



EVALUATION OF ALVEOLAR RIDGE AUGMENTATION WITH TITANIUM MESH ADAPTED ON 3D MODEL AND BONE SUBSTITUTE GRAFT IN THE MANDIBLE

Esam Abd-El-Mohsen^{1*}, Ahmed Mohammed Hosni², Ahmed Ahmed Hussein El Feky³

ABSTRACT

Objective: to evaluate the alveolar ridge augmentation with titanium mesh adapted on 3D model and bone substitute graft in the mandible. **Subjects and Methods:** A total of 14 patients with mandibular alveolar ridge defects were selected. A preliminary CBCT scan was performed to evaluate alveolar residual bone anatomy and to create 3D model then adapted titanium mesh on the model before surgery. The deficient bone site was exposed by making a three line pyramidal flap. The recipient site was decorticated using diamond round bur. The titanium mesh fixed firstly lingual by 1.5mm diameter micro screws selfdrilling, then applied bone graft in the recipient site and adapted by condenser. Then titanium mesh fixed buccally by 1.5mm diameter micro screws. The flaps were repositioned and sutured passively with 4-0 vicryl suture. **Results:** Results revealed that, there was statistically a significantly higher value in bone height and width after 4 months of bone augmentation and there was statistically a significantly lower value of bone density after 4 months of bone augmentation. **Conclusion:** The use of titanium mesh in bone augmentation have a protective effect to the grafted bone during the healing period. The use of the titanium mesh has disadvantages, for example, the necessity of a second surgical step increases the morbidity for the patient and it has a risk of soft tissue dehiscence and membrane exposure. 3D model provide more time for adaptation of the titanium mesh during time of surgery.

KEYWORDS: Bone augmentation, Titanium mesh, Bone height, Bone width, Bone density.

INTRODUCTION

Augmentation of alveolar ridges for implant placement is still a challenging surgical procedure, especially in the case of extensive vertical and horizontal bone atrophy. If implant stability or appropriate positioning cannot be achieved, alveolar ridge augmentation is needed. Several bone-augmentation techniques have been introduced,

of which autogenous bone grafting is the “gold standard”⁽¹⁻⁵⁾. A major complication of bone grafting is bone resorption. Alveolar bone defects may be treated with various bone regeneration techniques including block bone graft, guided bone regeneration (GBR), ridge splitting, and distraction osteogenesis⁽⁶⁻⁹⁾. Titanium meshes have been widely used for oral and maxillofacial defect reconstruction in terms of guided bone regeneration (GBR) technique⁽¹⁰⁻¹³⁾.

1. Masters Candidate, Ministry of Health, Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Boys, Cairo, Al Azhar University
2. Lecturer of Oral and Maxillofacial Surgery Department Faculty of Dental Medicine, Boys, Cairo Al Azhar University.
3. Assistant Professor of Oral and Maxillofacial Surgery Department Faculty of Dental Medicine, Boys, Cairo Al Azhar University.

• **Corresponding author:** esam.dentist@yahoo.com.

GBR is one of the most predictable methods, which mostly uses a barrier membrane to separate the grafted defect and the surrounding connective tissue for successful bone regeneration ⁽⁷⁾.

Titanium meshes are rigid enough to maintain the grafted space and to avoid soft tissue collapse. Onlay osseous graft protected by a titanium mesh has significantly a demonstrated less bone resorption compared with an onlay bone graft alone ⁽¹⁴⁾. Titanium mesh is also an alternative to a resorbable membrane for ridge augmentation ⁽¹⁵⁾. With its advantages, such as biocompatibility and corrosion resistance, substantial bone augmentation can be achieved using the titanium construct in conjunction with bone grafting ⁽¹⁶⁾.

It has been demonstrated that titanium mesh supports the grafted space and prevents soft tissue collapse ⁽¹⁷⁾. However, the clinical outcome of augmentation depends on many factors one of them is the type of preoperative bone defect ⁽¹⁸⁾. In addition, titanium mesh has a good mechanical strength, and it can be shaped readily and fixed with screws or pins with resulting potential space ⁽¹⁹⁾.

SUBJECTS AND METHODS

Sample Size: A sample size of 14 has a 80% power to detect a difference between means of 0.70 with a significance level (alpha) of 0.05 (two-tailed).

Patient selection: A total of 14 patients with mandibular alveolar ridge defects were selected from the from the Out-Patient Clinic of the Oral Surgery Department at Faculty of Dental Medicine, Cairo-boys, Al-Azhar University, Egypt.

Planning and manufacturing of three-dimensional model: A preliminary CBCT scan onDemand3D software was performed to evaluate alveolar residual bone anatomy. The CT scan was saved in DICOM format. DICOM file was opened in the software program Mimics version 21.0 (Materialise NV, Leuven, Belgium) then thresholding is performed and 3D reformatted scan of the deficient ridge is generated.

Then it was contoured and smoothed using the software 3-Matic version 13.0 (Materialise NV, Belgium). These digital structure, provided a 3D simulation about the morphology of the alveolar bone defect, after which it was saved as an STL file, then it printed (by Anycubic i3 Mega printer, China) to three-dimensional model, Fig. (1). A titanium mesh (thickness: 0.2mm/Hole Size: Φ 1.0mm, Bio Materials Korea, Korea) was adapted on the alveolar defect on the 3D model, Fig. (2).

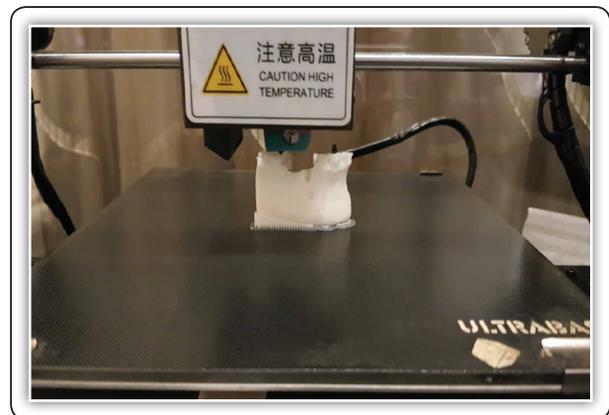


FIG. (1): Printing the 3D model

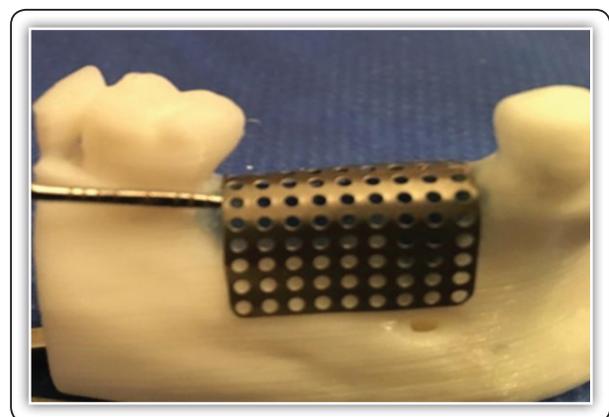


FIG. (2): Titanium mesh adapted on the 3D model

Surgical procedures: The patients were instructed to rinse their mouth with chlorhexidine mouthwash for 2 minutes just before surgery. All procedures were performed under sterile conditions. Local anesthetic solution ARTINIBSA (Inibisa Dental, Spain) with vasoconstrictor epinephrine 1:100000 was injected as inferior alveolar nerve

block and infiltration into operative site for anesthesia and hemostasis.

At recipient site:

The deficient bone site was exposed by making a three line pyramidal flap. A crestal incision was made at the recipient site and vertical incision was performed on the buccal side then a full-thickness flap was raised to the mucogingival junction. After separating the periosteum, the preparation of the flap was continued. The lingual and buccal subperiosteal tissue was carefully elevated to gain adequate visibility of the recipient site without applying tension to the ipsilateral mental nerve. The recipient site was decorticated using diamond round bur (3mm) to increase the vascularity to the bone graft. The titanium mesh fixed firstly lingual by 1.5mm diameter micro screws (micro system, Bio Material Korea) self drilling, then applied bone graft (xenograft) hypro-oss (natural collagenated bovine bone graft, Giessen, Germany) in the recipient site and adapted by condenser. Then titanium mesh was fixed buccally by 1.5mm diameter micro screws. Scoring of the buccal periosteum with no.15 blade allowing for tension free closure of the wound with maintenance of the periosteal cover of the graft. The flaps were repositioned and sutured passively with 4-0 vicryl suture.

Postoperative evaluation

Clinical evaluation

Postoperative follow-up was carried out every week during the first month, and then every month for 3 months and clinical parameters were evaluated such as examination of the wound, suture breakdown or dehiscence and checking for any post-operative complication such as: pain, swelling, Bleeding, infection, bone graft exposure. After 4 months postoperatively the titanium mesh was removed to evaluate bone graft and bone integration.

Radiographic evaluation:

CBCT onDemand3D software was used to evaluate vertical height, horizontal width and bone density of mandibular ridge in mm after bone augmentation after 4 month postoperatively. Linear measurement obtained from 3D images got through on Demand 3D software in mm used to evaluated and measure the vertical and horizontal lengths. Linear measurements obtained at two points in each augmented site from above 2mm of inferior alveolar nerve to the crest of the augmented ridge after 4 months postoperatively in the same cuts of CBCT and calculate the mean height of the augmented ridge and Linear measurements obtained at two points in each augmented site from buccal to lingual cortices at the crest of the augmented ridge after 4 months postoperatively in the same cuts of CBCT and calculate the mean width of the augmented ridge.

Statistical analysis:

In this in vitro study all the collected data were presented as minimum, maximum, means, mean difference and standard deviation (SD) values. Comparison between before and after 4 months of augmentation regarding bone height, bone width and density was performed by using paired t-test.

RESULTS

Clinical evaluation was performed immediately and every month for four months and revealed, there was no infection except after 1 month in only 3 cases (21.4%), there was pain in all 14cases immediately after the procedure (100%), then pain disappeared. There was no nerve injury in all cases. During follow up, there was only 3 cases (21.4%) with graft exposure after 1 month only, while re-grading soft tissue dehiscence there was 3 cases (21.4%) after 1 and 2 months and 4 cases (28.5%) after 3 and 4 months.

The minimum mean of bone width was (0.49), the maximum was (6.54) while the mean \pm standard

deviation was (3.25 ± 1.16) . Regarding bone height the minimum was (7.73), the maximum was (10.18), while the mean \pm standard deviation was (8.98 ± 0.71) . But the minimum density was (1068.75), the maximum was (1297.77), while the mean \pm standard deviation was $(1184 \pm 0.52.38)$ as presented in table (1).

TABLE (1): Total count, minimum, maximum, mean, and standard deviation of bone height, width and density before ridge augmentation:

Before	N	Min.	Max.	M.	SD.
Bone width	14.00	0.49	6.54	3.25	1.16
Bone height	14.00	7.73	10.18	8.98	0.71
Density	14.00	1068.75	1297.77	1184.00	52.38

*N; total count Min; minimum
Max; maximum M; mean SD; standard deviation*

The minimum mean of bone width was (3.20), the maximum was (6.42) while the mean \pm standard deviation was (5.17 ± 0.78) . Regarding bone height the minimum was (9.97), the maximum was (10.44), while the mean \pm standard deviation was (10.14 ± 0.12) . But the minimum density was (991.31), the maximum was (1133.87), while the mean \pm standard deviation was (1049 ± 38.18) as presented in table (2).

TABLE (2): Total count, minimum, maximum, mean, and standard deviation of bone height, width, and density after 4 months of ridge augmentation:

After 4 months	N	Min.	Max.	M.	SD.
Bone width	14.00	3.20	6.42	5.17	0.78
Bone height	14.00	9.97	10.44	10.14	0.12
Density	14.00	991.31	1133.87	1049.00	38.18

*N; total count Min; minimum
Max; maximum M; mean SD; standard deviation*

The bone width before augmentation was (3.25 ± 1.16) , while after 4 months was (5.17 ± 0.78) with

59.07% of changes, comparison was performed between mean bone width before and after 4 months of augmentation by using Paired t-test which revealed significant difference ($P < 0.05$) as presented in table (3)

TABLE (3): Changes in bone width after 4 months of augmentation:

	Before		After		P value	% of changes
	M	SD	M	SD		
Bone width	3.25	1.16	5.17	0.78	0.001*	59.07%

*M; mean SD; standard deviation
P: probability level %: percentage of changes*

The bone height before augmentation was (8.98 ± 0.71) , while after 4 months was (10.14 ± 0.12) with 12.9% of changes, comparison was performed between mean bone height before and after 4 months of augmentation by using Paired t-test which revealed significant difference ($P < 0.05$) as presented in table (4).

TABLE (4): Changes in bone height after 4 months of augmentation:

	Before		After		P value	% of changes
	M	SD	M	SD		
Bone height	8.98	0.71	10.14	0.12	0.001*	12.91%

*M; mean SD; standard deviation
P: probability level %: percentage of changes*

The bone density before augmentation was (1184 ± 52.38) , while after 4 months was (1049 ± 38.18) with 11.4% of changes, comparison was performed between mean bone density before and after 4 months of augmentation by using Paired t-test which revealed significant difference ($P < 0.05$) as presented in table (5)

healing; three cases after two months , four cases after three months and last four cases after four months before the time of second surgery, did not cause significant bone resorption and mesh seemed to tolerate infection. And with care of good oral hygiene measurement and brushing well. In our study we use one type of bone substitutes, which is xenograft. Bone substitutes ideally should be able to form new bone and be biocompatible, completely resorbable, non-antigenic, non-carcinogenic, inexpensive, and pose no risk of disease transmission. The use of xenografts for bone grafting was reported in 1889 by Senn⁽³⁰⁾. Xenografts are tissue grafts obtained from a species other than the host species. The representative xenograft materials are natural hydroxyapatite (HA) and deorganified bovine bone (anorganic bone matrix or ABM). Natural hydroxyapatite is extracted from animal bones. It has the three-dimensional microstructure of natural bone and is highly biocompatible to adjacent hard and soft tissues. ABM is an inorganic bone of bovine origin. It is a carbonate containing apatite with crystalline architecture and a calcium/phosphate ratio similar to that of natural bone mineral in humans. With time, ABM graft material becomes integrated into the human bone and is slowly replaced by newly formed bone⁽³¹⁾. Xenografts are considered to be biocompatible and osteoconductive. Grafted bovine bone particles once embedded in mineralized bone, and as long as no special stimuli occurs, act similarly to host bone, which often undergoes remodeling process⁽³²⁾. In our study we use only xenograft, without autogenous bone to avoid doing other surgery to the patients in another area of oral cavity or extra oral.

CONCLUSION

The use of titanium mesh in bone augmentation have a protective effect to the grafted bone during the healing period. The use of the titanium mesh has disadvantages, for example, the necessity of a second surgical step increases the morbidity for the patient and it has a risk of soft tissue dehiscence and membrane exposure. 3D model provide more time for adaptation of the titanium mesh during time of surgery.

REFERENCES

1. Jemt T, Lekholm U. Single implants and buccal bone grafts in the anterior maxilla: measurements of buccal crestal contours in a 6-year prospective clinical study. *Clin Implant Dent Relat Res* 2005; 7:127–135.
2. Gaggl AJ, Bürger HK, Chiari FM. Free microvascular transfer of segmental corticocancellous femur for reconstruction of the alveolar ridge. *Br J Oral Maxillofac Surg* 2008; 46:211–217.
3. Chiapasco M, Romeo E, Casentini P, Rimondini L. Alveolar distraction osteogenesis vs. vertical guided bone regeneration for the correction of vertically deficient edentulous ridges: a 1-3-year prospective study on humans. *Clin Oral Implants Res* 2004; 15:82–95.
4. Takahashi T, Inai T, Kochi S. Long-term follow-up of dental implants placed in a grafted alveolar cleft: evaluation of alveolar bone height. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008; 105:297–302.
5. Merli M, Migani M, Esposito M. Vertical ridge augmentation with autogenous bone grafts: resorbable barriers supported by osteosynthesis plates versus titanium-reinforced barriers: a preliminary report of a blinded, randomized controlled clinical trial. *Int J Oral Maxillofac Implants* 2007; 22:373–382.
6. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. *Int J Oral Maxillofac Implants* 1997; 12: 767–776.
7. Hammerle CH, Karring T. Guided bone regeneration at oral implant sites. *Periodontology* 2000. 1998; 17:151–175.
8. Simion M., Baldoni M., Zaffe D. Jawbone enlargement using immediate implant placement associated with a split-crest technique and guided tissue regeneration. *Int J Periodontics Rest Dent* 1992; 12: 462–473.
9. Oda T, Sawaki Y. Experimental alveolar ridge augmentation by distraction osteogenesis using a simple device that permits secondary implant placement. *Int J Oral Maxillofac Implants* 2000; 15: 95–102.
10. Buser D, Halbritter S, Hart C. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in the esthetic zone: 12-month results of a prospective study with 20 consecutive patients. *J Periodontol.* 2009; 80: 152–162.
11. Tinti C, Parma-Benfenati S, Manfrini F. Space making metal structures for nonresorbable membranes in guided bone regeneration around implants. Two case reports. *Int J Periodontics Rest Dent* 1997; 17: 53–61.

12. Parma-Benfenati S, Roncati M, Galletti P, Tinti C. Resorbable dome device and guided bone regeneration: an alternative bony defect treatment around implants. A case series. *Int J Periodontics Rest Dent* 2014; 34: 749–755.
13. Merli M, Moscatelli M, Mariotti G, Rotundo R. Bone level variation after vertical ridge augmentation: resorbable barriers versus titanium-reinforced barriers. A 6-year double-blind randomized clinical trial. *Int J Oral Maxillofac Implants* 2014; 29: 905–913.
14. Aytac S, Ozbek S, Kahveci R, Ozgenel Y. Titanium mesh fracture in mandibular reconstruction. *J Craniofac Surg* 2005; 16: 1120–1122.
15. Her S, Kang T, Fien MJ. Titanium mesh as an alternative to a membrane for ridge augmentation. *J Oral Maxillofac Surg* 2012; 70: 803–810.
16. Rakhmatia YD, Ayukawa Y, Atsuta I, Furuhashi A. Fibroblast attachment onto novel titanium mesh membranes for guided bone regeneration. *Odontology*. 2015; 103: 218–226.
17. Rakhmatia YD, Ayukawa Y, Furuhashi A, Koyano K. Current barrier membranes: titanium mesh and other membranes for guided bone regeneration in dental applications. *J Prosthodontics Res*. 2013; 57: 3–14.
18. Miyamoto I, Funaki K, Yamauchi K, Kodama T. Alveolar ridge reconstruction with titanium mesh and autogenous particulate bonegraft: computed tomography-based evaluations of augmented bone quality and quantity. *Clin Implant Dent Relat Res*. 2012; 14: 304–311.
19. Proussaefs P & Lozada J. Use of titanium mesh for staged localized alveolar ridge augmentation: clinical and histologic-histomorphometric evaluation. *J Oral Implantol*. 2006; 32: 237–247.
20. McAllister BS & Haghighat K. Bone Augmentation Techniques. *J Periodontol* 2007; 78: 377-96.
21. Peltola SM, Melchels FPW, Grijpma DW, Kellomäki M A review of rapid prototyping techniques for tissue engineering purposes. *Ann Med*, 2008; 40:268–280.
22. Rengier F, Mehndiratta A, von Tengg-Kobligk H, et al. 3D printing based on imaging data: review of medical applications. *Int J Comput Assist Radiol Surg*. 2010; 5: 335–341.
23. Erickson DM, Chance D, Schmitt S, Mathis J. An opinion survey of reported benefits from the use of stereolithographic models. *J Oral Maxillofac Surg* 1999; 57: 1040-3.
24. P. J. Louis, R. Gutta, N. Said-Al-Naief, and A. A. Bartolucci, “Reconstruction of the maxilla and mandible with particulate bone graft and titanium mesh for implant placement,” *Journal of Oral and Maxillofacial Surgery*, vol. 66, no. 2, pp. 235–245, 2008
25. Sumi Y, Miyaishi O, Tohnai I, et al. Alveolar ridge augmentation with titanium mesh and autogenous bone. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; 89: 268-70.
26. Jovanovic SA, Nevins M. Bone formation utilizing titanium reinforced barrier membranes. *Int J Periodont Restorat Dent* 1995; 15: 56-69.
27. von Arx, T., Hardt, N. & Wallkamm, B. (1996) The TIME technique: A new method for localized alveolar ridge augmentation prior to placement of dental implants. *International Journal of Oral & Maxillofacial Implants* 11: 387–394.
28. Proussaefs P, Lozada LJ, Kleinman A, Rohrer M. The use of titanium mesh in conjunction with autogenous bone graft and inorganic bovine mineral (Bio-Oss) for localized alveolar ridge augmentation. A human study. *Int J Periodont Restor Dent*. 2003; 23: 185–195.
29. Rocuzzo, M. & Wilson, T.G. (2002) a prospective study evaluating a protocol for 6 weeks loading of SLA implants in the posterior maxilla. One-year results. *Clinical Oral Implants Research* 13: 502–507.
30. Senn N. On the healing of aseptic bone cavities by implantation of aseptic decalcified bone. *Am J Med Sci* 1889; 98: 219.
31. van Steenberghe D, Callens A, Geers L. The clinical use of deproteinized bovine bone mineral on bone regeneration in conjunction with immediate implant installation. *Clin Oral Implants Res* 2000; 11: 210-6.
32. Zitzmann NU, Scharer P, Mrinello CP, Schupbach P. Alveolar ridge augmentation with Bio-oss: A histological study in humans. *Int J Periodontics Restorative Dent*. 2001; 21: 288–95.