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ORIGINAL ARTICLE

Horizontal ridge augmentation using native collagen membrane vs titanium mesh in atrophic maxillary ridges: Randomized clinical trial

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Abstract

Background: Several techniques have been proposed to reconstruct deficient alveolar ridges including bone blocks, ridge splitting and guided bone regeneration (GBR). GBR has been successfully established in restoring horizontal bone deficiency. However, yet still there is a debate regarding the ideal barrier for GBR.

Purpose: To evaluate the quantity and the quality of the bone gained using collagen membrane with 1:1 mixture of autogenous and anoraganic bovine bone mineral compared to titanium mesh with the same mixture of bone for GBR of horizontally deficient maxillary ridges.

Materials and Methods: Two different grafting techniques were evaluated, 10 patients receiving GBR using native collagen membrane using 1:1 autogenous and anorganic bovine bone mineral (ABBM) bone mixture, and 10 patients receiving GBR using titanium mesh with same mixture of bone.

Results: Statistical analysis showed a significant increase in alveolar bone width in both techniques with a mean bone gain of 4.0 mm for Collagen group and 3.7 mm for titanium mesh group. Bone area percent was almost 28% for both groups. For Ti-mesh group, six sites soft tissue healing was uneventfully with no signs of wound dehiscence. However, four cases showed mesh exposure first 3 patients showed this exposure 3 weeks postoperatively while the fourth patient showed exposure 4 months postoperatively. The mean graft resorption in the Collagen and mesh group 6 months postoperative was considered nonsignificant.

Conclusions: GBR with both collagen membrane and titanium mesh using a 1:1 mixture of autogenous and ABBM is a viable technique for horizontal augmentation of deficient maxillary alveolar ridges. Titanium mesh is a more technique sensitive compared to collagen membrane. Soft tissue dehiscence and difficulty during second stage removal should limit its use in augmentation of horizontally deficient maxillary ridges.

KEYWORDS

ABBM, atrophic maxilla, dehiscence, guided bone regeneration, histological analysis, particulate mix, titanium mesh

1 | INTRODUCTION

Dental implants have become one of the most sought procedures to restore missing teeth. Among the challenges that may hinder successful implant placement is the inadequate ridge volume. According to literature, alveolar ridge resorption reaches 40% in height and 60% in width after 2 to 3 years, meaning that horizontal ridge dimension is affected more than vertical dimension.[1] Horizontal ridge atrophy can be attributed to the unavoidable ridge resorption following tooth extraction or traumatic tooth removal.[2]

Many techniques have been discussed in literature to manage horizontal ridge deficiency including onlay block grafting, ridge splitting, and guided bone regeneration.[3-5] Guided bone regeneration (GBR) has been successfully established in restoring horizontal bone deficiency in maxilla,[4] which rely on preventing the soft tissue cells incorporation into the bone graft or the space created by the defect and allow only the osteogenic cells to be present, thus resulting in bone formation into this space. This is achieved by different barriers which can be resorbable or nonresorbable.[6]

Among resorbable barriers are collagen membranes, crosslinked or non-crosslinked, polyglygolic acid membranes and other types as reported in literature. Nonresorbable membranes include d-PTFE, e-PTFE, titanium foils, and titanium meshes. Different mixtures of particulate bone graft have been proposed in literature. These include an equal mixture of autogenous and anorganic bovine bone mineral which showed successful horizontal augmentation for guided bone regeneration with a non-crosslinked collagen membrane as shown by Urban[4] et al in 2013.

The factors that enable successful guided bone regeneration with native collagen membrane include its biocompatibility, the rapid vascularization for the particulate graft necessary for its maturation and its elasticity allows for a higher volume of particulate graft. However, it cannot maintain the shape of the augmented defect without collapsing. On the other hand, titanium mesh can provide volumetric stability without being affected by the overlying muscle action despite the reported risk of wound dehiscence associated with titanium meshes.

Hence, the aim of the present study was to evaluate the horizontal bone gain as a primary outcome and histomophometric analysis of bone area percent as a secondary outcome using native collagen membrane with 1:1 mixture of autogenous particulate and anorganic bovine bone mineral (ABBM) vs using titanium mesh with the same mixture of bone particulate for GBR of horizontally deficient maxillary ridges with residual alveolar width ranging from 2 to 4 mm. The bone area percent of the newly generated bone will affect the bone to implant contact after implant placement.

2 | PATIENTS AND METHODS

Patient recruitment was carried out from the out-patient clinic of the Oral and Maxillofacial Department at Cairo University. Inclusion and exclusion criteria are reported in (Table 1).

TABLE 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age: 20-60 years	Pathological lesions in the defect site
Totally or partially edentulous maxillary ridges (Cawood Class IV)	Systemic diseases that would interfere with bone metabolism
Residual alveolar width ranging from 2 to 4 mm	Uncontrolled diabetic patients
Minimum of 10mm vertical dimension to nasal floor or sinus floor	Ongoing treatment or a history of recent chemotherapy or radiotherapy

Using a power of 80% and a 5% significance level, a total of 20 patients were included for horizontal ridge augmentation using guided bone regeneration by either native collagen membrane or titanium mesh with an equal mixture of autogenous particulate and anorganic bovine bone mineral.

This study was approved by the Ethical committee of Faculty of Dentistry, Cairo University. The benefits and risks were explained to all patients and all included patients accepted to enroll in the study. After discussing the treatment plan with the patients, they were educated about the nature of the procedure and written consents were signed by each candidate.

For all patients, clinical examination including preoperative impressions, photographs, and radiographs were done. Both digital panorama with 1:1 magnification and preoperative cone beam computed tomography (CBCT) were done to exclude any pathosis and measure the bone width of the deficient area, respectively. Bone width was measured from the reformatted cross sectional image of the CBCT 2.0 mm below the tip of the crest at every single deficient site taking a specific anatomical landmark in the opposing teeth as a reference point for the measurements taking into consideration that the patients were biting in maximum intercuspation. The average of these measurements was calculated to be a representative value of the preoperative width for each case from the preoperative CBCT. Immediate and 6 months postoperative CBCT was done while the patients were also biting in maximum intercuspation and the same measurements were taken from the same reference areas that were previously selected from the preoperative scan. Alveolar height was measured from crest of the ridge to the nasal floor or sinus floor.

The patients were randomly divided by using block randomization with stratification (four blocks) and were assigned into two groups, the collagen group received the augmentation using collagen membrane while the titanium mesh group received augmentation with titanium mesh and for both groups the particulate graft was an equal mixture (1:1) of autogenous and ABBM.

All procedures were carried out by the same surgical team under local anesthesia in combination with midazolam 10 mg (Dormicum, Roche) intramuscular and amoxicillin/clavulanate 2 g (Hibiotic, Amoun, Egypt) 1 hour before the surgery.

2.1 | Surgical procedure

A full thickness flap was elevated with two releasing incisions extending at least just distal to each tooth adjacent to the defect site. However, vertical incisions at the canine eminence were avoided and instead extended distal to the canine to avoid future dehiscence at this site. The flap was reflected adequately to expose the defect.

Autogenous bone particulate was harvested either from the mandibular symphysis or ramus. A beveled partial to full thickness mucoperiosteal incision 5 to 10 mm below the mucogingival junction was performed at the symphyseal region to expose the donor site. The incision extended just distal to the mandibular canines to allow for adequate access and easier adaptation of the flap. When the mandibular ramus was used as a donor site, a submarginal incision was placed within the keratinized mucosa opposite to the lower first molar and extending 1 cm along the ramus of the mandible.

For both donor sites, autogenous bone was harvested either by using a trephine of 4 mm inner diameter (Mr. Curette Dental Instruments, Korea) and after retrieval of the cortical rings they were crushed using a bone mill (Quetin, Leimen, Germany). An Auto-chip maker (ACM) bur (Neobiotech, Korea) was used in some cases instead of the conventional trephine bur to skip the milling procedure as this bur crushes the bone as it is being harvested (Figures 1 and 2).

The donor site at the chin was closed in two layers, the deep muscular layer was first sutured using 4-0 resorbable interrupted sutures (Polyglactin, Assut, Switzerland) and the mucosal layer was then closed using simple interrupted sutures with 5-0 synthetic monofilament suture (Prolene, Assut, Switzerland).

Equal volume of particulate ABBM (Cerabone, botiss biomaterials, Germany) was added to the harvested autogenous bone to create 1:1 composite graft. The recipient site was debrided from any soft tissue or periosteum remnants and for the collagen group a resorbable collagen membrane (Jason membrane, botiss biomaterials, Germany) was placed and fixed starting from the palatal side with at least two titanium tacks (titan pin set, botiss biomaterials, Germany) (Figure 3). The particulate composite graft was packed onto the defect and overfilling was done to compensate for future resorption.[7] The membrane was stretched tightly over the graft and titanium tacks was placed at the

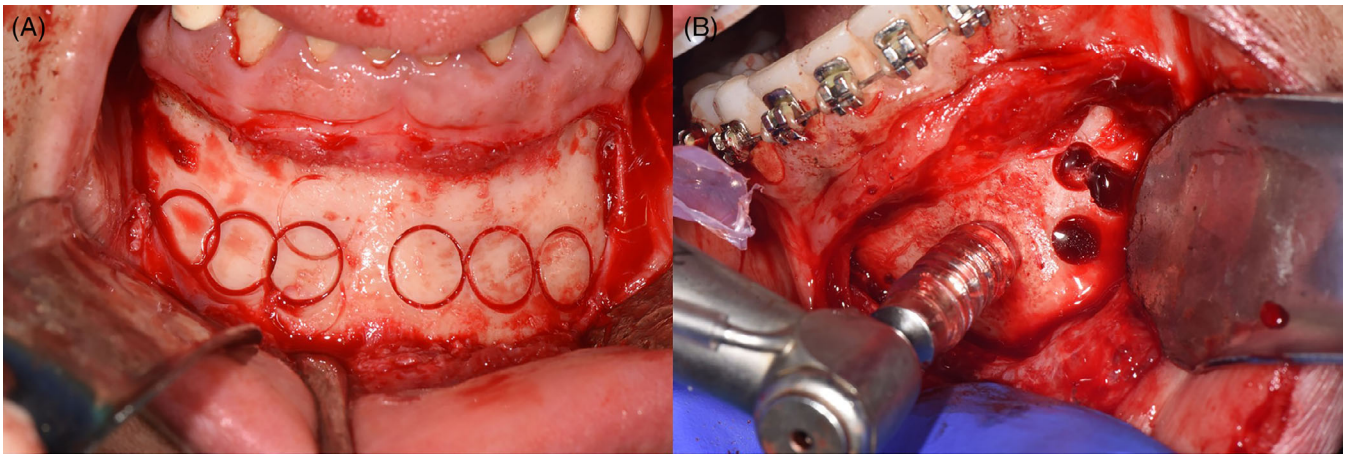

FIGURE 1 A, Bone harvesting using trephine bur 4.0 mm (case 1—collagen group). B, Particulate bone harvesting using Auto chip maker (ACM) bur (case 19—collagen group)

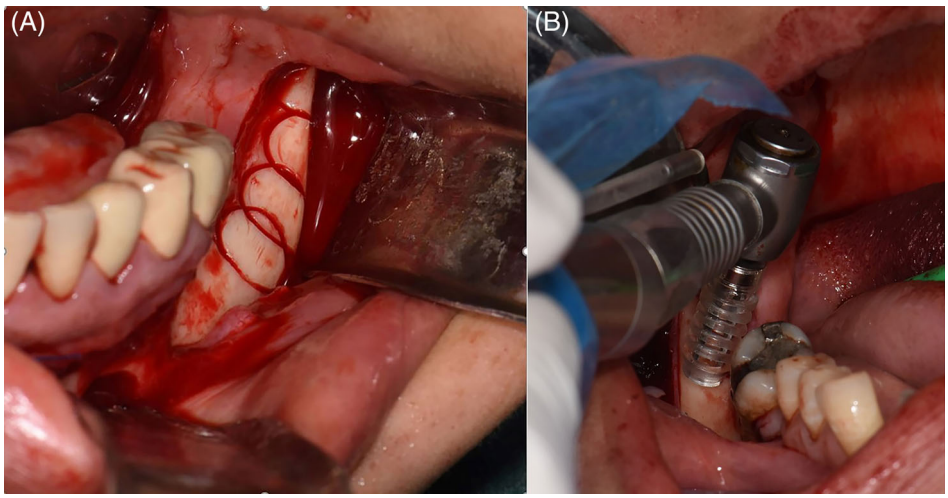

FIGURE 2 A, Bone harvesting from retromolar area (case 4—titanium mesh group). B, Particulate bone harvesting using Auto chip maker (ACM) bur (case 20—collagen group)

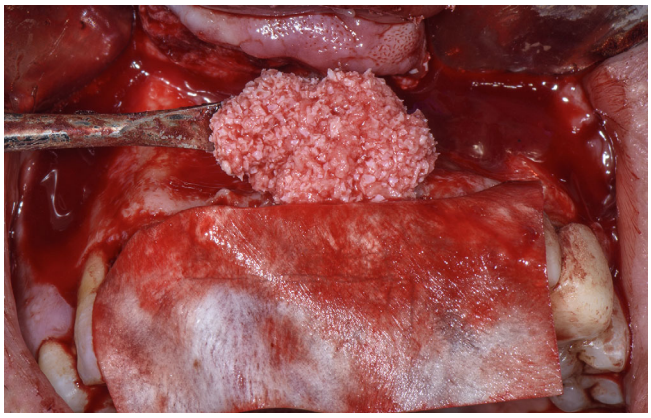

FIGURE 3 Fixation of the membrane on the palatal side first using bone tacs then filling the defect with the bone mixture is done (case 1—collagen group)

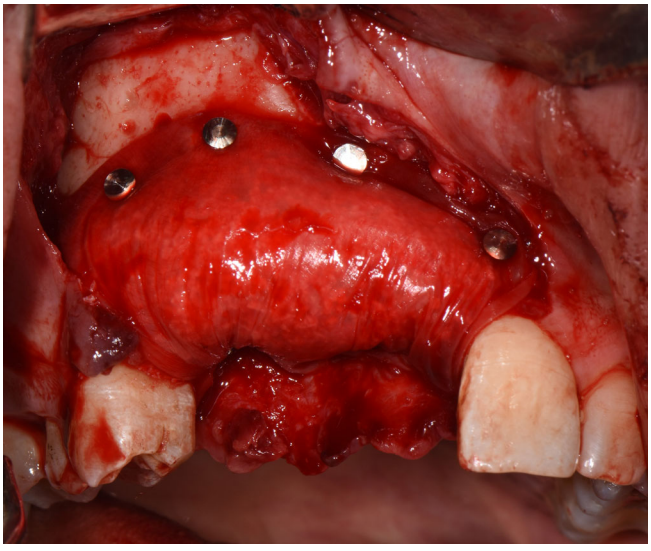

FIGURE 4 Fixation of the membrane on the labial side (case 11—collagen group)

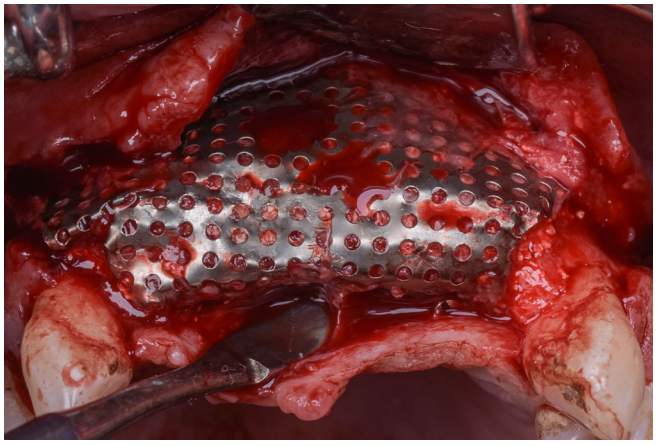

FIGURE 5 Fixation of the mesh labial and palatal using osteosynthesis mini screws 2.0 mm (case 14—titanium mesh group)

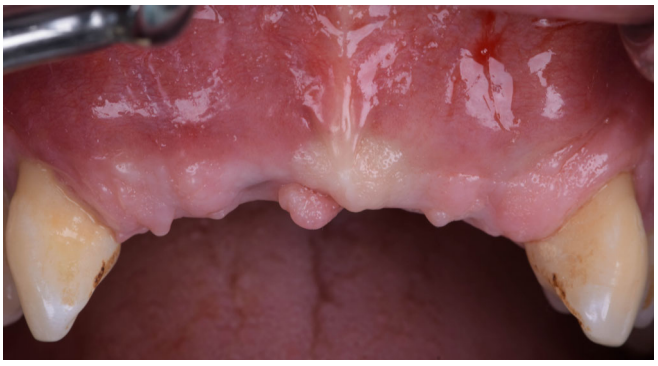

FIGURE 6 Clinical evaluation of case 14 (titanium mesh group) 3 months postoperatively

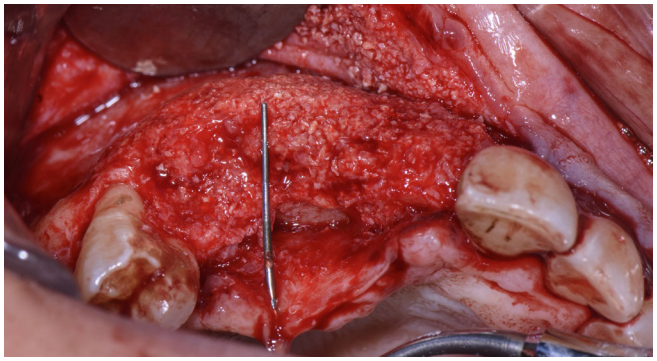

FIGURE 7 Exposure of the augmented ridge (case 11—collagen group)

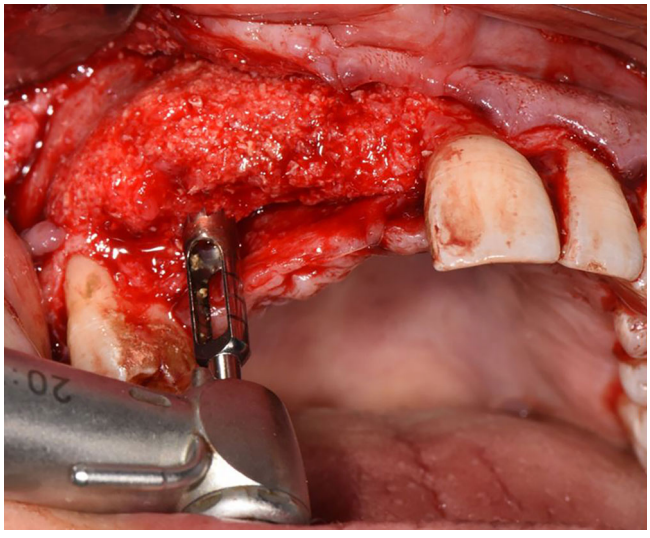

FIGURE 8 Core biobsy harvesting (case 11—collagen group)

labial side to fix the membrane in place. Additional particulate was packed under the membrane laterally to over fill the site (Figure 4).

For the titanium mesh group, an aluminum foil was adapted to the defect site and used as a guide for trimming the titanium mesh and ensure its adequate fit. The titanium mesh (Bioinnovation, Brazil) was

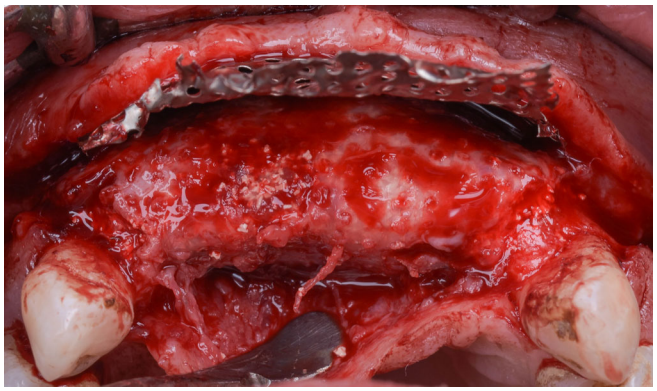

FIGURE 9 Removal of titanium screws and mesh (case 14—titanium mesh group)

polished to prevent dehiscence or premature exposure. It was then stabilized over the particulate graft by 2 mm titanium mini screws (Optimus D, Osteonic, Korea) at the labial and palatal sides (Figure 5).

Finally, after flap advancement, closing was done with a double layer suturing technique using an apical horizontal mattress 5 mm below the incision and simple interrupted coronal to the matress using 4-0 polypropylene sutures (Prolene, Assut, Switzerland).

Postoperatively, all patients received amoxicillin/clavulanic acid 1 g (Hibiotic, Amoun, Egypt) every 12 hours for 5 days and ibuprofen 600 mg (Brufen, Abbott, Egypt) every 8 hours for 5 days. A chlorhexidine 0.2% (Claradine, Medpharma, UAE) mouthwash was prescribed to be used every 8 hours for 14 days. Postoperative instructions included cold fomentation for 10 minutes every half hour for the first

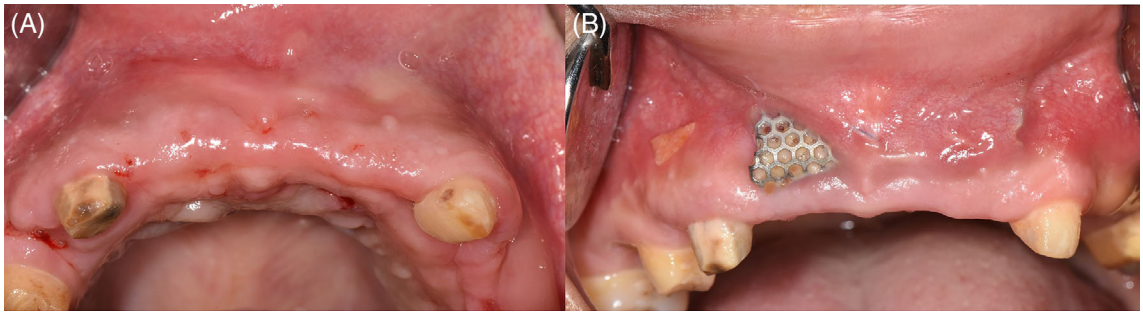

FIGURE 10 Case 2—titanium mesh group, A, absence of dehiscence at 3 weeks postoperative. B, Titanium mesh exposure 4 months postoperative

TABLE 2 Summary of treated cases showing defect size, preoperative bone width, bone gain after 6 months, and complications during treatment

Treatment group	Patient number	Defect size (number of teeth)	Preoperative bone width (mm)	Bone Gain after 6 mo	Complications
Collagen group	1	4	3	4	
	3	3	3.7	4.3	
	5	2	3.5	4.5	
	7	3	3.5	1.5	Dehiscence and infection
	8	1	3	4	
	11	3	3.2	4.3	
	16	4	3	4.5	
	17	1	3.5	4.1	
	19	3	2.8	4.2	
	20	2	4	4	
Titanium mesh group	2	4	3.5	3.5	Delayed exposure
	4	2	3.6	3.9	
	6	3	4	1	Premature exposure
	9	4	4.3	1.7	Premature exposure
	10	4	2.5	4.5	Premature exposure
	12	3	3	4.5	
	13	2	4.1	3.9	
	14	2	3.8	3.7	
	15	1	3	3	
	18	2	4.2	3.8	

day and hot fomentations starting the day after the surgery. The patients were instructed to follow strict hygiene measures including brushing their teeth and using the mouthwash.

Follow-up protocol was as follows, every other day for the first week, weekly for the first month, and then monthly for 3 months (Figure 6). Immediate postoperative CBCT scans were ordered for all patients and at 6 months interval, to assess the amount of horizontal bone gain which is the primary outcome.

2.2 | Second stage surgery

After 6 months, re-entry was done utilizing a full thickness mucoperiosteal flap (Figure 7), and a core biopsy was taken using a 2 mm trephine bur from the preplanned implant positions in the direction of the implant osteotomy (Figure 8) for histomorphometric analysis of the augmented bone to measure the bone area percent which is the secondary outcome. For the titanium mesh group, the titanium mini screws were removed and the mesh was rolled off the alveolar ridge (Figure 9). Dental implants with diameters ranging 3.7 to 4.2 mm were inserted in the augmented ridge.

2.3 | Histomorphometric and statistical analysis

The core biopsies were sectioned and stained with H&E stain for examination under a light microscope with a ×50 magnification (Olympus CX23, Olympus, Japan). Bone volume was measured for each specimen and the mean volume for native bone and newly formed bone was calculated for statistics. Quantitative histomorphometric analysis was performed by OLYMPUS Stream software (Olympus, Japan). Data management and statistics were done by using the Statistical Package for Social Sciences version 22 (SPSS Inc., Chicago, IL). Description of numerical data was done as means and standard deviations. Normality in the data was explored by using Kolmogorov-Smirnov (KS) test and Shapiro-Wilk test. Comparisons between two groups and overtime were done by two way repeated measure ANOVA. Comparisons between the two groups at each time point were done using the independent *t* test. Overtime comparisons in each group were done by repeated measure ANOVA followed by post hoc-paired *t* test. All tests were two tailed. A P value ≤ 0.05 was considered significant.

3 | RESULTS

For both groups, all patients showed uneventful soft tissue healing with no infection except one case in the collagen group (case 7) who

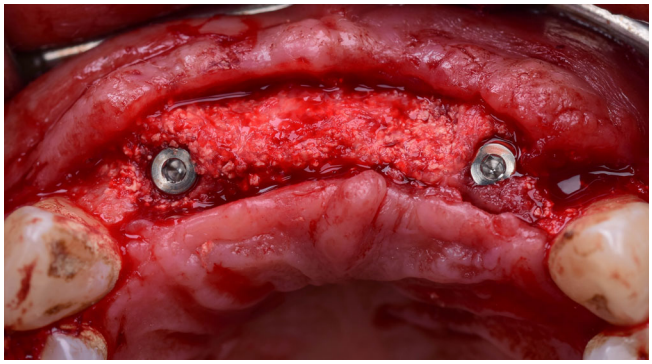

FIGURE 11 Implants in place 6 months postopratively (case 14—titanium mesh group)

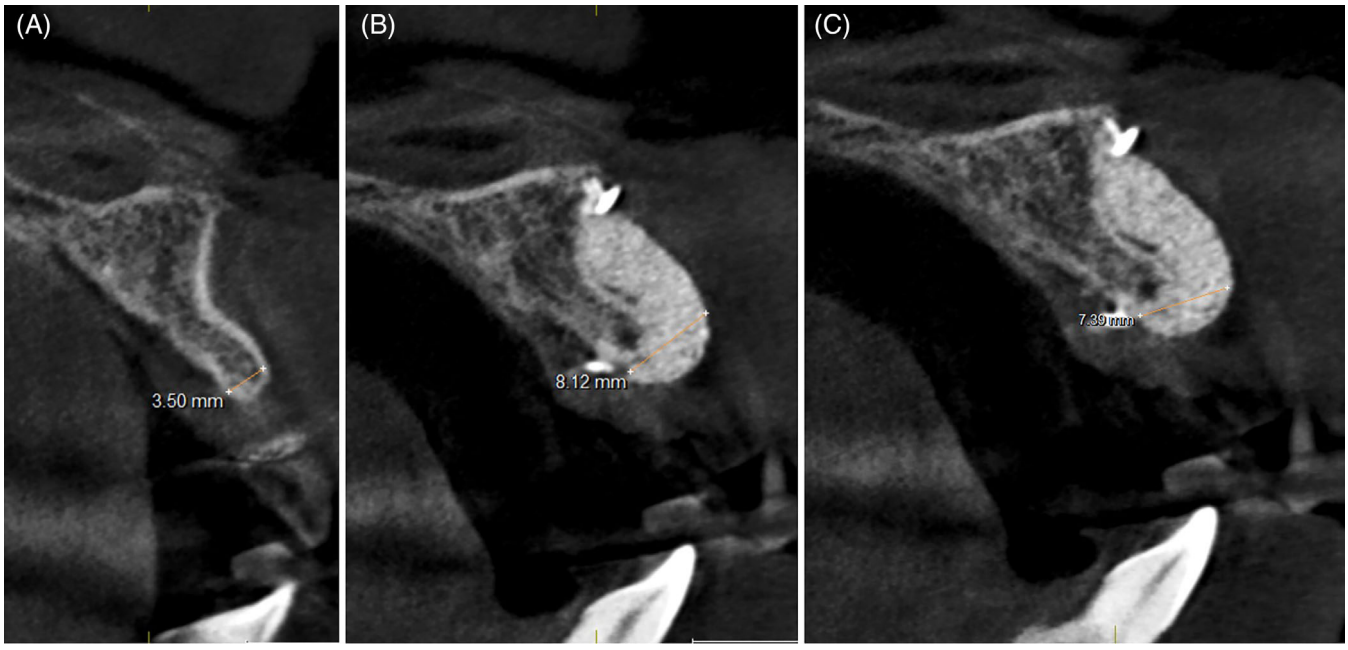

FIGURE 12 Collagen group: A, preoperative, B, immediate, and C, 6 months postoperative cross-section cuts

reported postoperative infection and graft exposure after 1 week. During the follow-up period, four patients in the titanium mesh group presented with soft tissue complications, cases 6, 9, and 10 showed soft tissue dehiscence with subsequent mesh exposure 3 weeks postoperatively. Broad spectrum antibiotics of amoxicillin/clavulanic acid (Hibiotic, Amoun, Egypt) 1 g every 12 hours orally was prescribed and copious chlorohexidine irrigation was done for 7 days followed by removal of the mesh in cases 6 and 9.[8] While in case 10, the mesh was left as he had good oral hygiene. Case 2 had an exposure after 4 months leading to mesh removal (Figure 10), and copious chlorhexidine irrigation was performed until healing with secondary intention occurred.

In case 6, the amount of horizontal bone gain was 5 mm immediately postoperatively and 1 mm after 6 months losing 80% of the grafted volume, and in case 9, it was 4.7 mm immediately postoperative and 1.7 mm after 6 months losing 64% of the grafted volume. On the other hand, in case 10, the graft resorption was 18% after 6 months. A summary of the treated cases are represented in (Table 2).

Two patients showed prolonged altered sensation of the area supplied by the terminal branches of the infraorbital nerve due to aggressive reflection of the flap which resolved 1 month postoperatively. As for the donor site, chin harvesting in single showed postoperative morbidity regarding flap closure 2 weeks postoperatively, copious saline irrigation and follow up was done until complete healing 40 days postoperatively.

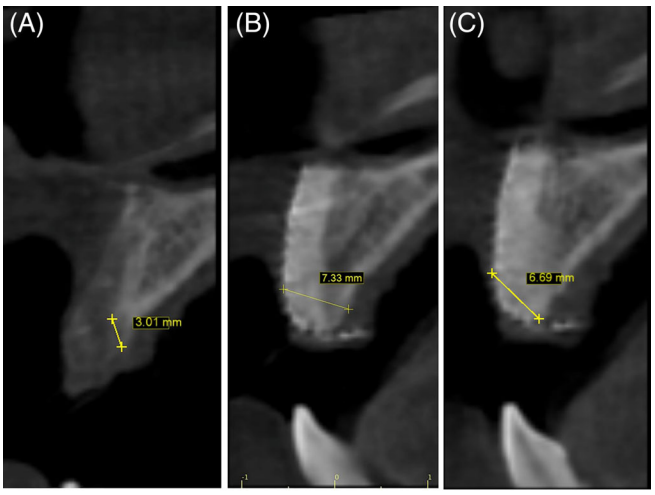

FIGURE 13 Titanium mesh group: A, preoperative, B, immediate, and C, 6 months postoperative cross-sectional cuts

At 6 months re-entry surgery, all cases showed sufficient bone gain that allowed conventional implant placement (Figure 11) except (case 6 and 9) in the titanium mesh group that showed insufficient bone gain and a regrafting procedure was carried out using mandibular cortical shells according to Khoury[9] et al.

Radiographically, the preoperative mean bone width of the collagen membrane group was 3.3 ± 0.4 mm and increased to a mean of 7.9 ± 0.6 mm immediately postoperative. At 6 months postoperative, it decreased slightly to reach a mean of 7.3 ± 0.9 mm. This was statistically significant ($P < .001$) (Figure 12). For the titanium

TABLE 4 Mean, SD, and independent *t* test of bone width in Collagen and Titanium mesh groups

	Collagen group		Titanium group		
	Mean	SD	Mean	SD	*P* value
Preoperative	3.3	0.4	3.6	0.6	.228
Immediate	7.9	0.6	8.0	0.7	.641
6 mo	7.3	0.9	7.0	0.9	.470

Note: $P \leq .05$ is considered statistically significant.

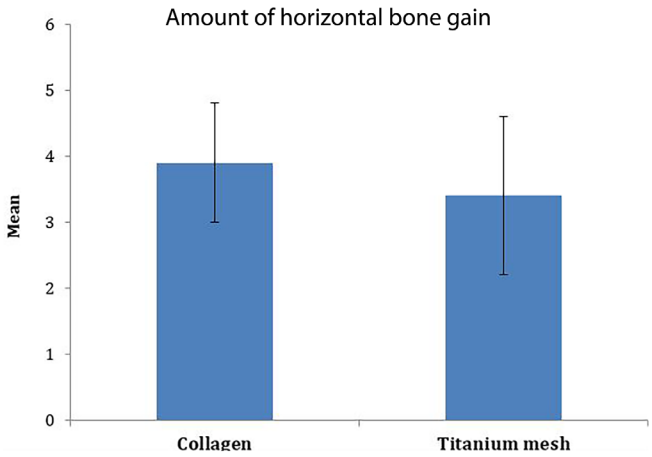

FIGURE 14 Bar chart representing mean and SD of Amount of horizontal bone gain between the studied two groups

TABLE 5 Mean, SD, and independent *t* test of horizontal bone gain in Collagen and Titanium mesh groups

	Collagen group		Titanium group		
	Mean	SD	Mean	SD	*P* value
Gain	3.9	0.9	3.4	1.2	.214

Note: $P \leq .05$ is considered statistically significant.

TABLE 3 Mean, SD, and repeated measure ANOVA test of bone width in both groups

	Preoperative		Immediate		6 mo		
	Mean	SD	Mean	SD	Mean	SD	*P* value
Collagen group	3.3	0.4	7.9	0.6	7.3	0.9	<.001
Titanium mesh group	3.6	0.6	8.0	0.7	7.0	0.9	<.001

Note: P value describes difference between preoperative and 6 months measurements. *P* value ≤.05 is considered statistically significant.

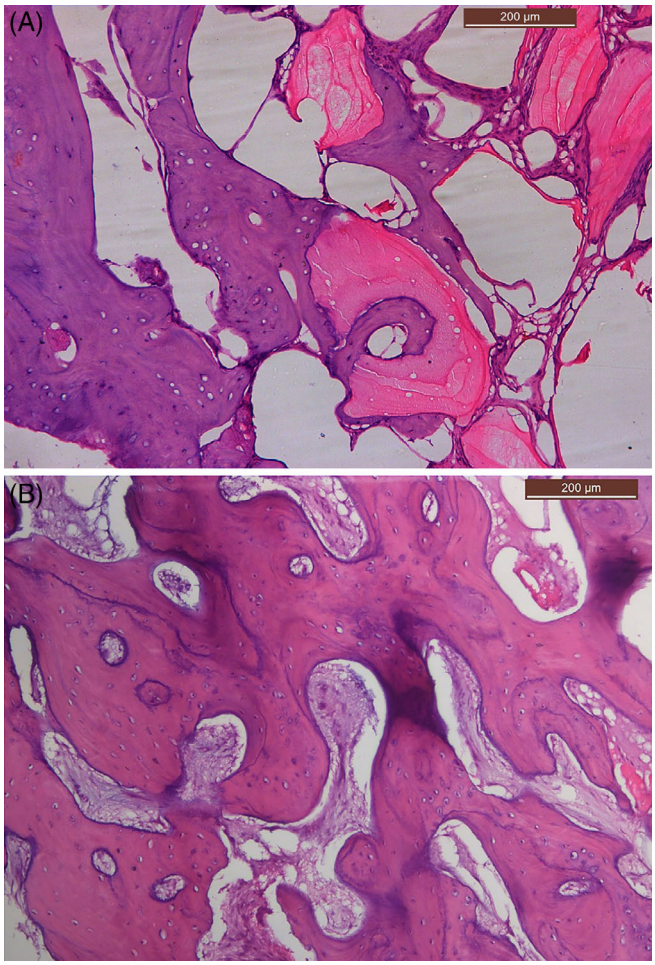

FIGURE 15 Overview of a histologic section (Hematoxylin & Eosin) of, A, collagen and, B, titanium group taken after 6 months of graft healing. The original maxillary bone can be seen. The augmentation area is connected with newly formed bone to the original maxillary bone (original magnification ×50). Formation of dense trabecular structures composed of newly formed bone with integrated ABBM granules

mesh group, the preoperative mean bone width was 3.6 ± 0.6 mm and increased to 8.0 ± 0.7 mm immediately postoperative. Six months postoperatively, it decreased slightly to reach 7.0 ± 0.9 mm (Figure 13). This was statistically significant ($P < .001$) (Table 3).

Comparing bone width between the two groups, the preoperative mean bone width of Collagen group was 3.3 ± 0.4 mm compared to 3.6 ± 0.6 mm in Titanium mesh group ($P = .228$). The immediate postoperative mean bone width of Collagen group was 7.9 ± 0.6 mm compared to 8.0 ± 0.7 mm in titanium mesh group ($P = .641$). Six months postoperatively, the mean bone width of Collagen group was 7.3 ± 0.9 mm compared to 7.0 ± 0.9 mm in titanium mesh group ($P = .470$). All differences were not statistically significant (Table 4).

The mean bone gain of collagen group was 3.9 ± 0.9 mm compared to 3.4 ± 1.2 in titanium mesh group. This was also statistically not significant ($P = .214$) (Figure 14 and Table 5).

3.1 | Histological results

Eleven specimens were examined histologically seven from collagen group and four from mesh group due to the difficulty to retrieve a sound and solid core biopsy from all cases. The histologic samples were taken 6 months postoperatively using a 2.0 mm trephine bur from the planned implant sites.

Histomorphometric analysis showed that the mean bone area percent at the augmented area within the Collagen group was 28.18% within the specimens, ABBM (residual particles) 23.78%, while bone marrow spaces 48.11%. Within all the evaluated specimens, particles of ABBM was found to be connected with new bone which showed different maturation degrees that was also connected to the native bone. The collagen membrane had no evidence in the histology. While in the Titanium mesh group average bone area percent was 27.8%, residual particles 23.6%, and marrow spaces 48.5% (Figure 15 and Table 6).

TABLE 6 Histomorphometric analysis for both groups

Group	Patients no.	Bone area (%)	Residual particles (%)	Marrow spaces (%)
Collagen group	3	29	25	46
	19	28.2	24.5	47.3
	11	27.5	23	49.5
	16	27	23	50
	5	29	24.2	46.8
	17	27.9	23	49.1
	20	28.7	24	47.3
Titanium mesh group	13	28	24	48
	14	28.5	24	47.5
	15	28	23.5	48.5
	18	27	23	50

4 | DISCUSSION

In the present study, 20 maxillary alveolar surgical sites were horizontally augmented using collagen membrane or titanium mesh with 1:1 mixture of autogenous and ABBM in both techniques. Autogenous bone particulate has been harvested from sympheseal region or mandibular ramus and both are intramembranous bone from the same embryological origin. The bone was harvested using a trephine bur and milled using a bone mill (Quetin, Leimen, Germany) as recommended by Urban.[10] However, from the authors subjective point of view, the use of autogenous chip particulate maker (ACM) saved time intraoperative and added to the viability of the harvested bone. Selection between mandibular symphysis and ramus is based on the quantity needed as the symphysis area has much more corticocancellous bone to harvest.

The cases were randomly divided into two equal groups using block randomization with stratification (four blocks). The aim of the study was to compare the amount of horizontal bone gained between both groups and compare the quality of gained bone between both groups using histomorphometric analysis. Since the crest of the ridge is the most commonly horizontally deficient area due to the pattern of resorption, the preoperative horizontal bone width measurement was taken 2 mm below the crest of the ridge in a plane perpendicular to the planned implant axis. Accordingly, the immediate postoperative and the 6 months measurement was taken using the same method.

Various treatment modalities have been proposed in literature for management of different bone defects. GBR can be utilized for management of fenestration, dehiscence defects and severely thin alveolar ridges (Cawood Class IV). Bone block grafts covered by biomaterials and membranes or autogenous cortical shells covering a particulate graft are used to treat these defects. More recently, particulate bone grafts covered by different barrier membranes were introduced to avoid the morbidity associated with autogenous block harvest.

Although autogenous bone blocks have been used for a long period of time as a successful technique for horizontal and vertical ridge augmentation with a success rate up to 97.1%.[11] It is also associated with varying degrees of morbidity at the second surgery donor site,[12] limited quantity of intraoral grafts, and the high morbidity of bone harvesting from extraoral sites with the disadvantage of rapid resorption,[13] unlike GBR technique.

Resorbable membranes especially collagen pericardium membranes that had been designed to slowly resorb over a period of time up to 4 to 6 months[14] provide a biocompatible barrier that will allow the grafted region to consolidate specially with the permeability of the collagen membrane that enrich the graft with blood supply from the periosteum, and they have shown better soft tissue compatibility compared with nonresorbable membranes.[15] The thickness of this type of resorbable membranes (0.5 mm) and the elastic property allowed for easy and more reliable immobilization of the bone graft as it can be stretched out during membrane tacking on both vestibular and palatal sides that is why the use of titanium micro tacks was mandatory.

Selection of titanium mesh in the present study was based on the fact that they are considered to be among the most predictable and successful barriers for guided bone regeneration. They are characterized by having a macroporous structure which is useful to enhance bone regeneration by providing the graft with rich blood supply for its vascularization and they have the advantage of being cheaper than other barriers. On the other hand, it may allow nonosteogenic cells from the surrounding soft tissues to penetrate into the grafted region leading to soft tissue incorporation within the regenerated bone.[16,17]

Nonresorbable membranes involve polytetraaflouroethylene (PTFE) membranes that can either be titanium reinforced or nonreinforced. They are characterized by maintaining the form and shape of augmentation and by being porous, which enhance nutrients and oxygen migration to the other side for graft viability and maturation. However, it may be associated with poor soft tissue reaction and dehiscence. A pore size of 5 to 30 μm in the e-PTFE membrane can permit bacterial penetration into the underlying graft.[18] Thus, in dense PTFE membranes a submicron sized pores were incorporated to overcome this drawback.[19]

Several controversies concerning two aspects: the type of barrier and the type of graft used.[20,21] Regarding type of barrier, two types have been compared in the present study: resorbable collagen membranes and nonresorbable titanium meshes. The two groups showed nonstatistically significant difference giving comparable clinical results compared to the results published by Friedmann et al[22] but there was a significant difference concerning the complications.

The mean horizontal bone gain of the titanium mesh group showed comparable results to Marco Rasia et al,[23] who stated that horizontal bone gain at re-entry ranged from 3.75 to 5.65 mm and exposure rate 16.1% unlike the exposure rate results in the current study that reached 40%.

In the present study, at least four cases in each group present with thin soft tissue biotype. One clear important factor behind exposure of the mesh in titanium mesh group was that thin soft tissue biotype. It was recommended to augment the soft tissue prior to the hard tissue augmentation procedure claiming that thin biotype is less resistant to trauma, has a compromised vascular network and render's surgical outcomes less predictable, while thick biotype may promote better blood supply to the underlying osseous structure affecting the early stage of wound healing and flap closure.

Proper flap management with adequate periosteal scoring and tension free closure without any blanching in the suture line or over the graft was crucial. It helps in preserving good blood supply to the flap in all cases in the current study which influence securing the underlying graft and preventing ischemia that may lead to a lack of adequate new angiogenesis if the flap is too thin. This is in agreement with Urban et al.[24] In collagen group (case no.7) suturing the flap under tension lead to flap dehiscence with subsequent membrane exposure and graft infection that altered the final result (bone gain was 1.5 mm).

Monofilament polypropylene suture was the material of choice as it has high-tension stability and less bacterial accumulation with bilayer suturing technique,[24] horizontal matters and interrupted suture in between. As a result of bilayer suturing, the flap margins were everted. This intimate contact between inner flap margins

protects the membrane and decreases the probability of dehiscence. But regarding the Titanium mesh group this technique did not prevent dehiscence of the flap and exposure of the membrane in cases no. 6, 9, and 10.

Management protocol for the cases that showed wound dehiscence or mesh exposure followed the recommendation of Urban[10] and Ghensi[8] et al, which involved broad spectrum antibiotics, copious chlorhexidine irrigation and strict oral hygiene instructions to keep the area clean by a cotton swab moistened with chlorhexidine 0.12%. The mesh was removed in two cases (case 6 and 9) due to failure of the patients to comply with the oral hygiene instructions.

Severe difficulty during removal of titanium mesh especially in full arch cases was another complication in the titanium mesh group due to soft tissue infiltration in the membrane pores which subsequently affects the superficial layer of the graft with that epithelial integration. Unlike the collagen group which presents with mature solid inner and outer layer of bone. Moreover, the difficulty to work with the mesh, adaptation, and trimming of the edges was also a hustle due to its stiffness.

Collagen membrane is used in the current study to overcome the complications of the titanium mesh, especially at the anterior maxilla which is considered an esthetic zone in addition to eliminate the need of second surgery to remove the mesh.

Tacks used was from titanium alloy that does not bend especially in severely resorbed cases with pure cortex, unlike easily deforming grade 4 titanium tacks. Curved handle applicator was used for stabilization of palatal tacks.

The use of autogenous bone in conjunction with ABBM combines the osteoconductive, osteoinductive and osteogenic properties of autografts with the osteoconductive and low-resorption rate of the ABBM. This keeps the volume of the graft very stable with favorable surface topography allowing good contact with the blood clot, and the interconnected internal channels allow cells and vessels to grow. In addition, the use of ABBM limits the amount of harvested autogenous bone needed.

Different mixing ratios for the autogenous particulate and ABBM were reported. Mordenfeld[25] et al in 2014 compared 90:10 with 60:40 (autogenous to ABBM). The mean horizontal bone gain was 4 and 4.5 mm for both groups, respectively. However, they concluded that significantly less graft resorption was observed with the 60:40 mixture which could be contributed to the high-resorption rate of autogenous particulate. Moreover, the results of Pieri[16] et al showed a mean of 4.16 mm horizontal bone gain with a 70:30 graft mixture. In the present study, the ratio of the graft mixture was 1:1 as recommended by Urban[10] as the current standard mixture ratio for guided bone regeneration, and bone area percent results were comparable to Urban[4] et al study in 2013.

Cortical bone chips had major impact on bone formation by proteins released from the extracellular matrix, transforming growth factors b1 and b2, osteoblast stimulating factor-1, galectin-1, bone morphogenic proteins, and others. Vitality of these cortical bone chips is a very important issue and had to be achieved. Auto chip maker (ACM) is an efficient and easy way for achieving this purpose that can harvest up to 1 cc of autogenous graft in a short time. Bone crusher caused wastes of material and the harvested autogenous bone lose some of it viability and it was sort of clear from the color of the bone after crushing unlike ACM which is recommended to use.[24,26] In the present study, the histomorphometric analysis in patients number 3, 19, and 20 (where the ACM was used for bone harvest) showed better results regarding the bone area percent (29%, 28.2%, and 28.70%) respectively.

Implant placement was at the second stage as the remaining alveolar bone in most of cases was not enough to attain primary stability during simultaneous implant placement. Moreover, if implants were inserted at the primary stage, their angulations would be less favorable and protruding more labial than natural teeth leading to esthetic challenges and require angled abutments for prosthesis fabrication. This might be contributed to higher resorption of alveolar ridge from labial aspect after tooth extraction. However, simultaneous implant placement in some cases considered successful treatment modality using this technique.

5 | CONCLUSIONS

1. Guided bone regeneration using native collagen membrane and titanium mesh as a barrier with a mixture of 1:1 autogenous and ABBM are viable techniques of horizontal augmentation for deficient maxillary ridges.
2. Titanium mesh is a more technique sensitive and complicated procedure as compared to collagen membrane and requires certain level of surgical experience to be performed successfully.
3. Complications associated with the nonresorbable Titanium mesh barriers regarding the considerable incidence of soft tissue dehiscence, the heavy soft tissue infiltration through the mesh, and the removing difficulty in the second stage should limit its use in augmentation for horizontally deficient ridges.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest with the contents of this article.

AUTHOR CONTRIBUTIONS

Mohammed Atef (MA), Ahmed Tarek (AT), Mostafa Shaheen (MS), Reem M. Alarawi (RA), Niveen Askar (NA). Study design, data collection, analysis and interpretation: MA, AT and MS with support from RA and NA. Manuscript drafting/proofreading: RA and NA with input from MA, AT and MS. Critical revision: NA, MA, AT, MS and RA. Providing general advice on the study: NA, MA, MS, RA and AT. Approval of final manuscript: All authors discussed the results and contributed to the final manuscript.

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