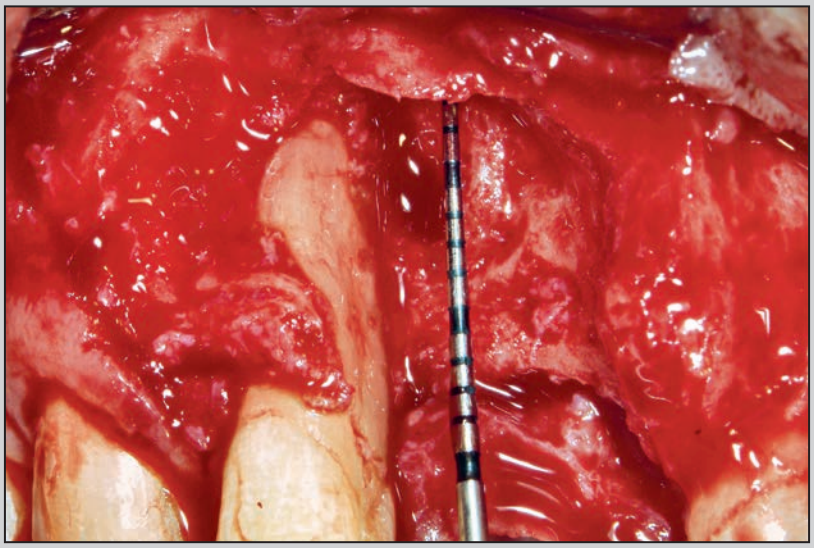
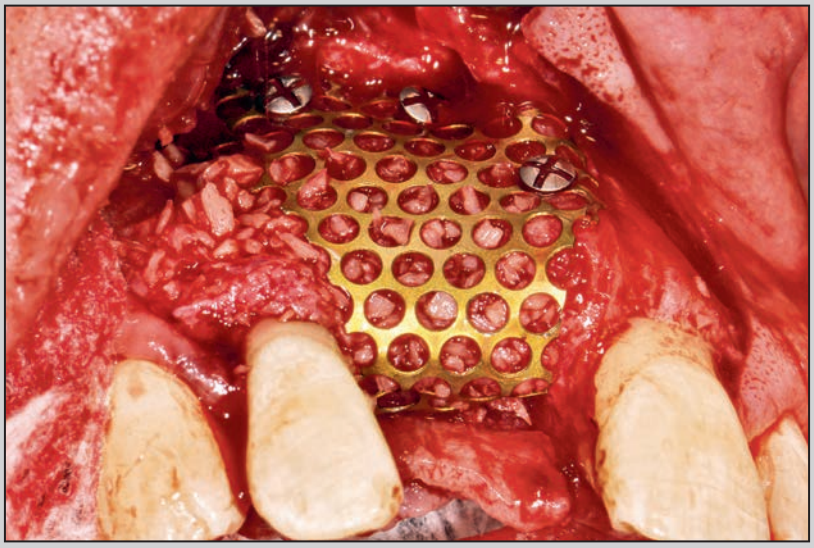
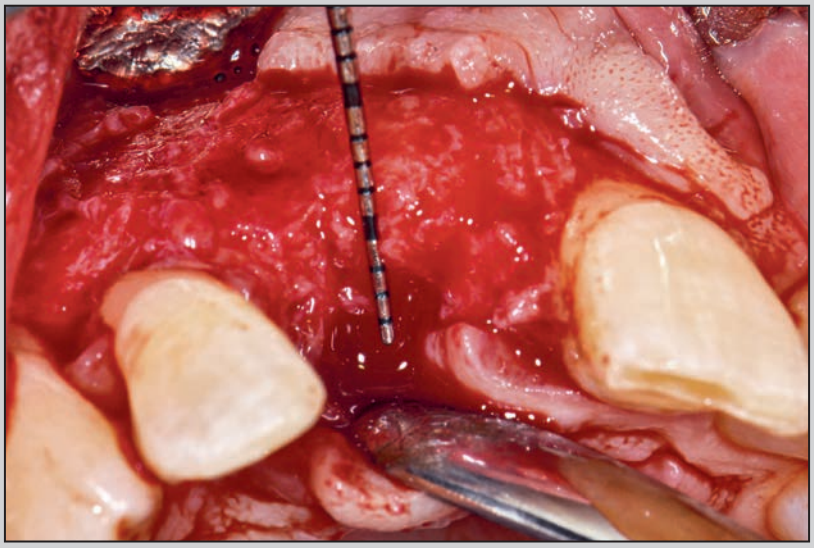
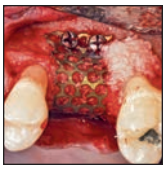






Implant Site Development Using Titanium Mesh in the Maxilla: A Retrospective Study of 58 Mesh Procedures in 48 Patients



Robert A. Levine, DDS[1]/Pin-Chuang Lai, DDS, PhD[2]
Aleem Manji, DDS, MS[3]/John Bruce, DMD[4]
Diksha Katwal, DDS, MSD[2]/Po-Hsu Allen Chen, PhD[5]
Joanie Faucher, DDS, MS[3]/Bradley S. McAllister, DDS, PhD[6]
Philip Fava, DMD, MDSc[7]/William C. Scarfe, BDS, MS[2]

This article presents a retrospective case series of implant site development using titanium mesh (Ti-mesh) in the maxilla. A total of 58 mesh procedures in combination with several different bone grafts (allograft, cellular allograft, and bovine xenograft) and biologics (including recombinant human platelet-derived growth factor, autogenous platelet-rich growth factor, and recombinant human bone morphogenetic protein-2) were performed in 48 patients. Ti-mesh guided bone regeneration procedures were performed 2 to 3 months after extraction of nonrestorable/hopeless teeth, and the implants were placed 6 to 8 months postaugmentation. The mean initial ridge width was 2.0 ± 1.0 mm, and the mean horizontal gain after Ti-mesh procedures was 4.7 ± 1.6 mm. The ridge width was first measured on the cross-sectional presurgical CBCT image and then confirmed clinically during surgical procedures. No statistical difference in the horizontal gain was found among different combinations of bone grafts and biomaterials. Ti-mesh exposure occurred 22% of the time. The middle-aged adults (odds ratio [OR] = 8.59; P = .046) and older adults (OR = 16.66; P = .02) had significantly higher chances of mesh exposure compared to young adults. While all implants were successfully placed, about 56% of the implants had < 2 mm of bone to the facial aspect of the osteotomy and received additional contour augmentation when placed in a prosthetically appropriate position for a screw-retained restoration. This study demonstrates that although Ti-mesh procedures result in significant bone regeneration in narrow alveolar ridges to predictably allow implant placement, the age-related mesh exposure rate and frequency of need for additional contour grafting should be discussed with patients. Int J Periodontics Restorative Dent 2022;42:43–51. doi: 10.11607/prd.5530

[1]Private Practice, Philadelphia, Pennsylvania, USA; Periodontology & Implantology, Kornberg School of Dentistry, Temple University, Philadelphia, Pennsylvania, USA.
[2]Department of Oral Diagnosis and Oral Health, School of Dentistry, University of Louisville, Louisville, Kentucky, USA.
[3]Private Practice, Langley, British Columbia, Canada.
[4]Graduate Periodontics, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA.
[5]Battelle Memorial Institute, Columbus, Ohio, USA.
[6]Private Practice, Portland, Oregon, USA; Department of Periodontology, Oregon Health Sciences University, Portland, Oregon, USA.
[7]Private Practice, Philadelphia, Pennsylvania, USA.

Correspondence to: Dr Robert A. Levine, The Pennsylvania Center for Dental Implants & Periodontics, 9880 Bustleton Ave, Suite 211, Philadelphia, PA 19115, USA.
Fax: 215-677-7212. Email: rlevine@padentalimplants.com

Submitted November 4, 2020; accepted September 1, 2021.

Severe alveolar ridge defects present a challenge because the bone deficiency may make implant therapy extremely difficult or sometimes impossible.[1] Bone augmentation procedures to rebuild alveolar ridge width and height at the implant sites are necessary for long-term esthetic and functional outcomes.[2–5] Both horizontal and vertical bone augmentation can be achieved with varying results using several well-established techniques, various bone grafts, and biologics.[6] No matter the approach selected, all techniques must meet the three main principles of regeneration: primary intention healing, space provision, and wound stability.[7,8]

A positive esthetic outcome is critical in the reconstruction of an edentulous ridge, and it only happens when tooth replacement results in harmony with the remaining natural dentition upon smiling.[5,9,10] Several key factors should be assessed during planning and executed during treatment to achieve excellent final esthetics: an esthetic risk assessment analysis, ≥ 2 mm of bone facial to the implant after placement, and facial soft tissue that is ideally ≥ 2 mm thick.[10–13] This thick buccal bone, which could be obtained through contour augmentation upon implant placement, becomes increasingly important and beneficial in the esthetic zone.[14,15]

Table 1 Demographic Data of the Participants	
Total patients, n	48
Age, y	
Mean ± SD	51.4 ± 14.1
Range	20–77
Gender, n (%)	
Male	22 (46%)
Female	26 (54%)
Smoking status, n (%)	
Smokers	4 (8%)
Nonsmokers	44 (92%)
Total implant sites, n	91
Location, n (%)	
Anterior	47 (52%)
Posterior	44 (48%)
Gingival phenotypes, n (%)	
Thin	28 (31%)
Medium	46 (50%)
Thick	17 (19%)
Provisional restorations, n (%)	
None	40 (44%)
Fixed	10 (11%)
Transitional partial denture	14 (15%)
Complete denture	27 (30%)
Final prostheses, n (%)	
Single crown	44 (49%)
Implant bridge	23 (25%)
Hybrid denture	11 (12%)
Overdenture	13 (14%)

The use of a titanium mesh has been utilized since the mid-1980s.[16] While Ti-mesh is not cell-exclusive, it shows promise through provision of enhanced space maintenance, stabilization of the blood clot, and graft revascularization.[16] The effectiveness of Ti-mesh in implant site development has been well documented, showing substantial bone augmentation in both horizontal and vertical directions.[17] The present retrospective study reviews the clinical results of bone augmentation in the maxillae with three representative cases utilizing a Ti-mesh scaffold to achieve a prosthetically driven implant placement. Data regarding the frequency and need for buccal contour grafting upon prosthetically driven implant placement are also included.

Materials and Methods

The present retrospective study included patients receiving ridge augmentation using Ti-mesh between March 2009 and July 2013 at a private periodontal practice (R.A.L.) in Philadelphia, Pennsylvania, for replacement of nonrestorable or hopeless maxillary teeth. Patients signed a written informed consent for the surgical procedures and data collection for potential future publication, in accordance with the guidelines of the World Medical Association Declaration of Helsinki.[18] Patients who underwent Ti-mesh ridge augmentation, had an implant placed in the maxilla, and had complete pre- and postoperative clinical and radiographic data were included; the exclusion criteria were history of alcoholism or drug abuse, medical contraindications affecting bone/soft tissue healing, history of cervicofacial radiation, use of bone sparing medications, poor oral hygiene, poor compliance, and smoking > 20 cigarettes/day.

A total of 48 patients (demographic data in Table 1) were identified through the records. Seven different combinations of biomaterials were used along with Ti-mesh: *(1)* AG/rhPDGF: freeze-dried bone allograft (AG) + recombinant human platelet-derived growth factor (rhPDGF); *(2)* AG/PRGF: demineralized AG + calcium sulfate powder and autogenous platelet-rich growth factor (PRGF); *(3)* AG/NB: demineral-

ized AG + calcium sulfate powder (no biologics [NB]); *(4)* Cellular AG: cellular AG containing a minimum of 250,000 cells/cc; *(5)* XG/BMP: deproteinized bovine bone mineral (DBBM) + recombinant human bone morphogenetic protein-2 (BMP-2); *(6)* XG/rhPDGF: DBBM + PDGF; and *(7)* XG/rhPRGF: DBBM + PRGF. All patients received two CBCT scans: one taken within a month prior to ridge augmentation, and the other taken prior to Ti-mesh removal and implant placement. The selection of treatment group was arbitrarily decided by the same periodontist (R.A.L.) after acquiring each patient's presurgical CBCT image.

Surgical Procedure

Tooth extraction and guided bone regeneration with Ti-mesh

The overall treatment protocol was described in previously published case reports.[2–4] Briefly, following tooth extraction, the wounds were allowed to heal spontaneously for 2 to 3 months to have complete soft tissue closure. Once the bony defect was confirmed and measured on the presurgical CBCT scan, the Ti-mesh ridge augmentation procedure was performed.

Under profound local anesthesia, a full-thickness flap was raised with vertical incisions at the distal ends of the flap for better visualization and access. After debridement of the granulation tissue, numerous intramarrow penetrations were made at the buccal surface of the alveolar ridge. The Ti-mesh was firstly carefully secured to the buccal plate using stabilizing screws, creating a buccal wall to pack the bone graft, and then trimmed with surgical scissors to keep a 1.5-mm distance from the adjacent tooth to prevent postoperative bacterial penetration from the tooth surfaces. When needed, additional tenting screws were used to support the mesh. One of the seven combinations of biomaterials was placed at the bony defects, followed by securing the mesh on to the palatal wall to prevent any micromovement. The stability of the mesh was examined carefully. In three treatment groups (AG/PRGF, AG/NB, and XG/PRGF), a collagen membrane was used to cover the mesh, while a collagen dressing tape was used in the other groups. When applicable, the collagen membranes were soaked in PRGF, and the tapes were soaked in rhPDGF, respectively, before being applied to the augmented sites.

The surgical site was then sutured to obtain tension-free primary closure. The provisional restorations (either nothing, temporary partial dentures, flippers, or complete dentures) were delivered, with special attention to exert no pressure on the graft during the initial healing period.

Postoperative healing and implant placement

Each patient was followed up at 2 to 3 weeks for suture removal with plaque control reinforcement and at 4, 8, and 12 weeks postoperatively to ensure appropriate healing and complete soft tissue coverage over the Ti-mesh. Any early (≤ 6 weeks) or late (> 6 weeks) mesh exposure was recorded. The patients with mesh exposure would clean the areas with chlorhexidine and have individualized recall appointments before the implant placement surgery.

A second CBCT scan was taken 5 to 6 months postoperatively. The patient then met their restorative dentist to fabricate a clear acrylic tooth-borne (when present), digitally designed, anatomically correct surgical guide template (ACSGT) for prosthetically driven implant placement. The implant surgery took place 7 to 9 months after the Ti-mesh procedures. During surgery, the Ti-mesh was removed, and the implant was placed according to the ACSGT. All implants with < 2 mm of bone to the facial of the osteotomy received contour augmentation using DBBM and a collagen membrane.[10] Figures 1, 2, and 3 show representative cases at the central incisor, first premolar, and first molar locations, respectively.

Clinical Indices

The primary outcome is the gain in the ridge width resulting from the Ti-mesh procedure. The initial width was first measured at the widest point (no more apical than 4 mm from the crest) to the nearest 0.5 mm at the mesiodistal center of the ridge on the cross-sectional CBCT image, and then confirmed clinically by the periodontist during surgery. The buccolingual width of the ridge at the future implant site was measured by placing a 15-mm periodontal probe at the crest, measuring to the nearest 0.5 mm,

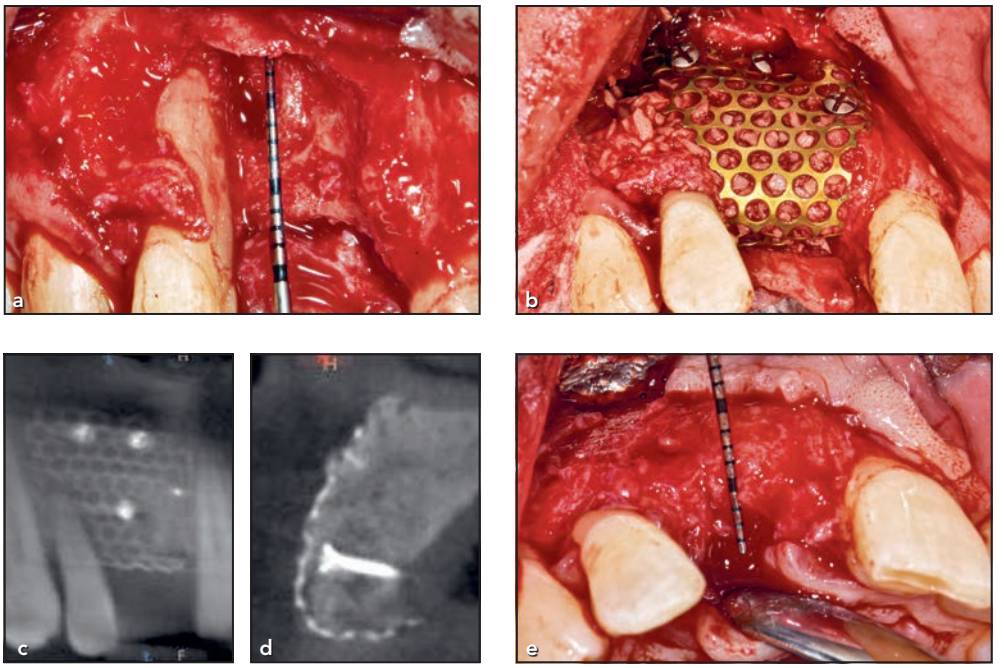


Fig 1 *Anterior single-tooth replacement at tooth site 11 (FDI tooth-numbering system).* (a) *Initial defect on the day of Ti-mesh surgery.* (b) *Ti-mesh in place.* (c and d) *CBCT scans at 6 months.* (e) *Day of Ti-mesh removal and implant placement.*

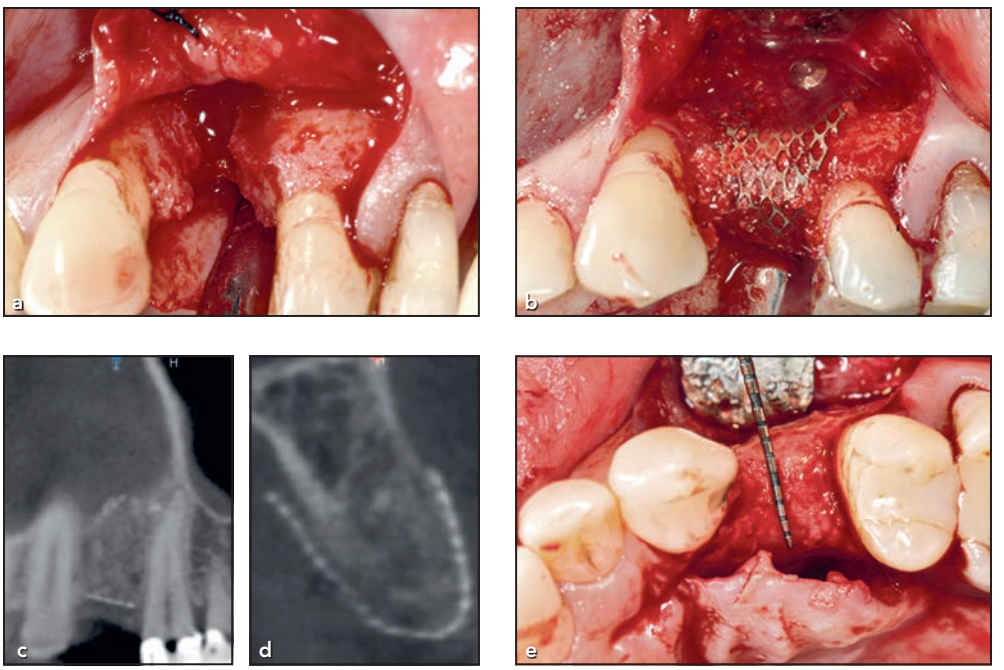


Fig 2 *Premolar single-tooth replacement at tooth site 24 (FDI system).* (a) *Initial defect on the day of Ti-mesh surgery.* (b) *Ti-mesh in place.* (c and d) *CBCT scans at 5 months.* (e) *Day of Ti-mesh removal and implant placement.*

and documenting it with digital photography. The clinical confirmation helped to avoid potential errors from residual bone grafts (vs healed bone).

Other recorded indices included the change in ridge height, mesh exposures (none, early, or late), smoking status (yes/no), the gingival phenotype (thin, medium, or thick; assessed using visual assessment with the aid of a periodontal probe),[11,19] implant location (anterior/posterior), age (younger adults [< 50 years], middle-aged [50 to 65

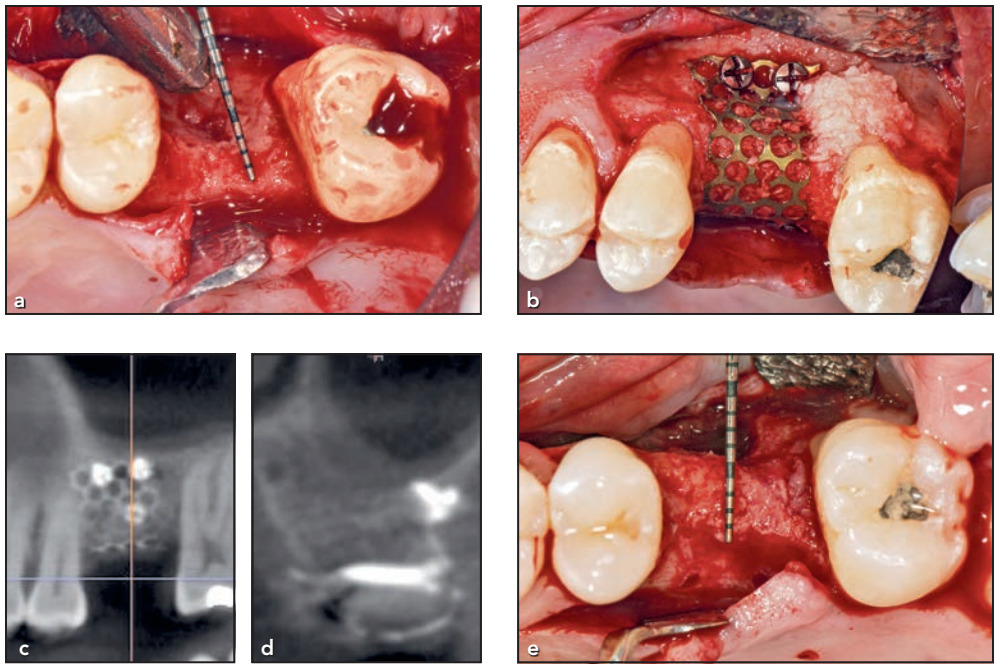


Fig 3 *Molar single-tooth replacement at tooth site 26 (FDI system).* (a) *Initial defect on the day of Ti-mesh surgery.* (b) *Ti-mesh in place.* (c and d) *CBCT scans at 5 months.* (e) *Day of Ti-mesh removal and implant placement.*

years], or older adults [65+ years]), gender, the provisional restorations (none, fixed, transitional partial denture, or complete denture), contour augmentation at implant placement (yes/no), and treatment groups (seven biomaterial combinations).

Statistical Analysis

Descriptive statistics for all data were performed. The effects of age, gender, implant location, gingival phenotype, treatment group, provisional restorations, smoking, and mesh exposure on the gain in ridge width were analyzed by fitting a linear regression model. For the contour augmentation, the variance inflation factor was used to diagnose problematic multicollinearity, followed by a model selection approach to examine the critical variables affecting the fitness of the model, and then the final logistic regression model was determined using the Akaike information criterion. For mesh exposure, the final logistic regression model was determined by stepwise selection. All analyses were completed using R statistical software (The R Foundation).

Results

A total of 58 mesh procedures covering 91 implant sites were performed in the maxillae of 48 patients. More than half of the mesh procedures covered a single implant site (32 of 58), while 20, 5, and 1 mesh procedures covered 2, 3, and 4 implant sites, respectively. The demographic data of the participants are summarized in Table 1.

The clinical outcomes from each treatment group are summarized in Table 2. The gross mean horizontal gain was 4.7 ± 1.6 mm, ranging from 4.5 ± 1.8 mm in the AG/PDGF group to 5.7 ± 1.0 mm in the XG/PRGF group. The gross mean vertical gainfrom available sites was 2.8 ± 1.7 mm, ranging from 1.5 ± 0.7 mm in the XG/BMP group to 3.4 ± 2.9 mm in the AG/rhPDGF group. Based on the fitted regression model on the horizontal gain, posterior location (vs anterior) was significantly associated with more horizontal gain (P = .016; Table 3).

Postoperative mesh exposure occurred after 13 procedures, or 22% of the time, but no mesh required early removal. Late exposure was more frequent than early exposure (62.5% and 37.5%, respectively). Among the sites with exposure, thin phenotype was related to 3 exposures (3 implant sites), medium phenotype was related to 7 exposures (10 implant sites), and thick phenotype was related to 3

Table 2 Descriptive Statistics of All Treatment Groups

	AG + rhPDGF	AG + PRGF	AG + NB	Cellular AG	XG + rhPDGF	XG + PRGF	XG + BMP	Total / gross mean
Use of a collagen membrane	N	Y	Y	N	N	Y	N	
Mesh, n	26	6	10	6	4	3	3	58
Implant sites, n	36	8	14	9	12	8	4	91
Ridge width, mm								
Initial	2.2 ± 1.0	2.0 ± 1.0	2.2 ± 1.0	1.4 ± 0.8	2.4 ± 1.3	1.8 ± 0.3	1.0 ± 0.6	2.0 ± 1.0
Final	6.6 ± 1.4	6.6 ± 1.1	7.4 ± 1.1	5.9 ± 0.9	7.1 ± 1.1	7.5 ± 1.0	5.7 ± 2.8	6.8 ± 1.4
Dimensional gain, mm								
Horizontal	4.5 ± 1.8	4.6 ± 1.7	5.2 ± 1.4	4.5 ± 1.3	4.7 ± 1.3	5.7 ± 1.0	4.7 ± 2.2	4.7 ± 1.6
Vertical	3.4 ± 2.9	2.7 ± 1.1	2.3 ± 1.1	2.5 ± 1.4	2.8 ± 0.5	N/A	1.5 ± 0.7	2.8 ± 1.7

AG = allograft; rhPDGF = recombinant human platelet-derived growth factor; PRGF = platelet-rich growth factor; NB = no biomaterials; XG = xenograft; BMP = bone morphogenetic protein; Y = yes; N = no.
Ridge width, horizontal gain, and vertical gain values are all presented as mean ± SD.

Table 3 The Stepwise Linear Regression Analysis on the Horizontal Gain of Alveolar Ridge Width

	Estimate	SE	t	*P*
Gender – male	0.65	0.33	1.96	.0535
Location – posterior	0.77	0.32	2.46	.016*
Multiple R-squared: 0.2037				

SE = standard error.
*The difference between mean values of the treatment group (eg, location-posterior) and the reference group (eg, location-anterior) is statistically significant ($P < .05$) when other factors were held at a fixed value.

exposures (3 implant sites). The logistic regression model indicated that age was positively associated with mesh exposure: Both the middle-aged adults (odds ratio [OR] = 8.59; 95% confidence interval [CI]: 1.04 to 71.09; $P = .046$) and the older adults (OR = 16.66; 95% CI: 1.56 to 177.5; $P = .02$) had significantly higher chances of mesh exposure than younger adults. The mean horizontal gain in the exposed sites was slightly less than that in the unexposed sites (4.4 ± 1.1 mm and 4.8 ± 1.7 mm, respectively), but the difference was not statistically significant ($P > .05$). The mean thickness of the pseudoperiosteum at the exposed site was thicker than that at the unexposed sites (1.5 ± 0.6 mm and 1.1 ± 0.8 mm, respectively), but the difference was not statistically significant ($P > .05$).

Contour augmentation during implant placement was performed in 56% of the sites (51 of 91 sites), ranging from 25% in the AG/PRGF and XG/PRGF groups to 78% in the cellular AG group. The differences in the percentages among treatment groups were not statistically significant. Significantly lower odds of needing additional contour augmentation were associated with using a complete denture as the provisional restoration (vs no provisional restoration; OR = 0.03, $P < .001$) and posterior location (vs anterior; OR = 0.21, $P = .016$) (Table 4). Only 7.5% of sites (2 of 27) covered by complete dentures needed contour augmentation, while 72.5% to 85.7% of sites covered by either nothing or other provisional restorations received grafting.

Discussion

Vertical and horizontal regeneration procedures allow for ideal implant placement in the reconstruction of deficient alveolar ridges.[20] The use of Ti-mesh for implant site development procedures is well-supported in the literature.[21–23] Although Ti-mesh is not cell-occlusive, its biocompatibility and handling properties that enable it to act as a form-stable scaffold are beneficial in 3D augmentation procedures.[23] The present study found that Ti-mesh with various combinations of biomaterials produced effective horizontal and vertical bone gain, allowing prosthetically driven implant placement if the space is well maintained and stabilized.

Postoperative mesh exposure is the most common complication.[21] Early exposure was reportedly more detrimental to bone gain than late exposure.[24] Two systematic reviews reported mean exposure rates of 16.1%[21] and 34.8%[22] (range: 0% to 80%). In a recent systematic review regarding vertical augmentation, other nonresorbable barrier membranes were reported to have a lower complication rate (6.9%) than Ti-mesh (20%).[25] The mesh exposure rate of 22% in the present study was consistent with systemic reviews: The exposure risk increased as age increased. In the younger adults, only 3% (1 of 33) of implant sites had exposure, while the values were 23% and 36% in the middle-aged and older adults, respectively. While most studies did not report an association between age and exposure, the association between aging and delayed wound healing and increased soft tissue fragility was biologically plausible.[26] Other studies reported male gender[27] and thin gingival biotype[28] as being more likely to have exposure, while using platelet concentrates[27,28] over the mesh reduced the chance of exposure. Thick, soft tissue is advantageous because of the high volume of extracellular matrix collagen to withstand collapse and contraction, as well as the increased vascularity that boosts wound healing.[29] Removable provisional restorations should be passive to reduce the risk of flap dehiscence from loading over the surgical site.[30] Although mesh exposure was related to reduced horizontal bone gain in other studies,[24,28] the difference in the present study was not statistically significant. No mesh was removed early in the present study, though one systematic review reported the necessity for early removal at 22.8%.[21] It is possible that the soft tissue migrates under the exposed mesh, protecting the graft from infection and limiting the amount of resorption. Consistent with other studies,[22] mesh exposure did not interfere with successful implant placement in the present study.

The dimensional changes in bone volume in the present study were consistent with previous Ti-mesh studies. In a randomized clinical trial of 30 patients,[28] effective bone augmentation was achieved using Ti-mesh with or without platelet-rich plasma (PRP). In the PRP group, the mean horizontal and vertical gains were 4.1 ± 0.6 mm and 3.5 ± 0.7 mm, respectively. The values in the non-PRP group were 3.7 ± 0.6 mm for width gain and 3.1 ± 0.8 mm for height gain. One systemic review reported a mean horizontal augmentation of 4.36 mm (range: 3.75 to 5.65 mm) and a mean vertical augmentation of 4.91 mm (range: 2.56 to 8.6 mm).[22] While not all included studies reported implant-related data, the survival rate was 100% among the 130 analyzed implants.[22]

Table 4 The Stepwise Logistic Regression Analysis on the Need for Contour Augmentation

	OR (95% CI)	*P*
Location – posterior	0.21 (0.06–0.75)	.016*
Provisional – fixed	0.82 (0.13–5.27)	.838
Provisional – TPD	1.13 (0.19–6.92)	.893
Provisional – CD	0.02 (0.004–0.13)	< .001*
Null deviance: 124.82 on 90 degrees of freedom		

OR = odds ratio; CI = confidence interval; TPD = transitional partial denture; CD = complete denture.
*The difference between the odds of needing contour augmentation at the treatment group (eg, provisional – CD) and the reference group (eg, provisional – nothing) are statistically significant ($P < .05$) when other factors were held at a fixed value. In the model, the reference groups were: location – anterior and provisional – nothing.

Conclusions

With the limitations of this retrospective study, Ti-mesh used with a variety of biomaterials is an effective technique for implant site development in the maxilla. All cases had sufficient bone gain for implant placement, and the small differences in horizontal bone gain among different combinations of bone grafts and biologics were not statistically significant. Older adults seemed to have a higher chance of mesh exposure than the younger adults. Patients, especially those undergoing procedures in the anterior region, should be informed of the possibility of additional contour bone grafting at the time of implant placement to achieve the desirable bone thickness buccal to the implants for long-term implant success.

Acknowledgments

The authors declare no conflicts of interest.

References

1. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants 2009;24(suppl):237–259.
2. Levine RA, McAllister BS. Implant site development using Ti-mesh and cellular allograft in the esthetic zone for restorative-driven implant placement: A case report. Int J Periodontics Restorative Dent 2016;36:373–381.
3. Levine RA, Manji A, Faucher J, Present S. Use of titanium mesh in implant site development for restorative-driven implant placement: Case report. Part 1—Restorative protocol for single-tooth esthetic zone sites. Compend Contin Educ Dent 2014;35:264–273.
4. Levine RA, Manji A, Faucher J, Fava PL. Use of titanium mesh in implant site development for restorative-driven implant placement: Case report. Part 2—Surgical protocol for single-tooth esthetic zone sites. Compend Contin Educ Dent 2014;35:324–333.
5. Morton D, Chen ST, Martin WC, Levine RA, Buser D. Consensus statements and recommended clinical procedures regarding optimizing esthetic outcomes in implant dentistry. Int J Oral Maxillofac Implants 2014;29(suppl):s216–s220.
6. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol 2007;78:377–396.
7. Susin C, Fiorini T, Lee J, De Stefano JA, Dickinson D, Wikesjö UM. Wound healing following surgical and regenerative periodontal therapy. Periodontol 2000 2015;68:83–98.
8. Retzepi, M, Donos N. Guided bone regeneration: Biological principle and therapeutic applications. Clin Oral Implants Res 2010;21:567–576.
9. Chappuis V, Martin W. Buser D, Chen S, Wismeijer D (eds). ITI Treatment Guide, vol 10. Implant Therapy in the Esthetic Zone: Current Treatment Modalities and Materials for Single-Tooth Replacements. Chicago: Quintessence, 2017.
10. Levine RA, Huynh-Ba G, Cochran DL. Soft tissue augmentation procedures for mucogingival defects in esthetic sites. Int J Oral Maxillofac Implants 2014;29(suppl):s155–s185.
11. Levine RA, Ganeles J, Gonzaga L, et al. 10 keys for successful esthetic-zone single immediate implants. Compend Contin Educ Dent 2017;38:248–260.
12. Belser U, Martin W, Jung R, et al. Buser D, Belser U, Wismeijer D (eds). Achieving Optimal Esthetic Results. ITI Treatment Guide, vol 1: Implant Therapy in the Esthetic Zone: Single-Tooth Replacements. Chicago: Quintessence, 2007:25–230.
13. Levine RA, Ganeles J, Kan J, Fava PL. 10 keys for successful esthetic-zone single immediate implants: Importance of biotype conversion for lasting success. Compend Contin Educ Dent 2018;39:522–530.
14. Chappuis, V, Rahman L, Buser R, Janner SFM, Belser UC, Buser D. Effectiveness of contour augmentation with guided bone regeneration: 10-year results. J Dent Res 2018;97:266–274.
15. Thoma DS, Bienz SP, Figuero E, Jung R, Sanz-Martín I. Efficacy of lateral bone augmentation performed simultaneously with dental implant placement: A systematic review and meta-analysis. J Clin Periodontol 2019;46:257–276.
16. Boyne PJ, Cole MD, Stringer D, Shafqat J. A technique for osseous restoration of deficient edentulous maxillary ridges. J Oral Maxillofac Surg 1985;43:87–91.
17. Roccuzzo M, Savoini M, Dalmasso P, Ramieri G. Long-term outcomes of implants placed after vertical alveolar ridge augmentation in partially edentulous patients: A 10-year prospective clinical study. Clin Oral Implants Res 2017;28:1204–1210.
18. World Medical Association. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA 2013;310:2191–2194.
19. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH. Gingival biotype assessment in the esthetic zone: Visual versus direct measurement. Int J Periodontics Restorative Dent 2010;30:237–243.
20. Rocchietta I, Ferrantino L, Simion M. Vertical ridge augmentation in the esthetic zone. Periodontol 2000 2018;77:241–255.
21. Briguglio F, Falcomatà D, Marconcini S, Fiorillo L, Briguglio R, Farronato D. The use of titanium mesh in guided bone regeneration: A systematic review. Int J Dent 2019;2019:9065423.
22. Rasia-dal Polo M, Poli PP, Rancitelli D, Beretta M, Maiorana C. Alveolar ridge reconstruction with titanium meshes: A systematic review of the literature. Med Oral Patol Oral Cir Bucal 2014;19:e639–e646.
23. Misch CM, Basma H, Misch-Haring MA, Wang HL. An updated decision tree for vertical bone augmentation. Int J Periodontics Restorative Dent 2021;41:11–21.
24. Lizio G, Corinaldesi G, Marchetti C. Alveolar ridge reconstruction with titanium mesh: A three-dimensional evaluation of factors affecting bone augmentation. Int J Oral Maxillofac Implants 2014;29:1354–1363.

25. Urban IA, Montero E, Monje A, Sanz-Sánchez I. Effectiveness of vertical ridge augmentation interventions: A systematic review and meta-analysis. J Clin Periodontol 2019;46(suppl 21): s319–s339.
26. Kim YG, Lee SM, Bae S, et al. Effect of aging on homeostasis in the soft tissue of the periodontium: A narrative review. J Pers Med 2021;11:58.
27. Hartmann A, Seiler M. Minimizing risk of customized titanium mesh exposures—A retrospective analysis. BMC Oral Health 2020;20:36.
28. Torres J, Tamimi F, Alkhraisat MH, et al. Platelet-rich plasma may prevent titanium-mesh exposure in alveolar ridge augmentation with anorganic bovine bone. J Clin Periodontol 2010;37:943–951.
29. Hwang D, Wang HL. Flap thickness as a predictor of root coverage: A systematic review. J Periodontol 2006;77:1625–1634.
30. Livada R, Hottel TL, Shiloah J. Provisional prostheses during ridge augmentation and implant dentistry. J Tenn Dent Assoc 2013;93:13–16.