volume at T0 (C), Relative buccal bone volume at T6 (D).

Relative bone density: The relative bone density (RBD) was measured after six months at the graft–implant interface, and in Hounsfield units [28] a straight line was drawn just parallel to the long axis of the implant from the crest of the bone graft buccally to the apical end of the implant at the same level of 1 mm, 3-mm, and 5-mm from the implant platform in cross-section, Figure 4A & 4B; the mean bone density was obtained from CBCT using the Region of Interest (ROI) tool present in the software.

Statistical Analysis: Data were fed to the computer and analyzed using IBM SPSS Corp. Released in 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using numbers and percentages. Quantitative data were described using median (minimum and maximum) and mean, and standard deviation for parametric data after testing normality using the Shapiro-Wilk test. The significance of the obtained results was judged at the (0.05) level.

Results:

A total of 12 patients who received 14 dental implants were included in the study immediately replaced teeth in the maxillary aesthetic region which were placed simultaneously with titanium mesh-GBR (Group I) or with an allograft bone ring (Group II)

Clinical Evaluation: Assessment of implant stability, Figure 5: The comparison of implant stability between group I and group II revealed that was no statistically

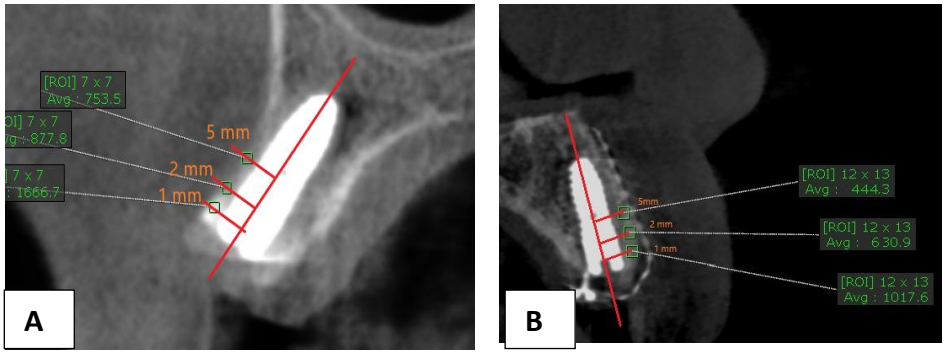

Figure 4: Cross sectional CBCT view showing a relative bone density for allograft ring at T6 (A). Cross sectional CBCT view showing a relative bone density for Ti-mesh at T6 (B).

The comparison of implant stability between group I and group II revealed that was no statistically significant difference between them at T0 and T6. However, within each group implant stability showed a statistically significant increase in implant stability from T0 to T6 p<0.001).

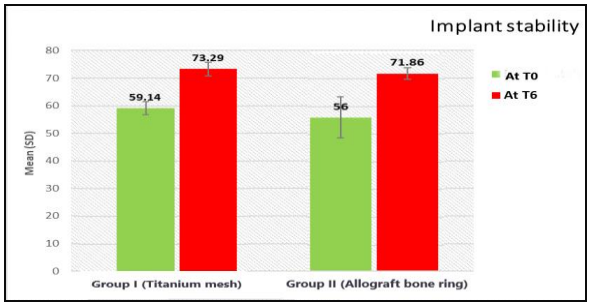

Figure (5): showing implant stability assessment

Assessment of soft tissue healing, Figure (6): Among group (I), 3 cases had no dehiscence and 4 cases with dehiscence where one of them healed at T6, and for the group (II), 7 cases had no dehiscence and 2 cases had dehiscence, because of early exposure in the allograft block, these two cases were removed from the search as failed cases.

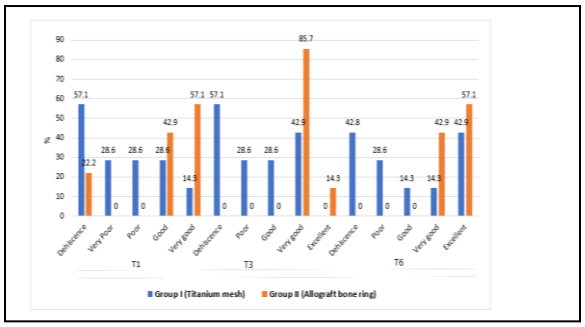

Figure (6): Soft tissue healing among studied groups.

-The healing index showed a statistically significant difference between groups I and II at T3(P=0.048) which was distributed as follows; 57.1% soft tissue dehiscence, 28.6% poor & good, and 42.9% very good for group (I) versus 0% soft tissue dehiscence, 85.7% very good and 14.3% excellent for the group (II).
- The soft tissue healing index showed statistically significant improvement within each of the studied groups (p=0.008&0.02 for groups I & II respectively).

Radiographic Evaluation Comparison of relative bone gain (RBG) and relative bone resorption (RBR), Figure 7.
The current study demonstrated that there was a statistically significant higher mean RBG at T6 and T0 as well as RBR at T6 among group I than in group II.

At T0, the mean RBG was higher in group I, which was 11.55mm^2, compared to 4.51mm^2 for group II, p<0.001.

At T6, the mean RBG for group II was 2.76 mm^2 less than for group I, which was 7.09mm^2, p<0.001. on the other hand, At T6, the mean RBR in group I was 4.45mm^2, which was more than in group II 1.75mm^2, p<0.001.

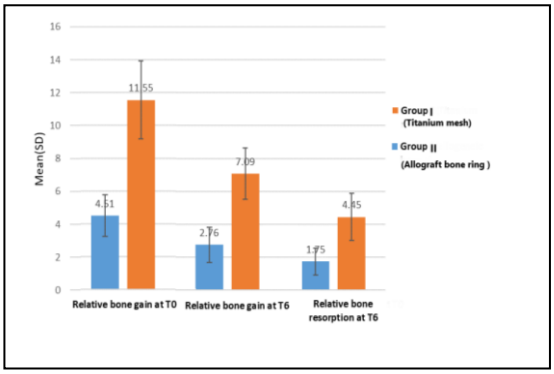

Figure (7): Relative bone gain and resorption among studied groups.

Assessment of relative bone density Figure (8):
Compared bone density group II had a statistically significantly higher mean bone density at 1 mm, 2 mm, and average measured at T6 than group I.

In group I, the bone density varied from D2 to D3 bone types, whereas in group II varied from D1 to D3 according to Hounsfield unite.

Discussion:

One of the main challenges with IIP is bone resorption

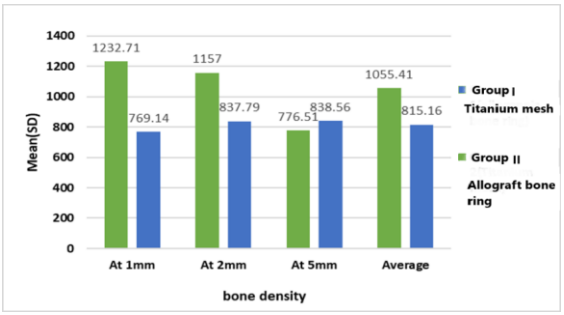

Figure (8): Relative bone density distribution among studied groups.

which may negatively influence the aesthetic outcomes, implant success, and long-term survival rates.[29]

Therefore, several grafting procedures have been developed to fill the space around the implants by using a variety of grafting substitutes. Autografts achieve the best bone graft requirements, including osteogenesis and osteoinductive and osteoconductive properties, as well as avoiding rejection or disease transmission. However, autogenous grafting has several drawbacks, such as donor site morbidity, increased operating time, unexpected resorption, and insufficient bone amount.[30]

To avoid these complications, allograft bone was chosen as an optimal bone substitute for autogenous bone with comparable clinical results.[31] A comprehensive review by Titsinides et al.[32] mentioned some benefits of allograft bone as including an infinite supply, reduced operation stress, no donor site morbidity, and availability in a variety of shapes and sizes as cortical, cancellous, or cortico-cancellous grafts. On the other hand, allografts exhibited slow bone integration and less revascularization, as well as a highly responsive immune system as compared to autologous grafts.[33]

In this research, the implant was placed simultaneously to avoid two surgical interventions or any possibility of bone resorption due to the second surgery; which possibly requires additional augmentation, and decreased overall treatment time.[31] However, taking into consideration IIP with simultaneous augmentation usually increases the risk of complications and low success rate compared to the two-stage approach.[34]

One of the appropriate techniques introduced to place IIP with simultaneous block graft is the bone ring technique (BRT). BRT originally described by Giesenhagen in 2010 allows three-dimensional alveolar ridge augmentation with simultaneous implantation as a one-stage approach.[35]Additionally, the treatment duration for this procedure is faster than

other block grafting procedures because the surgeon uses trephine burs in different diameters to achieve a tight seal for the bone ring within the implantation site (recipient site) when creating the implant bed.[35, 36] Unfortunately, considering a BRT necessitates at least 3–4 mm of apical natural bone to maintain stability for the implant and bone ring. Flap closure without tension is also mandatory to reduce the possibility of ring exposure, which could lead to an adverse effect or failure.[31]

Moreover, another regenerative procedure has been proposed to give three-dimensional alveolar bone augmentation, guided bone regeneration (GBR). The GBR is described as a regenerative technique that uses a barrier membrane with bone graft material to prevent penetration of soft-tissue cells into the defect while allowing growing osteo-cells to recolonize the defect underlying the membrane and new bone formation.[15]

In our study, we evaluated the clinical and radiographical outcomes of two simultaneous techniques in the maxillary aesthetic zone: GBR by using titanium mesh and allograft particulates (group I) and allograft bone ring (group II).

The results of the current study were measured using the Osstell device by recording ISQ (implant stability quotient) at T0 and T6 and revealed no statistically significant difference in implant stability between the two groups at T0 or T6, but both groups I and II showed a statistically significant increase in implant stability at T6 73.29 and 71.86 ISQ respectively, ($p < 0.001$) due to increased bone-implant contact and osseointegration around implants.

This result was comparable to a study by Cucchi et al.[37] who used a simultaneous GBR procedure with titanium mesh in vertical augmentation and found that after 9 months the mean implant stability was 66.56 ± 10.0 ISQ. However, our results are less than Janyaphadungpong et al.[38] evaluated implant stability in simultaneous GBR in the posterior mandible and found mean ISQ values of 72.55 ± 3.10 and 76.20 ± 2.68 at two and three months, respectively.

Furthermore, the implant stability in our study in group II showed comparable results to Elnebairy et al.[39] who conducted a randomized clinical trial to evaluate allograft bone rings around IIP in the aesthetic zone and showed that the mean ISQ value for the allograft ring was 58.0 ± 1.5 immediately after surgery and 68.0 ± 1.4 after 6 months post-surgery. Also, a study published by Pallavi et al.[40] used allograft BRT with IIP in the anterior region and showed the mean ISQ score at the time of surgery was 58 ±1.62, and at 6 months, 69 ±1.59.

In the current study, 4 cases of titanium mesh (57.1 %) were exposed. At T6, only one of them was completely healed. All exposed cases were classified as "Type A" exposure except one which was classified as "Type B" According to Hartmann et al.[41] all of these cases were treated by careful oral hygiene and the application of 0.12 % chlorohexidine gel until all signs of infection disappeared.

Group I, was more challenged regarding the soft-tissue index this may be due to sharp edges and bendings during cutting the mesh, which may cause

trauma to covered tissue and increased incidence of mesh exposure. A study by Atef et al.[42] used 10 titanium meshes to treat atrophic maxillary ridges, three of them exposed within 3 weeks postoperatively and one exposed 4 months later, for a 40% exposure rate. On the other hand, according to Ciocca et al.[43], a 66% rate of mesh exposure occurred during the use of customized titanium mesh due to the stiffness of the titanium mesh, which could cause mechanical irritation to the mucosal flap.

On the other hand, all cases with allograft rings healed well in the current study with no signs of infection, except two failed cases (22.2%), which had soft tissue dehiscence within two weeks of follow-up. This was most likely due to sharp edges or occurred as a result of cracks or fractures in the ring wall during implant insertion, as well as a thin biotype mucosa may be another factor. Krasny et al.[44] used allogeneic bone block in ridge augmentation and reported four cases of failure and a 19% complication rate due to loss of suture support. Pérez-González et al.[45] assessed clinical outcomes in allogenic rings and discussed that the most common complication in the studies examined was block exposure, which affected approximately 30% of the allogeneic bone block, which is comparable to our findings.

The GBR group in our study had a higher average in bone gain compared to the allograft ring group with statistically significant at T0 (11.55 mm2 and 4.51 mm2 $p<0.001$ respectively) and at T6 (7.09 mm2 and 2.76 mm2, $p<0.001$ respectively).
These results were comparable to other studies that used a titanium mesh GBR in a simultaneous approach, Louis et al.[46] and Corinaldesi et al.[47] found that the average bone gain varied from 2.56 to 6 mm at a time of an 8 to 9-month period. The same authors mentioned that the horizontal regeneration was on average 4 mm. Particulate grafts demonstrate higher osteoinduction and osteoconduction than block grafts, according to Pallesen et al.[48] because a much larger area of the graft surface is exposed to growth factors, which could explain why the GBR group gained more bone. According to Briguglio F et al. [49] the maximum vertical regeneration with simultaneous implant placement was 13.7 mm, and the capacity for bone regeneration using a titanium mesh does not have precise values due to differences in the standardization of results.
In terms of bone resorption in the present study, the allograft ring resorption rate at T6 (1.75±0.82 mm2 $P<0.001$) was statistically significantly lower than GBR (4.45±1.43 mm2), which is most likely due to the cortical bone in the ring that decreased vascular infiltration which may lead to a slow rate of remodeling. According to Gultekin et al.[50], several factors may affect resorption rates after block grafts including the type of reconstruction, technique, cortical bone amount and density at the donor site, biomaterial use, and healing time. Damash et al.,[51] expected some differences in remodeling and resorption patterns between the graft types because the particulate bone had a mix of cancellous bone at the surface while the block graft had an intact cortical layer facing the periosteum. Amorfini et al.[52] compared allograft block and GBR and found that the cancellous elements allow for more vascular infiltration, resulting in increased integration, while the cortical component allows for rigid fixation and resorption resistance. Sáez-Alcaide et al.[53] also reported that two studies assessed bone resorption after the bone ring technique, the maximum value recorded was 0.94 ± 0.86 mm[36], and the minimum 0.78 ± 0.23 mm.[54]

In the current study, bone density was measured in Hounsfield units (Hu) at T6 using the ROI tool in the CBCT software and showed statistically significant higher mean bone density at all reference points at 1 mm, 2 mm, and average ($p=0.001$, $p=0.019$ & $p=0.023$ respectively) in the allograft ring compared to the GBR group, except at 5 mm ($p=0.610$) there was no statistically significant difference between the two groups, with the GBR group slightly outperforming the allograft ring.

This result is reasonable given the difference in the amount of cortical bone between the ring block and the bone particles in GBR. Lumetti et al.[55] compared the density of fresh-frozen allograft block (FFB) and autogenous grafts and revealed that the mean initial density of FFB was 708 ± 335 HU, also the study concluded that even though FFB grafts had a wide density range depending on the portion harvested from, FFB grafts with a density of more than 800 HU clinically preferable to less dense grafts, and denser grafts show less resorption than low-density grafts. Macedo et al.[56] also, reported that all allograft blocks augmented in the maxilla and mandible exhibited acceptable bone density similar to bone type II. Cucchi et al.[37] used the simultaneous GBR procedure and titanium mesh, and they noticed Type I and II bone density in all cases. A study by Kumar et al.[57] evaluated titanium mesh with simultaneous implant placement and found that bone density in the mesial and distal sides was 1280 and 1850 Hu, respectively, at 6 months after surgery.

Conclusions:

The main limitations of this study are the short-term follow-up period, the implants being evaluated before loading, a variable defect size, and a small sample size which was unable to rule out all confounding factors.

Within the limitations of the current study, the simultaneous application of GBR-titanium mesh or allograft bone ring with IIP in the maxillary aesthetic zone appears to provide good and stable results in implant/prosthesis success.

Although the GBR procedure achieved better comparable clinical results than the allograft bone ring, the allograft ring technique was more acceptable to

patients because it was less time-consuming and less traumatic as it did not necessitate a second surgical intervention.

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