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Case Report

Application of a Custom Two-Piece Zirconia Device for Multidimensional Ridge Augmentation in a Trauma Patient: A Case Report

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Abstract: ***Background*:** Due predominantly to anatomic factors, most maxillary anterior extraction sockets exhibit greater resorption of facial rather than palatal alveolar walls. However, traumatic episodes can result in physical damage to interproximal and palatal alveolar walls, leading to complex deficiencies that can be difficult to manage. The purpose of this report is to describe the use of a two-piece, site-specific zirconia device to augment the facial, crestal, and palatal aspects of a deficient maxillary anterior alveolar ridge. ***Methods*:** A 25-year-old male with history of facial trauma presented to the Department of Periodontics, Army Postgraduate Dental School, Fort Eisenhower, Georgia, requesting replacement of teeth #8 through #10. A two-piece custom zirconia device was utilized to achieve multidimensional augmentation of a severely deficient alveolar ridge. ***Results*:** The procedure was well tolerated, resulting in favorable alveolar ridge volume for dental implant placement. Exposure of the device occurred at postoperative week 13. One of two planned implants were stabilized in the augmented alveolar ridge. At the #10 position a palatal dehiscence defect was noted during osteotomy preparation, and additional grafting was required. ***Conclusions*:** The custom zirconia device design shown in this report permitted convenient intraoperative packing of bone biomaterial and minimized loss of regenerative space during healing. The protocol relies upon technology that is increasingly accessible to periodontists and has the potential to substantially simplify a technique-sensitive procedure. Envisioned design improvements are presented.

Keywords: Dental implants, cone-beam computed tomography, clinical protocols, treatment outcome, zirconia, alveolar ridge augmentation.

INTRODUCTION

Oral trauma accounts for almost 5% of all human injuries despite the oral cavity representing only 1% of total body volume [1]. Trauma to the anterior maxilla, in particular, predictably initiates a cascade of negative biopsychosocial consequences [2, 3]. Unlike other causes of alveolar destruction [4], a traumatic episode typically involves sudden, unexpected, severe pain under disorienting and distressing circumstances. Emergency treatment can be painful or otherwise unpleasant, possibly leading to apprehension and avoidance of subsequent dental care [3, 5]. Moreover, trauma-induced alveolar deficiencies can be extensive and complex, involving loss of hard and soft tissue volume. Traumatic forces can damage the palatal and lingual alveolar walls which, compared with facial walls, are normally more resistant to resorption following tooth loss [6, 7].

Critical requirements for bone regeneration include establishment and protection of space in which bone formation may occur, clot stability, and wound closure for primary intention healing [8]. In circumstances requiring vertical alveolar ridge augmentation, evidence suggests that superior clinical outcomes are achievable when form-stable membranes and devices are used [9]. Intuitively, such devices may also aid in augmenting the palatal aspect of deficient alveolar ridges where thick, unyielding mucosa and pressure from tongue oppose maintenance of the regenerative space [10]. The purpose of this case report is to demonstrate application of a two-piece custom zirconia device in augmentation of the facial, crestal, and palatal aspects of a deficient alveolar ridge for a patient with history of trauma to the anterior maxilla.

MATERIALS AND METHODS

In February of 2022, a 25-year-old male with history of trauma to the anterior maxilla presented to the Department of Periodontics, Army Postgraduate Dental School, Fort Eisenhower, Georgia. At age 17, the patient was involved in a motor vehicle accident resulting in trauma to the anterior maxilla. Teeth #9 and 10 were lost. Following nonsurgical root canal therapy for teeth #6, 8, and 11, the patient received a six-unit fixed dental prosthesis (#6-7-8-X-X-11). Subsequently, tooth #8 had been extracted due to external root resorption. The patient's medical history was otherwise unremarkable; he reported no medications and no allergies.

Examination revealed vertical and horizontal alveolar ridge deficiency in the anterior maxilla (Fig. 1). The keratinized mucosa in the maxillary anterior exhibited irregular contours, and the vestibule was shallow. Recession type 1A- (≤ 1 mm) was present at teeth #11, 12, 20, and 21. At the remainder of the dentition, clinical gingival health was present, and radiographically, interproximal bone levels appeared ≈ 2 mm from the cementoenamel junctions generally (Fig. 2). A cone-beam computed tomography (CBCT) scan revealed severe alveolar ridge deficiency with apparent loss of facial, crestal, and palatal bone (Fig. 3). The patient requested replacement of the missing maxillary anterior teeth and expected to remain in Augusta, GA, USA, until June 2023. Treatment options were discussed in detail, and the patient elected alveolar ridge augmentation, implant placement, and restoration with a fixed dental prosthesis. The patient understood that the restorative phase of therapy would be completed at his next duty location due to time limitations. He completed an informed consent process involving verbal and written components. Treatment was coordinated with the restorative dentist at the patient's next duty station.

A two-piece custom zirconia device was designed using 3-dimensional modeling software (MeshMixer, Autodesk, San Rafael, CA) (Figs. 3 and 4). The Standard Tessellation Language (STL) files were submitted to the Army Dental Laboratory, Fort Eisenhower, GA, USA, where an automatic material management system (PrograMill PM7, Ivoclar, Schaan, Liechtenstein) was used to mill the device from an e.max ZirCAD puck (Ivoclar Vivadent). A crestal incision was made between tooth #7 and tooth #11, with intrasulcular incisions at teeth #5 through #7 and #11 through #14. Vertical incisions were placed at the distal margins of the facial flap. Full-thickness facial and palatal mucoperiosteal flaps were reflected, and a periosteal releasing incision was used to coronally advance the facial flap. Trauma-related scarring of the facial periosteum was noted. The incisive canal was enucleated, and the palatal segment of the custom device was inserted (Fig. 5). A 1.5-mL solvent-dehydrated bone allograft (SDBA) (Puros cancellous particulate allograft, ZimVie, Westminster, CO, USA) was applied, and each component of the device was secured with fixation screws (BioHorizons, Birmingham, AL, USA) (Figs. 5 and 6). Native collagen (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) and amnion-chorion (BioXclude, Snoasis Medical, Golden, CO, USA) membranes were layered over the device to minimize soft tissue irritation/atrophy and reduce risk of wound dehiscence. The wound was closed using horizontal mattress and simple interrupted sutures (4-0 Cytoplast, BioHorizons). The patient received amoxicillin (500 mg) 3 times daily for 7 days, starting the day prior, and dexamethasone (8 mg) immediately prior to initiating the procedure. Ibuprofen (400 mg) and acetaminophen (500 mg) were used as needed for analgesia with oxycodone (5 mg) reserved for breakthrough pain. Toothbrushing was withheld at the surgical site for 3 weeks, and a 0.12% chlorhexidine gluconate rinse was used for plaque control until normal oral hygiene measure could be reinstated.

Healing proceeded uneventfully, and no exposure of the zirconia device was detected at any postoperative assessment. A CBCT scan was acquired at postoperative month 3 to facilitate implant planning and surgical guide fabrication (Fig. 7). Favorable alveolar ridge dimensions for implant placement were appreciated. One week following the CBCT scan, the patient reported exposure of the zirconia device. The site was re-entered for implant placement ≈ 4 months following alveolar ridge augmentation (Fig. 8). Upon re-entry, a well-defined pseudoperiosteum was centered over the seam between the facial and palatal device segments. The pseudoperiosteum was slightly thicker on the left compared with the right side. Deep to the pseudoperiosteum, the clinical quality of the bone was favorable. All surfaces of the alveolar ridge were hard when challenged with a periodontal probe. Comparing the device at insertion and re-entry, Figs. 6(A) and 8(B), a small reduction in volume was detectable on the palatal aspect of the ridge. In addition, the fixation screw in the #10 area was not flush with the device surface.

A 4 x 11.5-mm implant (Osseotite Tapered Certain, ZimVie) was installed in the #8 position with insertion torque > 50 N-cm (Fig. 9). Osteotomy preparation at the #10 site resulted in a palatal dehiscence defect, and implant placement

was deferred. A cross-linked bovine collagen membrane (BioMend Extend, ZimVie) was fitted, and a 0.5-mL SDBA (Puros cancellous particulate allograft, ZimVie) was applied.

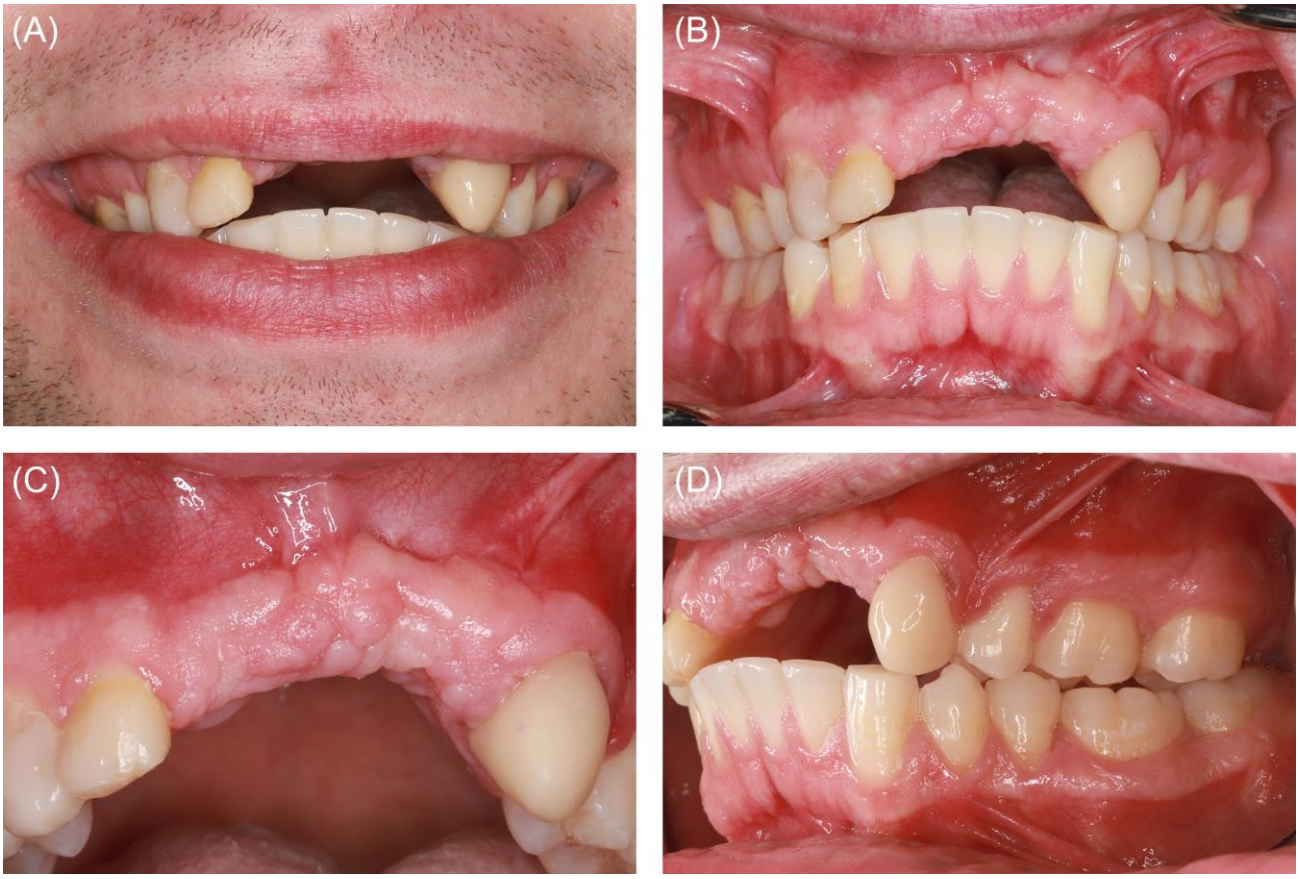

Figure 1: Baseline clinical appearance. (A) Smile. Teeth #9 and #10 were lost due to trauma at age 17. The mandibular incisors exhibited dentoalveolar extrusion. (B) Maximum intercuspation, facial view. A complex alveolar deficiency was noted in the maxillary anterior. The keratinized mucosa exhibited irregular contours. (C) Facial view of the deficient alveolar ridge. (D) Maximum intercuspation, left side.

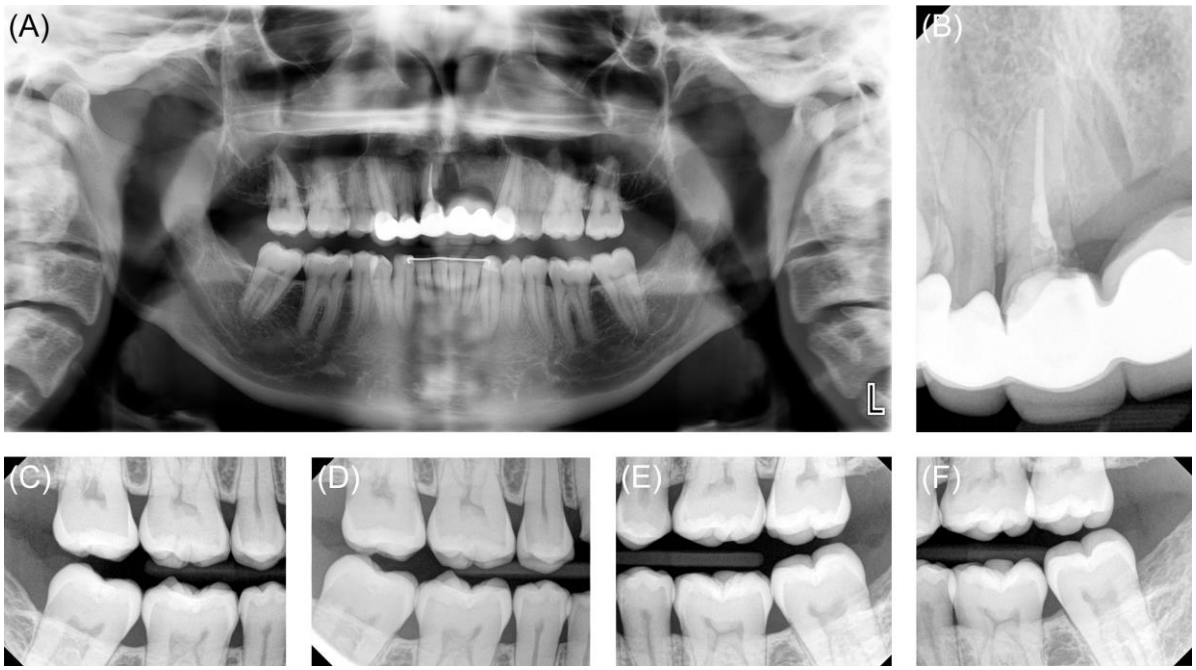

Figure 2: Baseline radiographs. (A) Panoramic radiograph. (B) Periapical radiograph, teeth #7 and #8. (C-F) Bite-wing radiographs.

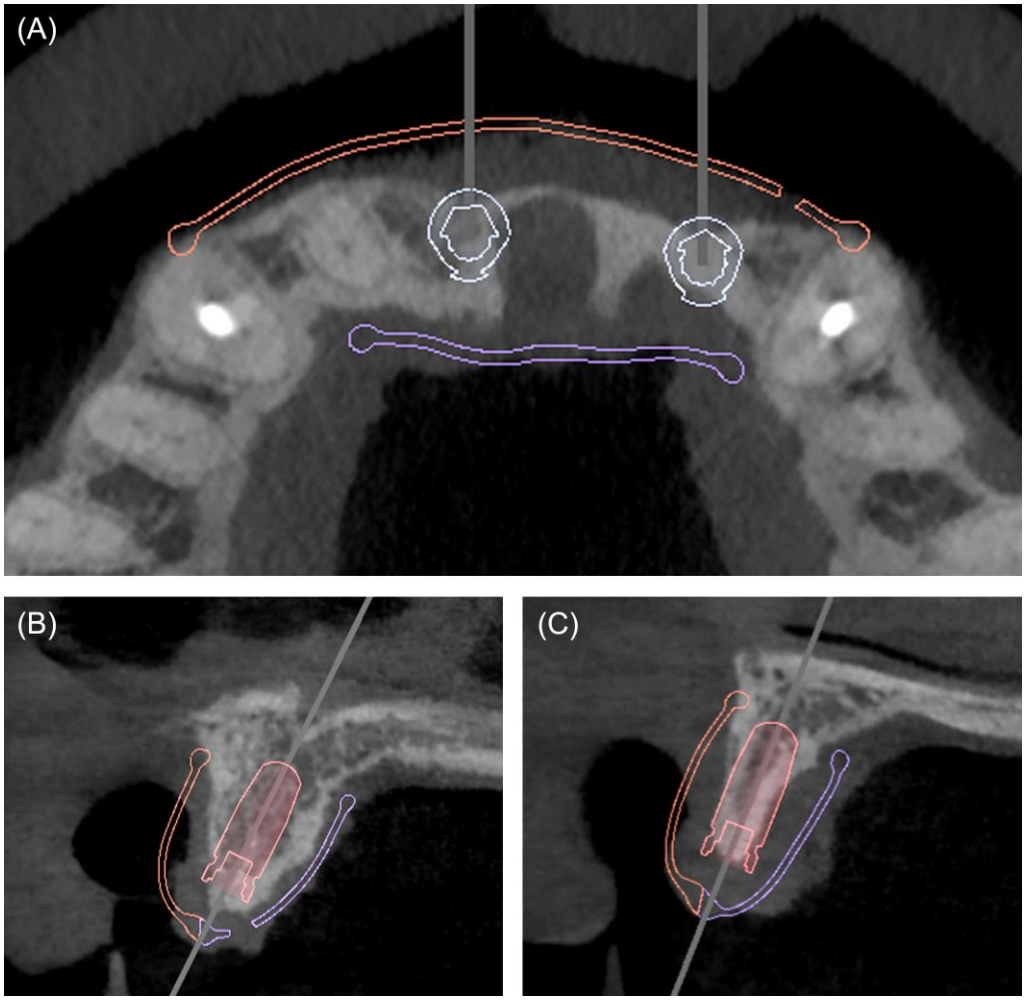

Figure 3: Baseline cone-beam computed tomography volume and computer-aided implant planning. (A) Axial view. (B) Cross sectional view, #8 area. (C) Cross sectional view, #10 area.

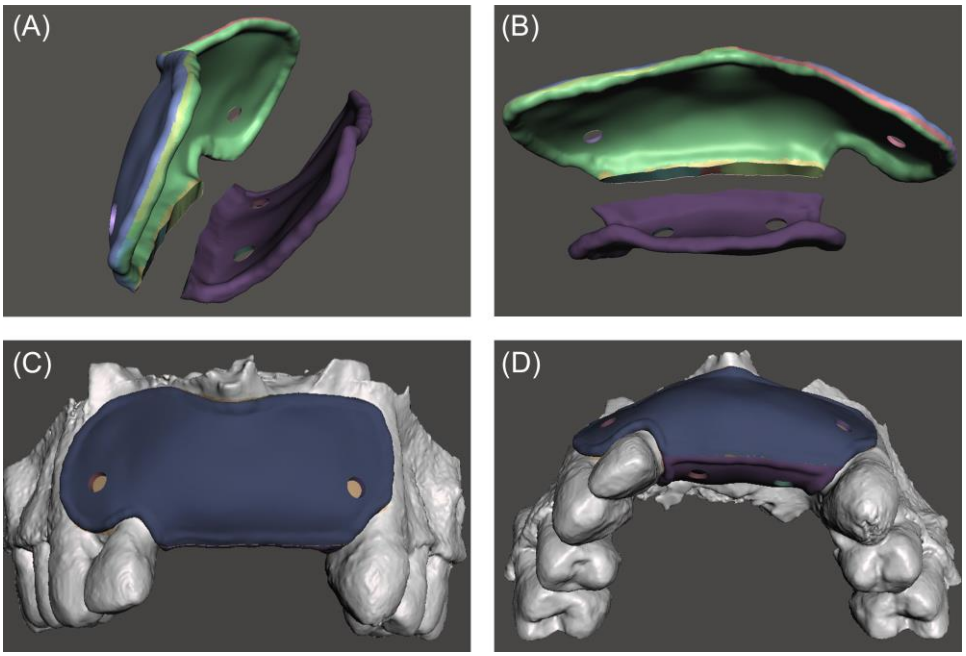

Figure 4: Custom zirconia device design. (A) Side view of the facial (left) and palatal (right) sections of the device. (B) Alveolar surface of the device. (C) Facial view on the scanned diagnostic cast. (D) Occlusal view on the scanned diagnostic cast.

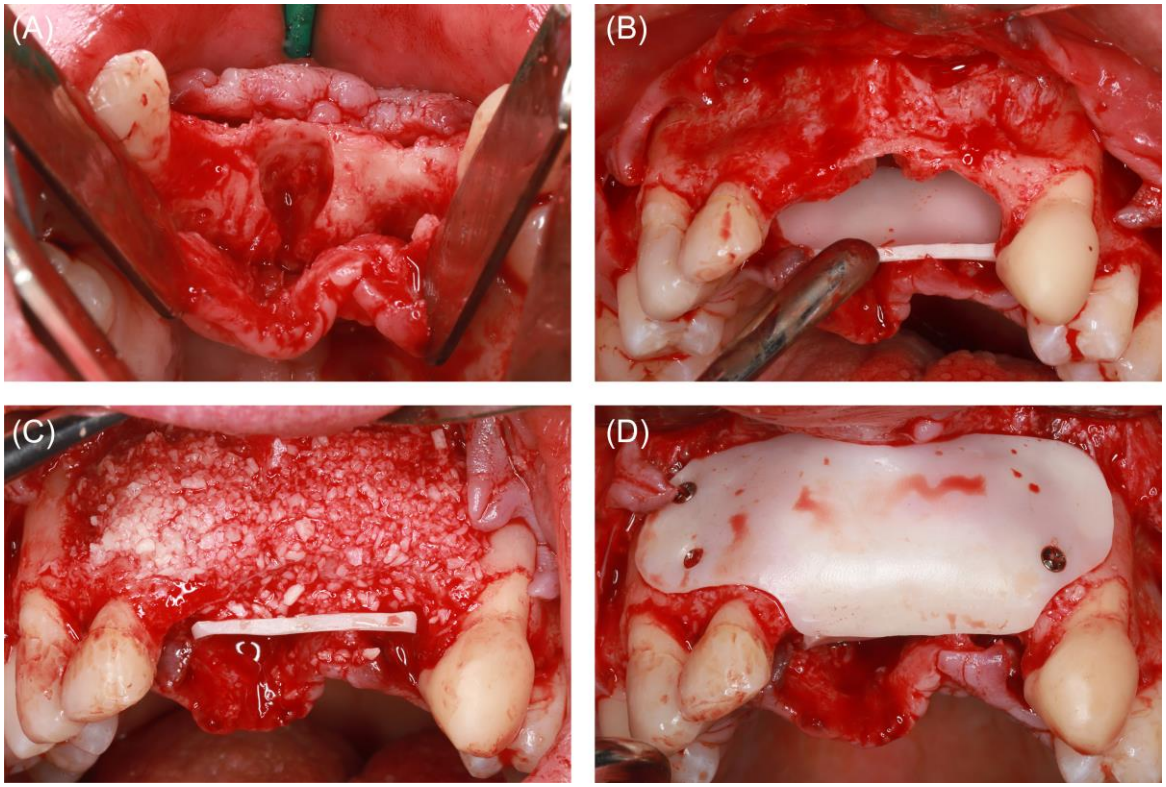

Figure 5: Alveolar ridge deficiency. (A) Palatal view after enucleation of the incisive canal. (B) Palatal segment of the two-piece custom zirconia device in place. (C) SDBA inserted between the palatal segment of the zirconia device and the alveolar bone. Additional SDBA material was applied on the facial aspect of the defect. (D) Facial segment of the zirconia device stabilized with fixation screws.

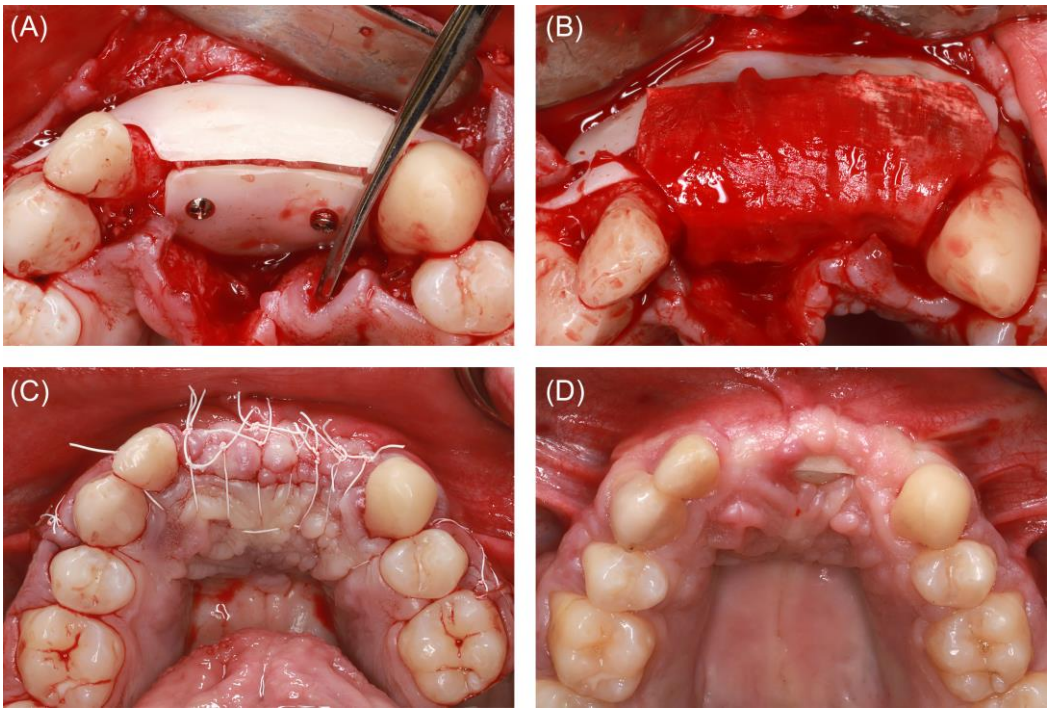

Figure 6: (A) Facial and palatal segments of the zirconia device stabilized, occlusal view. (B) To mitigate irritation of the overlying mucosa, a native collagen membrane and an amnion chorion membrane were layered over the zirconia device. (C) Wound closure for primary intention healing. Horizontal mattress and simple interrupted sutures were used to achieve wound closure. (D) The patient reported exposure of the device at postoperative week 13. After assessment, the decision was made to remove the device and place implants in the planned locations.

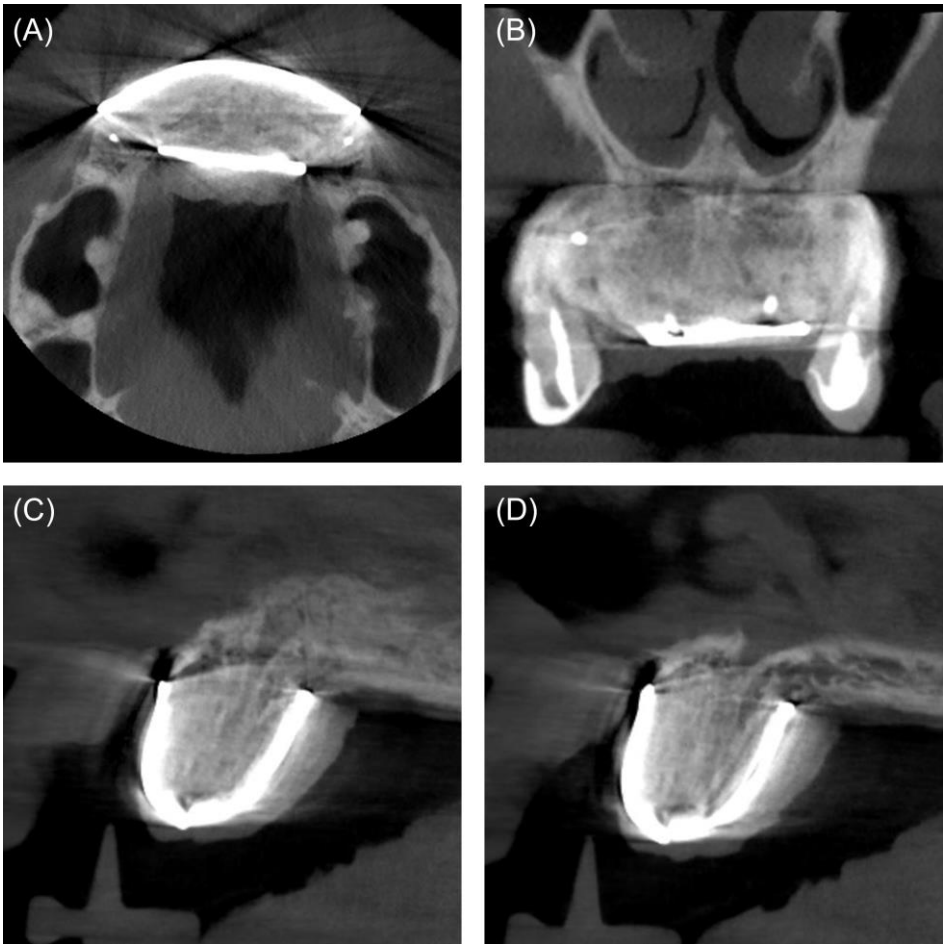

Figure 7: Cone-beam computed tomography volume at postoperative month 3. (A) Axial view. (B) Cross sectional view, #10 area. (B) Coronal view. (C) Cross-sectional view #8 area. (D) Cross-sectional view #10 area.

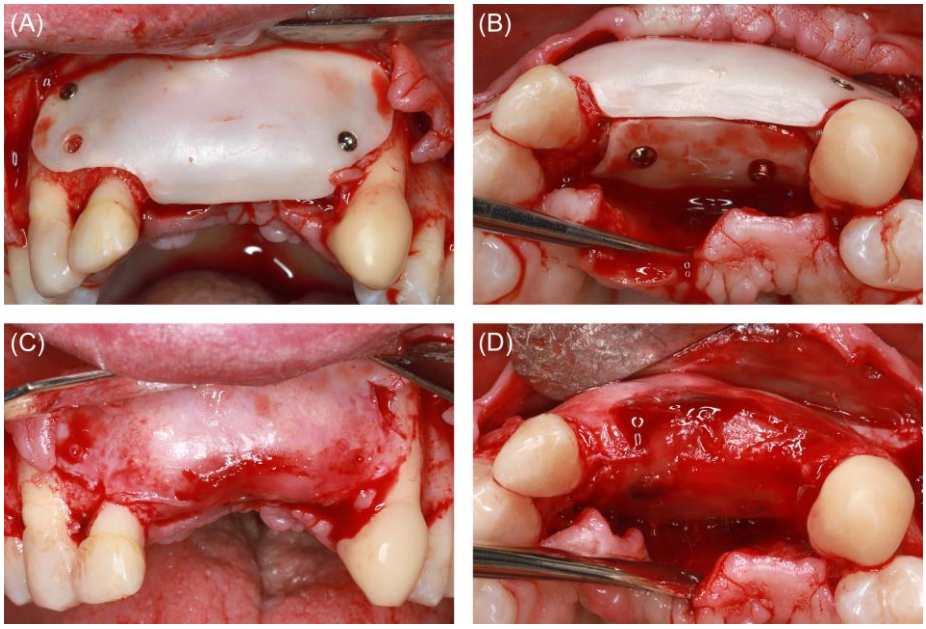

Figure 8: Re-entry for implant placement, ≈ 4 months following ridge augmentation. (A) Facial segment of zirconia device. (B) Occlusal view. Compared with baseline, the palatal segment appeared slightly displaced (loss of ridge volume), and the palatal fixation screw in the #10 area was no longer flush with the device surface. (C) Facial view of the regenerate. The allograft appeared well consolidated, and the ridge felt hard when challenged with a periodontal probe. Clearly delineated pseudoperiosteum was detectable along the seam between facial and palatal segments. (D) Occlusal view after device removal. The pseudoperiosteum was slightly thicker in the #10 area.

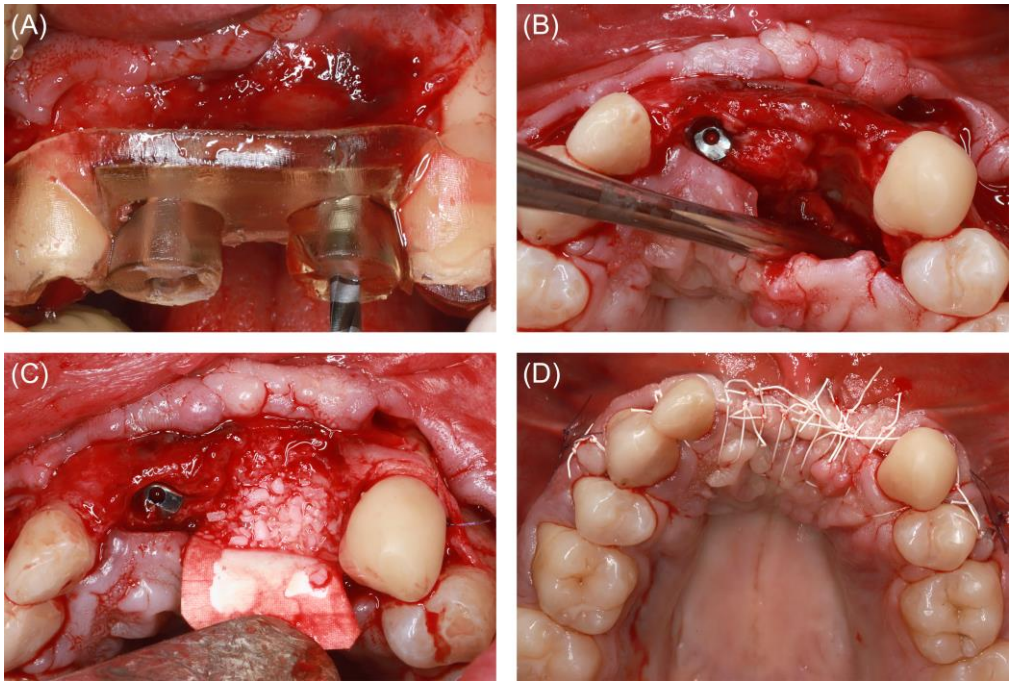

Figure 9: Implant placement. (A) Surgical template guiding the 2 mm twist drill. (B) Implant stabilized in the #8 position and crestal deficiency after initial osteotomy in the #10 position. Dense native cortical bone in the area likely deflected the osteotomy drills toward the palate. (C) Application of a particulate solvent-dehydrated bone allograft and a cross-linked bovine collagen membrane at the #10 site. A subepithelial connective tissue graft was placed at tooth #11 for root coverage and gingival augmentation. (D) Wound closure for primary intention healing.

DISCUSSION

The purpose of this report is to illustrate the use of a two-piece custom zirconia device in the multidimensional augmentation of a complex maxillary alveolar deficiency. Two complications were recorded in this case: device exposure and loss of the palatal wall during osteotomy preparation at site #10. Risk of device exposure was a concern from the outset. The prosthesis-driven implant position required facial, palatal, and crestal augmentation of the alveolar ridge. To coronally advance the facial flap, a periosteal releasing incision was placed apical to the mucogingival junction. This incision created a separation in the periosteum, exposing underlying submucosa. In contrast, the palatal mucosa lacks a submucosa [10]. Thus, coronal advancement of the palatal flap is not possible. To achieve wound closure, release of the facial flap must entirely account for the full volume of the implanted devices and materials. Thus, the requirement for multidimensional augmentation increases the likelihood of excess flap tension at closure. Moreover, use of form-stable devices such as titanium mesh, zirconia devices, and titanium-reinforced membranes has been associated with wound dehiscence [9, 11-13]. In attempt to reduce exposure risk in this case, a porcine native collagen membrane and an amnion-chorion membrane were layered over the device before closing. At each postoperative visit, the site was thoroughly inspected for signs of exposure, and the wound remained closed for 3 months.

Device Design

A two-piece zirconia device design was utilized in this case. This strategy facilitated application of bone biomaterial in the deficient areas of the ridge. By contrast, designs lacking access for graft placement may promote incomplete seating of the device or incorporation of voids. Use of a two-piece design eliminates the potential for locking the device in place after healing if an undercut is present. Moreover, depending upon the material and milling system used, technical considerations may limit device dimensions. Using two separate sections can increase the envelope of augmentation if necessary.

In the presented case, the site-specific zirconia device design included preplanned fixation screw positions but lacked perforations in the augmented area. Both device configurations—with and without perforations—have been described [14, 15]. The rationale for adopting a perforated design involves reducing flap atrophy and exposure risk. In addition, perforations offer the possibility of leveraging vascularity and cellular resources from the flap, particularly when a biologic such as bone morphogenetic protein-2 is applied [16] (not used in this case). Perforations also increase tissue integration with the device, improving wound stability. Avoiding perforations in the design enhances cell occlusivity, ensuring that cells originating from bone predominantly populate the site. Using a non-perforated design also reduces risk of device fracture during milling. When perforations are planned, beading (increased material thickness) at the device margins and incorporation of inter-perforation struts can enhance reliability in the milling process.

Observations at Re-entry

A postoperative CBCT scan was acquired 3 months after ridge augmentation. On the CBCT volume, device biocompatibility appeared favorable, consistent with prior reports [14, 17]. Tissue exhibiting bone density appeared in direct approximation with the zirconia (Fig. 9). A pseudoperiosteum deep to the device, which appeared thicker at the #10 site, was noted clinically. It is possible that the fixation screw in this area was of inadequate length to maintain stability over the healing period. This factor in combination with imperfect approximation of the two device segments (i.e. presence of a gap between segments at device installation) may have permitted micromovement of the palatal segment. Nevertheless, upon device retrieval, the alveolar ridge appeared clinically favorable for implant placement.

A surgical template was used to create osteotomies at the #8 and 10 positions. The #8 fixture was stabilized as planned. However, osteotomy preparation at the #10 site resulted in loss of the crestal aspect of the palatal wall, Fig. 9(B). It is likely that dense native cortical bone at the site, Fig. 3(C), deflected shaping drills in the palatal direction. To avoid this complication, initiating the osteotomy with a precision drill (1.5 mm starter drill, BioHorizons) and a side-cutting carbide (Lindemann drill, BioHorizons) may be helpful.

Design Improvements

Based on lessons learned in the presented case, several design and technique improvements could be considered. Intraoperatively, adaptation and stabilization at the junction of the two segments was not achieved in the presented case. In addition, only two fixation screws were used for each segment, and at re-entry, the stability of the screw in the #10 area was questionable. Planning four fixation screws per segment would reduce the influence of tipping and rotational forces, offer flexibility during surgery, and build redundancy into the system. At the seam, ball joints between facial and palatal device segments (Fig. 10) may permit some tolerance in adapting the two sections yet increase overall stability. The 3-dimensional modeling software (MeshMixer, Autodesk) offers convenient ball joint design using a preformed sphere tool then applying union and Boolean difference functions. Stability at the interface may be further enhanced by incorporating holes for sutures to position and reinforce the ball joints.

A variety of materials and devices could have produced a successful outcome in this case. Titanium mesh is a material commonly selected when space maintenance is difficult to achieve. Unfortunately, the overall mean reported exposure rate of titanium mesh is 16% (range 0% to 50%) [11]. Such exposures can severely compromise soft tissue contours and diminish keratinized mucosa dimensions. In the presented case, a late exposure was observed at 13 weeks. Currently available data do not permit conclusions regarding the relative exposure risks when zirconia devices and titanium meshes are used for space maintenance in ridge augmentation procedures. The approach presented in this report required substantial preoperative planning and a reliable digital workflow. However, the protocol shortened and simplified the ridge augmentation procedure by establishing a site-specific space maintenance device preoperatively.

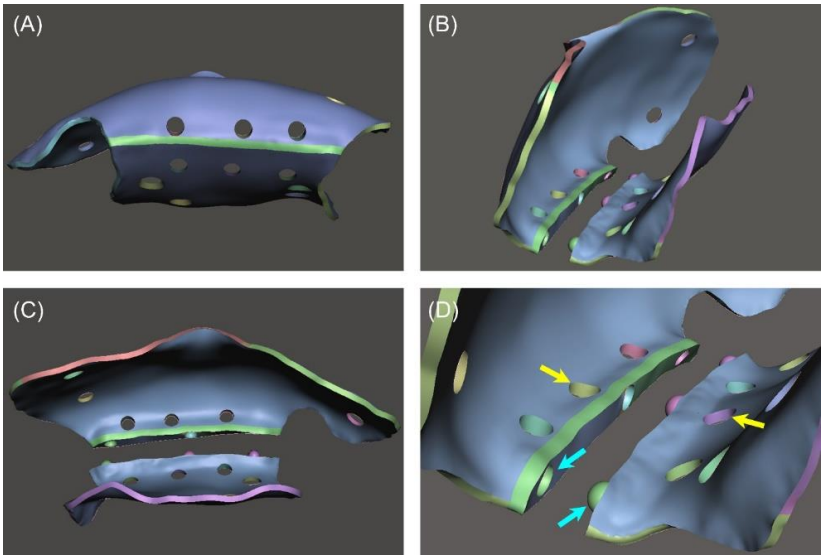

Figure 10: Envisioned design improvements. Based on lessons learned in the presented case, ball-socket joints between facial and palatal segments (blue arrows) may improve device stability while maintaining tolerance when approximating the two sections. In addition, perforations in the device to permit suturing (yellow arrows) may further enhance stability of the system.

CONCLUSIONS

Unlike other alveolar ridge deficiency etiologies, trauma has the potential to instantly produce a severe, complex defect at a previously pristine site. Technologies and materials increasingly accessible to periodontists may help

practitioners plan treatment, shorten surgery, and improve outcome predictability in such cases. The presented protocol demonstrates a two-piece custom zirconia device for maintaining alveolar ridge augmentation space. Controlled clinical investigation to determine optimal design parameters and establish relative efficacy compared with alternative treatment appears warranted. Successful use of the described device appears highly dependent upon detailed preoperative planning and a reliable digital workflow.

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REFERENCES

1. Andersson, L. (2008). Trauma in a global health perspective. *Dent Traumatol*, *24*, 267-267.
2. Al-Omiri, M. K., Karasneh, J. A., Lynch, E., Lamey, P. J., & Clifford, T. J. (2009). Impacts of missing upper anterior teeth on daily living. *Int Dent J*, *59*, 127-132.
3. Lee, J. Y., & Divaris, K. (2009). Hidden consequences of dental trauma: the social and psychological effects. *Pediatr Dent*, *31*, 96-101.
4. Hämmerle, C. H., & Tarnow, D. (2018). The etiology of hard-and soft-tissue deficiencies at dental implants: A narrative review. *J Periodontol*, *89*, S291-S303.
5. Litt, M. D. (1996). A model of pain and anxiety associated with acute stressors: Distress in dental procedures. *Behav Res Ther*, *34*, 459-476.
6. Pietrokovski, J., & Massler, M. (1967). Alveolar ridge resorption following tooth extraction. *J Prosthet Dent*, *17*, 21-27.
7. El-Chaar, E. S. (2011). Immediate placement and provisionalization of implant-supported, single-tooth restorations: A retrospective study. *Int J Periodontics Restorative Dent*, *31*, 408-419.
8. Polimeni, G., Xiropaidis, A. V., & Wikesjö, U. M. (2006). Biology and principles of periodontal wound healing/regeneration. *Periodontol 2000*, *41*, 30-47.
9. Urban, I. (2017). Vertical ridge augmentation. In: Urban I, ed. *Vertical and Horizontal Ridge Augmentation*. Chicago: Quintessence; 61-64.
10. Berkovitz, B. K. B., Holland, G. R., & Moxham, B. J. (1992). *A Colour Atlas and Textbook of Oral Anatomy, Histology, and Embryology*. 2nd ed. London: Wolfe Publishing Ltd.; 205-216.
11. dal Polo, M. R., Poli, P. P., Rancitelli, D., Beretta, M., & Maiorana, C. (2014). Alveolar ridge reconstruction with titanium meshes: a systematic review of the literature. *Med Oral Patol Oral Cir Bucal*, *19*, e639-e646. https://doi.org/10.4317/medoral.19998.
12. Elgali, I., Omar, O., Dahlin, C., & Thomsen, P. (2017). Guided bone regeneration: materials and biological mechanisms revisited. *Eur J Oral Sci*, *125*, 315-337.
13. Urban, I. (2017). Materials and graft materials. In: Urban I, ed. *Vertical and Horizontal Ridge Augmentation*. Chicago: Quintessence; 9-19.
14. Mandelli, F., Traini, T., & Ghensi, P. (2021). Customized-3D zirconia barriers for guided bone regeneration (GBR): clinical and histological findings from a proof-of-concept case series. *J Dent*, *114*, 103780. https://doi.org/10.1016/j.jdent.2021.103780.
15. Vargas, S. M., Johnson, T. M., Pfaff, A. S., Bumpers, A. P., Wagner, J. C., Retrum, J. K., ... & Lincicum, A. R. (2023). Clinical protocol selection for alveolar ridge augmentation at sites exhibiting slight, moderate, and severe horizontal ridge deficiencies. *Clinical Advances in Periodontics*, *13*(3), 174-196. https://doi.org/10.1002/cap.10239. Epub ahead of print. PMID: 36760073.
16. De Freitas, R. M., Susin, C., Spin-Neto, R., Marcantonio, C., Wikesjö, U. M., Pereira, L. A. V. D., & Marcantonio Jr, E. (2013). Horizontal ridge augmentation of the atrophic anterior maxilla using rhBMP-2/ACS or autogenous bone grafts: a proof-of-concept randomized clinical trial. *Journal of clinical periodontology*, *40*(10), 968-975.
17. Rodríguez-Lozano, F. J., López-García, S., Sánchez-Bautista, S., Pérez-López, J., Raigrodski, A. J., & Revilla-León, M. (2023). Effect of milled and lithography-based additively manufactured zirconia (3Y-TZP) on the biological properties of human osteoblasts. *The Journal of Prosthetic Dentistry*, *130*(6), 889-896. https://doi.org/10.1016/j.prosdent.2022.01.025. Epub ahead of print. PMID: 35264309.