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Modified 3-Dimensional Alveolar Ridge Augmentation in the Anterior Maxilla: A Prospective Clinical Feasibility Study

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Vertical and horizontal reconstruction of the alveolar ridge, especially in the anterior maxilla, is considered a clinical challenge for dentists. There is still a lack of a standard technique to address the hurdles in 3-dimensional bone regeneration in the anterior maxilla. In this clinical feasibility study, we aimed to modify Khoury's technique by combining the conventional guided bone regeneration standards with the principles of this technique. The autogenous bone blocks were harvested from the retromolar area and grafted into the deficient anterior maxillae by mini-screws, and the gap was filled with xenogenic bone particles. The grafted site was covered with multilayered resorbable collagen membranes. Cone-beam computerized tomographic scans were obtained at the 6-month follow-ups, and the changes in ridge width and height were measured. Five subjects with multiple missing teeth at the anterior maxilla were included. The radiographic outcomes of the 6-month follow-ups revealed 1.2 mm of height and 3.5 mm of width gain. Between the 4- and 6-month visits, approximately 2 mm resorption in height and 0.3 mm in width occurred. No complications occurred. The proposed modification for Khoury's technique can serve as a feasible method in the 3-dimensional reconstruction of the anterior maxilla without additional autogenous bone particles.

Key Words: bone regeneration, ridge augmentation, dental implants, autografts, alveolar ridge augmentation

Introduction

The phenomenon of alveolar ridge resorption occurs physiologically following tooth loss.[1,2] Achieving the optimal treatment outcomes in placing implants in the anterior maxillary area is critical due to esthetic concerns.[3] This becomes even more crucial in cases of severe vertical and horizontal loss of the alveolar ridge, and reconstruction of the defects in this area is utterly challenging.[3–5] Several surgical interventions have been introduced to regenerate the bygone structure. Among these, distraction osteogenesis,[6] onlay grafts,[7,8] guided bone regeneration[1] (GBR), and ridge splitting[9] can be mentioned.[1] Nevertheless, the latest conclusions in the current literature indicate that autogenous bone grafts still serve as the gold standard in 3-dimensional bone reconstruction.[1,8,10] The benefit of these grafts is superior regenerative capacity thanks to their osteogenic, osteoinductive, and osteoconductive properties.[8,11] Moreover, when considering autogenous bone harvesting extra- (iliac crest, tibia, etc) and intraoral (ramus, retromolar, chin, etc) sites are available.[12] The latter's advantages outweigh the former due to the easier surgical access, proximity to the recipient site, and lower morbidity.[13] However, the possible complications and especially patient discomfort should be acknowledged when this approach is followed. Thereby, other less-invasive methods such as conventional or 3-dimensionally–printed allogenic/xenogeneic/alloplastic bone grafts can also be considered in these procedures, which in turn reduce the treatment time and patient morbidity.[14]

Initially, Khoury et al[13] introduced the 3-dimensional bone augmentation technique by stabilizing 2 autologous bone blocks using microscrews and filling the generated gap with autogenous bone chips without using a barrier membrane field. This was somewhat different from the conventional GBR procedures, in which a resorbable or nonresorbable membrane would be used.[11]

Nevertheless, the drawbacks of not placing barrier membranes would possibly cause lack of cell exclusion and/or promotion of muscle disruption, which can contribute to bone (graft) resorption.[15] In addition, performing ridge augmentation solely using autogenous grafts has been shown to possess a higher risk of resorption.[15] Taking these possible limitations into consideration, we aimed to propose a modification for Khoury's technique by combining it with the standards of GBR using a xenogenic bone graft material and resorbable membranes, specifically in the esthetic zone.

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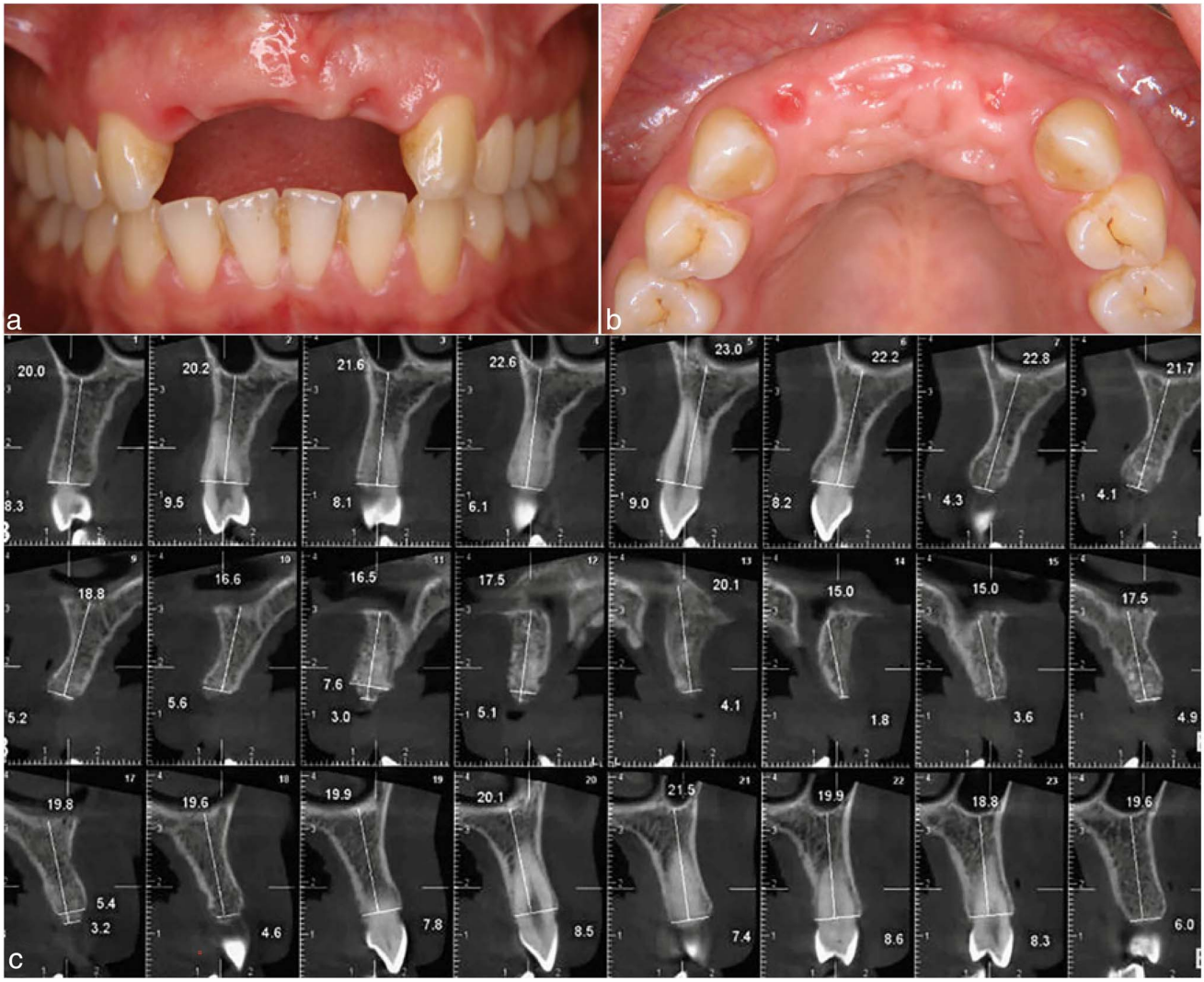

Figure 1. Preoperative clinical photographs of one of the subjects indicate missing 4 anterior teeth. (a) Frontal view. (b) Occlusal view. (c) Baseline cone-beam computerized tomographic images. Note the 3-dimensional loss of alveolar ridge in the anterior maxilla.

Materials and Methods

Study design and subject recruitment

The present study was conceptualized within a prospective clinical feasibility design in which a total of 5 patients who presented with extensive vertical and horizontal ridge deficiencies between 2017 and 2022 to a private clinic were treated and followed up for 6 months. The inclusion criterion for the selection of the cases was an edentulous anterior maxillary area (esthetic zone) with 3-dimensional ridge defects requiring ridge augmentation with a delayed implant placement approach. The exclusion criteria were (1) patients younger than 18 years, (2) >4-mm vertical ridge deficiency, (3) a smoking habit of ≥10 cigarettes per day, and (4) any general or medical condition or medication known to alter soft-/hard-tissue healing or contraindicating implant surgery (poorly controlled diabetes mellitus, bisphosphonates therapy, immunosuppressives, etc). After fulfillment of the inclusion criteria and a thorough explanation of the study protocol, patients were asked to provide informed consent before recruitment. The present research was conducted in full accordance with ethical principles, including the Declaration of Helsinki of 1965, as revised in Tokyo in 2013. Moreover, all patients had provided their written informed consent before all treatments, and the current article was prepared following the items presented in the STROBE statement (www.strobe-statement.org, checklist provided as a supplementary file).

Presurgical evaluations

Visual examination and digital palpation were performed in both the deficient region and donor site to obtain a preliminary estimation of the quality of the soft tissue and morphology, dimensions, and contours of the underlying bone (Figure 1). Moreover, cone-beam computerized tomographic (CBCT) scans and/or panoramic images were obtained to radiographically evaluate the defect and the characteristics of the donor sites (Figure 1c). Before moving forward to the surgical phase, all the

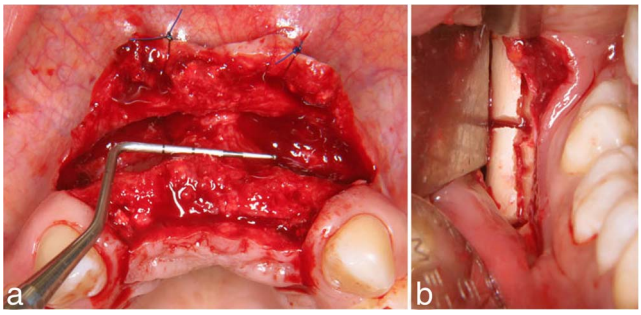

Figure 2. (a) Intraoperative photograph after flap reflection, depicting advanced atrophy in the anterior maxillary region. (b) The autograft blocks were harvested from the retromolar area as described by Khoury et al.

subjects underwent full-mouth ultrasonic debridement and oral hygiene instructions. All surgeries were performed by 1 surgeon (B.S.) applying a modified 3-dimensional GBR technique that combined a previously introduced technique by Khoury et al[13] and conventional GBR using xenogenic graft and resorbable membranes.

Surgical protocol

Administration of local anesthetic agents (4% articaine and 1:100 000 epinephrine) as infiltration at the buccal and lingual areas was performed. Mandibular block injection was avoided in order to keep the patient alert to sensation, as an alarm for the surgeon in case the inferior alveolar nerve was approached during cortical bone graft harvesting. This was performed by collecting the bone from the mandibular retromolar area following the previously described protocol.[13] Briefly, trapezoidal flap elevation achieved access to the retromolar area (Figure 2). This initiated by an anterior releasing incision on the second molar area and continued as a sulcular incision posteriorly to the distal of the third molar region. Next, a distally releasing incision was created toward the external oblique ridge area into the buccal mucosa. The mucoperiosteal flap was elevated, allowing for bone exposure at the donor site, at the level of the external oblique ridge (Figure 2). Subsequently, an area of bone approximately 20 × 20 mm in length and 4 mm in depth was exposed. Then, harvesting osteotomy was performed using Bone Micro Diamond Discs (Komet Dental, Lemgo, Germany). The dimensions of the graft were measured and outlined based on the defect size. With gentle manipulation, the graft was removed from the donor site. Next, tension-free suturing was performed to allow primary healing. The harvested bone was then split into two thinner plates using the same Micro Diamond Discs (Komet Dental). Likewise, the size of the blocks was adjusted based on the recipient site dimensions, which were on average 6 × 5 mm. The harvested blocks were kept in saline while performing the recipient site preparation for an average of 45 minutes. To limit trauma as much as possible, no additional scrapping was performed to collect autogenous bone. For the grafting procedure, in accordance with proper adaptation of the graft to the recipient site and careful trimming of the sharp edges with a round bur, fixation mini-screws (Zepf Dental, Seitingen-Oberflacht, Germany) were placed in two sites for each bone block (Figure 3a). Care was taken to actively engage the screws with the recipient bone for complete stabilization. Following this step, the first modification of the original technique[13] was achieved by filling the gap area with small particle–sized bovine bone graft particulates of Bio-Oss (Geistlich Pharma AG, Wolhusen, Switzerland) instead of autogenous bone (Figure 3b). Subsequently, the second modification, covering the grafted site using a multilayered approach by Bio-Gide collagen membranes (Geistlich Pharma AG) was performed (Figure 3c). Before suturing, minor adjustments to the graft site were performed if required using a Round Micro Diamond Bur (Komet Dental). Lastly, the donor site and grafted area were closed with tension-free single sutures of 6-0 Seralon (Serag-Wiessner GmbH, Naila, Germany; Figure 3d). After completion of the surgical procedure, the patients were provided complete postoperative instructions and medications that consisted of antibiotics (clindamycin 300 mg for 3 days, 3 times daily) and anti-inflammatory medication (as indicated). Patients were also asked to rinse with warm salt water before switching to twice-daily rinse with 0.2% chlorhexidine gluconate solution for 1 week until the postoperative appointment, at which time the sutures were removed.

Reentry procedure and implant placement

The patients were scheduled for implant placement after allowing for an undisturbed healing period of at least 4 months (Figure 4), at which point they returned for implant placement. At this stage, a split-thickness flap was reflected, and the sites were examined and debrided (Figure 5a). Next, the fixation screws were removed. The implant surgeries (Straumann BLT System, Straumann Holding AG, Basel, Switzerland) were planned digitally and 3-dimensionally using commercially available software (3Shape A/S, Copenhagen, Denmark) and performed with patient-specific computer-

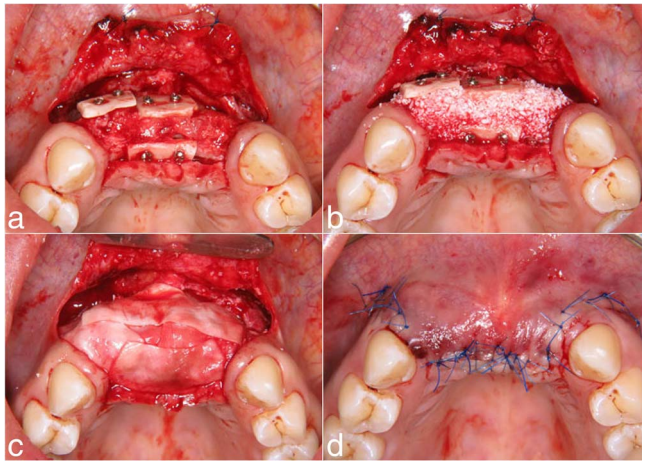

Figure 3. (a) Autogenous bone blocks were fixated according to Khoury's technique using mini-screws. (b) The gaps between the blocks were filled with Bio-Oss small-sized particles. (c) The grafted area was covered by a multilayered approach using resorbable (collagen) membranes. (d) Tension-free closure of the flap using 6-0 Seralon sutures.

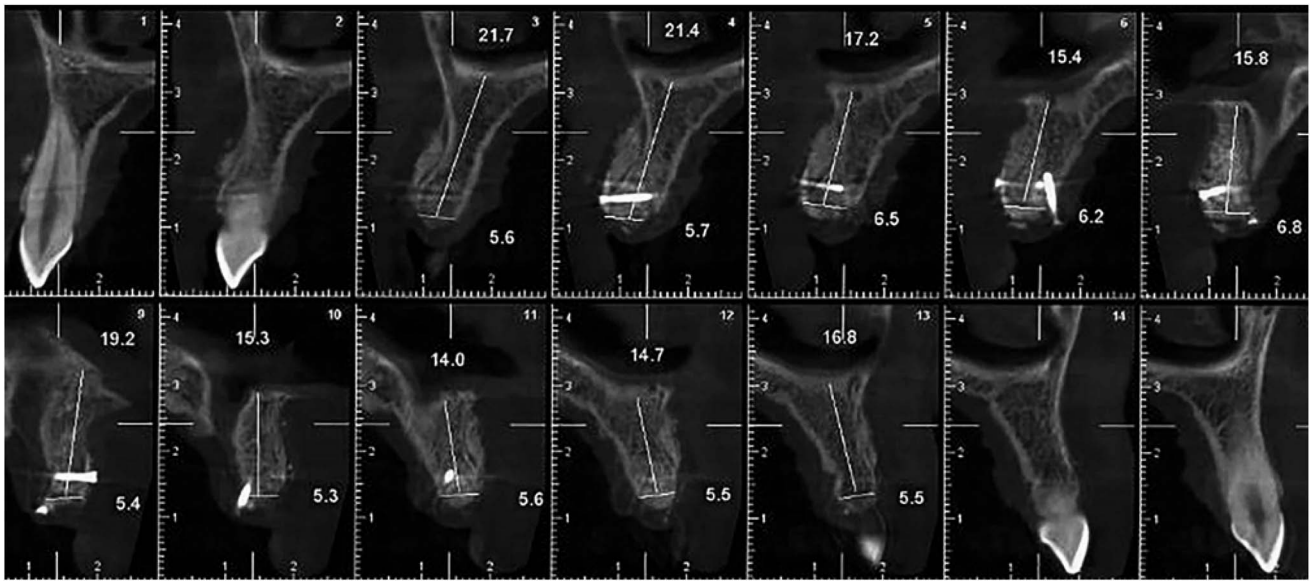

Figure 4. Cone-beam computerized tomographic images 4 months after the surgery showed optimal 3-dimensional ridge reconstruction.

aided design and computer-aided manufacturing–fabricated surgical guides (Figure 5b and c). All patients were seen approximately 2 weeks postoperatively and followed up regularly (Figure 6a).

Prosthetic workflow

To deliver esthetically appropriate restorations, each patient was prepared according to the guidelines of Digital Smile Design using frontal and lateral photography and 3Shape software (3Shape A/S).

Before implant placement, patients were consulted regarding their final prosthetic plan. Based on the decision of the patient and their esthetic expectations, the final prosthetic protocol was achieved. Following implant placement, the patients were given a temporary flipper but were instructed to use it for as short a duration as possible. The second-stage surgeries were performed approximately 2 months after the implant placement (Figure 6b), and at this step, to form optimal emergence profiles, the implants received custom fabricated poly-methyl meta-acrylate healing caps. Custom-made zirconia abutments were placed following the healing period, and zirconia restorations were delivered (Figure 6c–e).

Study outcomes and reporting

This study aimed to evaluate the changes in the ridge dimensions before and after modified 3-dimensional GBR. In this regard, the ridge width and height were measured from the CBCT images as follows:

- Ridge width: this was defined and measured as a line connecting the vestibular (buccal) alveolar plate to the palatal plate.
- Ridge height: this was defined and measured from a perpendicular line to the abovementioned ridge width line, to the nasal base.

The radiographic measurements were gathered at 3 time points: (1) 1 week before the 3-dimensional ridge augmentation surgery (preop), (2) 4 months after surgery (at the time of implant placement), and (3) 6 months postoperatively (2 months after implant placement). All radiographic measurements were taken by the same examiner (B.S.) at all time points and reported descriptively without

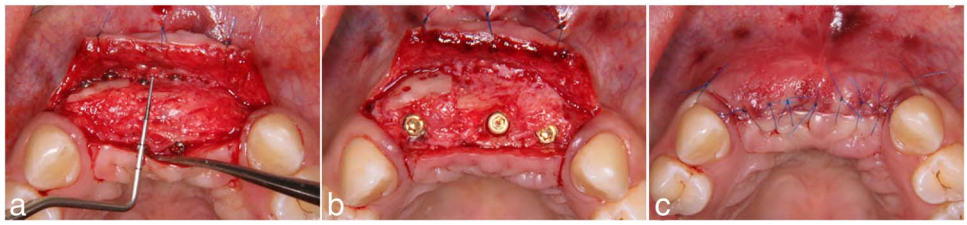

Figure 5. Reentry surgery. (a) Split-thickness flap and leaving the periosteum intact at the crestal region. The papillae were also preserved. Note fixation of the flap to the mucosal area by micro-holding sutures. (b) The mini-screws were removed, the implants were placed, and (c) the flap was closed.

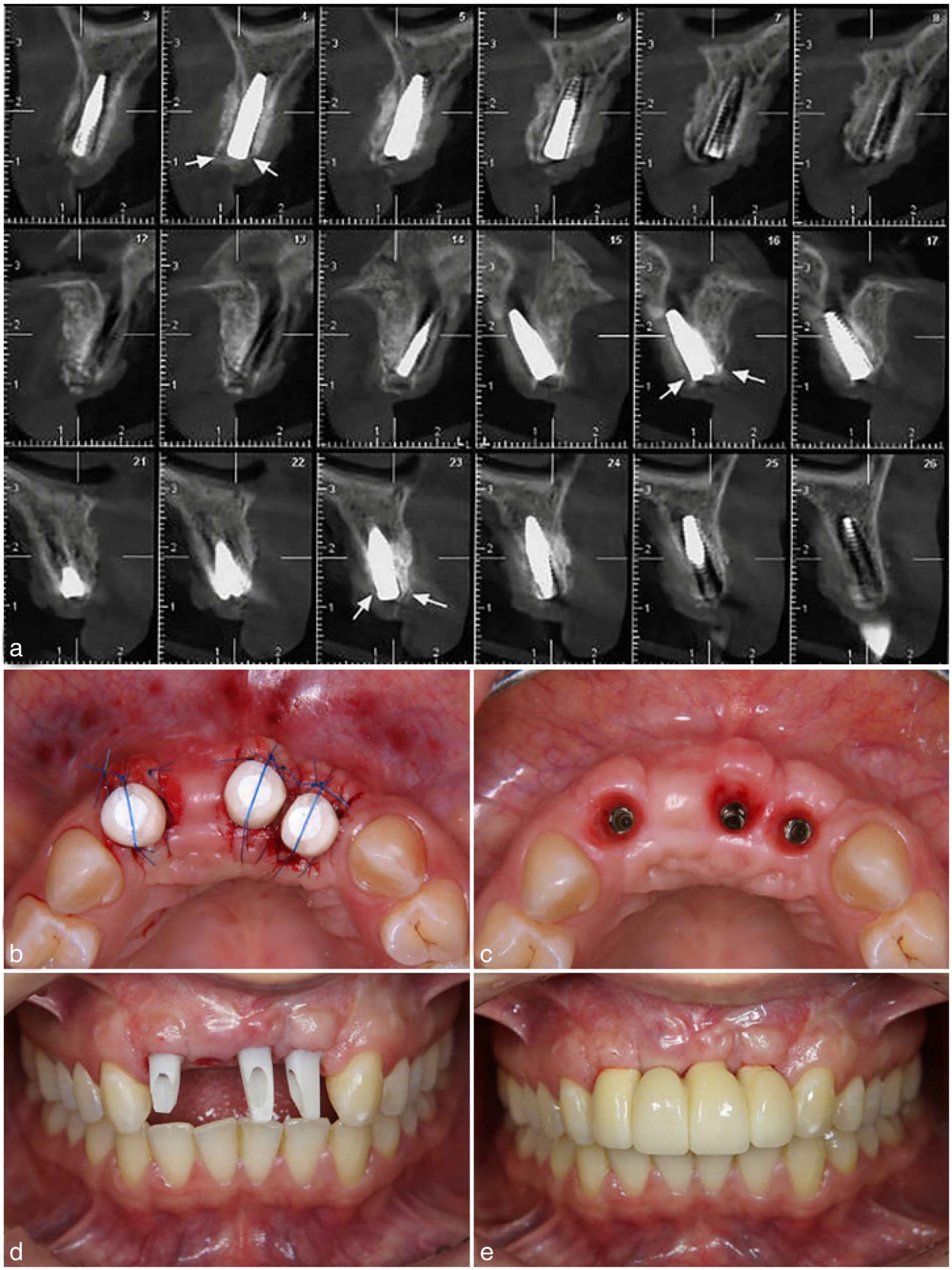

Figure 6. (a) Cone-beam computerized tomographic image of the case 2 weeks after implant placement. (b) Custom-made poly-methyl meta-acrylate healing caps were placed following the second-stage surgery. Coronally repositioned flaps were also performed to enhance tissue adaptation. (c) Emergence profile 6 weeks after the second-stage surgery. (d) Individually designed milled zirconia abutments were fabricated and placed. De-epithelialization of the soft tissue was also performed. (e) Final restoration was delivered.

Table

Demographics and characteristics of the patients included in the study

Characteristic	Value
Participants	5
Age, y, mean ± SD	34.4 ± 11.5 years
Male, n	2
Female, n	3
Total bone plates used, n	17
Upper central incisor, n	6
Upper lateral incisor, n	6
Upper canine, n	4

statistical inferences due to the pilot nature of the current technical feasibility report.

Results

Five participants (2 males and 3 females) with an average age of 34.4 ± 11.5 years enrolled and completed the study. All procedures related to ridge augmentation and implant placement were completed without any complications or dropouts. The implants were placed on 6 central, 6 lateral, and 4 canine areas in the anterior maxilla. The demographic data of the recruited patients are presented in Table 1. Figure 7 depicts the changes in ridge width and height throughout the follow-up period following the 3-dimensional ridge augmentation procedure and implant placement. The average ridge height at the baseline was 16.2 ± 1 mm, and this reached 19.4 ± 0.5 mm at the 4-month follow-up visit and decreased slightly to 17.5 ± 0.5 at 6 months postaugmentation (2 months following implant placement).

When it comes to the ridge width, the baseline average was 3.1 ± 0.5 mm. An average of 3.8-mm gain was achieved, and at the 4-month time point, this increased to 6.9 ± 1 mm. Moreover, a modest decrease occurred by 0.2 mm at the 6-month follow-up, where the average height was 6.7 mm.

Discussion

The insufficient bone volume in the esthetic zone and its limitedness by the sinonasal cavity result in a major challenge for clinicians in reconstructing the area for successful implant placement.[1,7,11] This becomes even more unpredictable and complex, as there is still a lack of a standard technique to 3-dimensionally augment the resorbed ridge in this region,[3,8,11] despite numerous techniques being presented.[16] The use of autogenous bone blocks to reconstruct the alveolar ridge 3-dimensionally was introduced in 1975 by Brånemark et al.[17] On the other hand, the conventional vertical GBR using bone graft substitutes and barrier membranes has been used for many years, and studies have reported feasible outcomes.[11] In our study, we aimed to propose a modification to the 3-dimensional ridge augmentation technique introduced by Khoury et al,[13] by combining this method with xenogenic bone graft particles and multilayered resorbable membranes, specifically used in the esthetic zone area and with the difference of avoiding the use of autogenous bone chips and added a multilayered resorbable membrane application to the site. When it comes to acknowledging the possible benefits that this modification would bring into practice, reduced patient discomfort and complications such as nerve injury can be mentioned (approximately 5% in Khoury's cohort versus 0% in this study).[13] Nevertheless, direct comparison of the primary outcome of bone gain would not be feasible since it was not reported in a similar way in the study by Khoury et al.[13]

In a study by Khojasteh et al.,[18] on the block graft tenting technique, one of the study groups comprised sites in the anterior maxilla. A mean increase of 3.25 ± 3.07 mm and 4.31 ± 0.93 mm

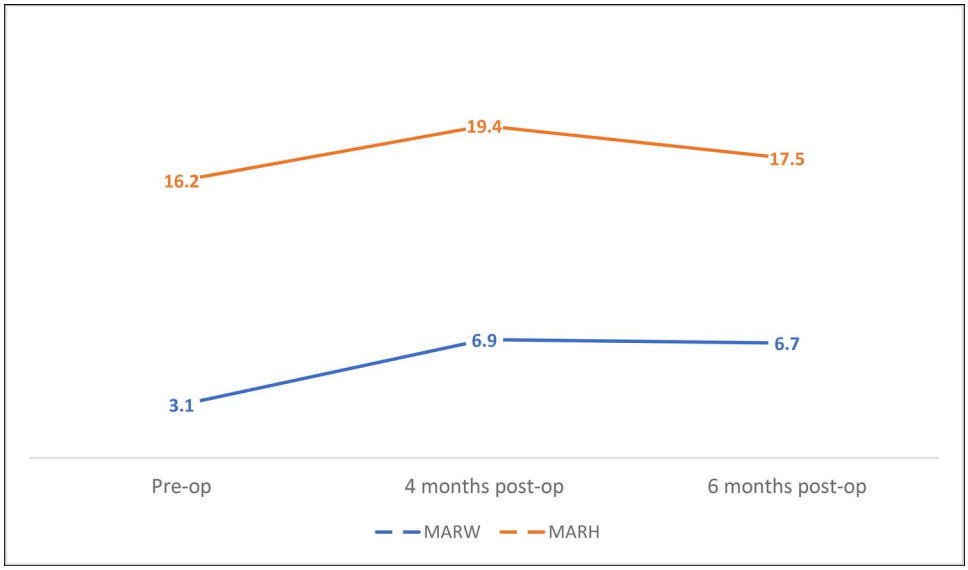

Figure 7. Mean alveolar ridge width and height changes at 3 different time points according to the cone-beam computerized tomographic images: 1 week before 3-dimensional ridge augmentation (PRE-OP), 4 months after 3-dimensional ridge augmentation (time of implant insertions), 6 months after 3-dimensional ridge augmentation (2 months after implant insertions).

in bone height and width were reported, respectively. In addition, the authors reported that the anterior maxilla had the highest occurrence of complications among their patient population. Despite having similar results in bone gain to our study, the recipient sites (primarily posterior) and also the donor sites (chin, ramus and tuberosity) in that study differed from our technique. Likewise, some cases received plasma rich in growth factors as an adjunct to the grafting materials.

Despite the fact that there have been numerous studies on the topic of 3-dimensional bone augmentation, there needs to be more literature regarding the augmentation in the esthetic zone.[1,3,5] Among these, in a study on 13 patients by Azab et al,[5] a similar bone grafting protocol was used (grafts harvested from the retromolar region) in the anterior maxilla. Moreover, a mean 4.6 mm of ridge width gain was reported at the 4-month follow-up. However, the total width loss occurred in 3 cases, detaining them from reporting the height gain. In another study by Gluckman and Du Toit[4] in which blocks were similarly harvested from the retromolar area, the authors reported a case with a single site defect on the anterior maxilla, aiming to achieve 3-dimensinoal augmentation using the same technique. Although no quantitative report was provided in that study, superior patient satisfaction outcomes and esthetic scores were reported. The difference between our method and theirs was that they used autogenous bone particulates and a rotated palatal pedicle flap. Using barrier membranes (collagen membrane in our study) would possibly make the procedure less sensitive to technique as compared with using a pedicle flap. However, to prove superiority, a controlled study design is required. Yu et al[3] followed the same technique as described here, with the difference of using a mixture of autogenous and xenogenic bone grafts. At the reentry surgery time point (4–6 months), an average of approximately 1.2-mm vertical and 5.5-mm horizontal bone gain were achieved. Nevertheless, clinical measurements were used to measure the amount of bone alterations opposite to our study, in which the CBCT images were used.

It should be mentioned that there are several other modifications to the original technique that have been introduced to be used in the esthetic zone such as using poly ether-ether ketone sheets[19] and autogenous bone ring technique[20]; nonetheless, the validation of these techniques is still required. Even though the introduced technique in this feasibility study yielded promising outcomes, the readers should be cautious about the pilot nature of this study, lack of a control group, and the limited number of cases. These limitations did not allow for performing a regression analysis to explore the possible contributing factors such as either addition of the membranes or xenografts to the observed promising outcomes. Thus, it is recommended that future research, while including a greater number of cases, explore the impact of each of these variables.

Conclusion

Within its limitations, this prospective clinical feasibility study proposed a modification to 3-dimensional ridge augmentation in the esthetic zone using block grafts from the retromolar area and xenogenic bone substitutes, covered by multilayered collagen membranes. The 6-month follow-ups showed 1.2 mm of bone height and 3.5 mm width gain with approximately 2 mm and 0.3 mm of resorption in height and width, respectively.

Abbreviations

CBCT: cone-beam computerized tomography
GBR: guided bone regeneration

Note

The authors declare no conflict of interest regarding this study. All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All patients provided their consent to participate in this study. The data sets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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