Implant-supported restorations have proven to be a predictable option for replacing missing teeth. In cases of inadequate bone quantity, the bone volume can be increased by bone augmentation procedures. Several factors can affect bone regeneration, including the morphology of the defect at the implant site. A defect surrounded by bony walls (an intraosseous defect) is known to yield a highly successful regeneration. The purpose of this retrospective case series study was to present a new step-by-step surgical procedure known as the Custom Alveolar Ridge-Splitting (CARS) technique for maxillary anterior ridge augmentation. This technique creates an intraosseous defect while splitting and augmenting an atrophic ridge. Sixteen consecutive cases were treated with the CARS procedure. All implants were restored and followed for 12 to 24 months after loading, and all cases were effectively treated with successful implant placement. According to this retrospective study, the CARS procedure is simple, successful, and predictable and may be used as a surgical option for horizontal alveolar ridge augmentation in the anterior maxilla. Int J Periodontics Restorative Dent 2021;41:397–403. doi: 10.11607/prd.5411

The Custom Alveolar Ridge-Splitting (CARS) Technique for Predictable Horizontal Ridge Augmentation in the Atrophic Anterior Maxilla: A Retrospective Case Series Study

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Implant-supported restorations have been proven to be a predictable option for replacing missing teeth. In cases of inadequate bone quantity, the bone volume can be increased by bone augmentation procedures. Several factors can affect bone regeneration, including the morphology of the defect at the implant site. A defect surrounded by bony walls (an intraosseous defect) is known to yield a highly successful regeneration. The purpose of this retrospective case series study was to present a new step-by-step surgical procedure known as the Custom Alveolar Ridge-Splitting (CARS) technique for maxillary anterior ridge augmentation. This technique creates an intraosseous defect while splitting and augmenting an atrophic ridge. Sixteen consecutive cases were treated with the CARS procedure. All implants were restored and followed for 12 to 24 months after loading, and all cases were effectively treated with successful implant placement. According to this retrospective study, the CARS procedure is simple, successful, and predictable and may be used as a surgical option for horizontal alveolar ridge augmentation in the anterior maxilla. Int J Periodontics Restorative Dent 2021;41:397–403. doi: 10.11607/prd.5411

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regeneration techniques, the outcomes in many cases are not highly predictable. Several factors can affect bone regeneration. One of those is the morphology of the defect at the implant site, which has been reported to be a critical factor for the success of bone augmentation. A defect surrounded by bony walls is an intraosseous defect, and this type of defect is known to yield a highly successful regeneration due to good blood and osteoblast supply in addition to being well contained. In contrast, an extraosseous defect with fewer bony walls has been shown to be less predictable for bone augmentation procedures.

The purpose of this retrospective case series study was to present a new step-by-step surgical procedure known as the Custom Alveolar Ridge-Splitting (CARS) technique for maxillary anterior ridge augmentation, document the results in 16 patients, and discuss the advantages and limitations of this technique.

Materials and Methods

Clinical data was obtained from the Implant Database (ID) at New York University College of Dentistry (NYUCD). This data set was extracted as de-identified information from the routine treatment of patients at the Ashman Department of Periodontology and Implant Dentistry at NYUCD. The ID was certified by the Office of Quality Assurance at NYUCD. This study is in compliance with the Health Insurance Portability and Accountability Act requirements.

Sixteen consecutive cases were selected from patients who desired dental implants with a fixed prosthesis to replace their missing teeth in the anterior maxillary arch and had implants placed with the CARS procedure. Eleven women and 5 men (age range: 22 to 65 years; mean age: 45 years) were included. All 16 cases were effectively treated with successful implant placement. Follow-up times were recorded for each of the implants placed.

The CARS procedure follows a specific set of steps and can be modified according to the surgical scenario. Following a CBCT of the surgical site, the point of entry of the trephine guide and trephine are determined on an axial section of the site. After elevation of a full-thickness flap, the initial drilling is made with the help of a guide (Fig 1), and a guide cylinder is placed into this first osteotomy, which was prosthetically selected for future implant placement (Fig 2). A circular vertical cut is then created by an appropriately sized trephine bur (with the bur diameter similar to the diameter of the future implant) and guided by the guide cylinder (Fig 3). The guide cylinder is then removed, and the final cut is made with the same trephine bur to the planned length (2 mm more than the future implant length). During cutting, the surgeon evaluates the stability of the split segment. If the segment is stable, the second stage can be performed in the same surgery. If it is not stable, the flap is sutured, and reentry is performed 3 to 4 weeks later. At the second stage, a green-stick fracture is created by the same trephine bur (or a small periosteal elevator or small bone carrier), and the segment is moved buccally and wedged in the surrounding buccal bone plate. Again, the stability of the segment is evaluated. If good stability is achieved, implant placement can then be attempted. Otherwise, bone grafting is performed.
to maintain the space, and the flap is sutured. The patient then returns 3 to 4 weeks later, and the last stage is performed, including osteotomy and implant placement. Tapered implants are the most indicated for this technique.

In the present study, implants were loaded 6 to 21 months after implant placement. In 11 cases, the CARS procedure was performed 3 to 4 weeks before implant placement. In 3 cases, the CARS procedure was performed simultaneously with implant placement and guided bone regeneration (GBR). In 1 case, the CARS procedure was performed 3 months prior to implant placement. In 1 case, the segment was fractured, and successful retreatment was performed 2 months later. The technique for all cases included in this study was first performed on a 3D model of the patient, printed from the CBCT scan file. Using these models for surgical simulation familiarized the surgeon with the actual site and procedure that was to be performed on the patient. It also allowed the clinicians to experience the risks and helped them evaluate whether the site was more amenable to a two- or three-stage approach and whether the site required augmentation by a GBR procedure or any other procedure to manage any associated conditions.

The following two case reports are examples to illustrate the technique with its various aspects and procedures.

Case 1
A 22-year-old woman presented to the Ashman Department of Periodontology and Implant Dentistry at NYUCD missing her maxillary right canine. She had a high smile line,18 malocclusion, and parafunctional habits. The patient was first treated orthodontically (at the NYUCD’s Orthodontic Department) to manage the malocclusion and parafunctional habits before she was referred to restore her missing tooth (Figs 4a and 4b). For this patient, the CARS technique was performed 4 weeks prior to implant placement. All procedures were performed under local anesthesia (2% lidocaine, 1:100,000; Henry Schein).

The initial surgery was performed with a crestal incision made at the edentulous site, extending from the maxillary right lateral incisor to the maxillary right first premolar, with intrasulcular incisions around the buccal aspects of the maxillary right lateral incisor and right first premolar. This was followed by two vertical labial releasing incisions at the mesial aspect of the right lateral incisor and distal aspect of the right first premolar. A full-thickness flap was then elevated. Initial drilling was performed, and a guide cylinder was placed in the area that had been prosthetically selected for a future implant. A circular vertical cut was created with a 4.3-mm–diameter trephine bur (Straumann) guided by the guide cylinder. The guide cylinder was then removed, and the final cut was made with the same trephine bur with copious irrigation to the planned length (Figs 4c and 4d). During the cutting, the stability of the split segment was evaluated, and the decision was made to perform the second stage of the CARS procedure. A greenstick fracture was created using a small bone carrier, and the segment was moved buccally and wedged in the surrounding buccal bone plate. The stability of the segment was then evaluated and was found to be poor. Therefore, a bone graft consisting of small particles of cancellous bovine bone (Bio-Oss, Geistlich) was moistened with normal saline and packed in the newly created intraosseous defect (Fig 4e). The flap was then repositioned and adapted, and tension-free closure was achieved and stabilized by simple interrupted resorbable sutures (chromic gut 4/0 suture, Ethicon, Johnson & Johnson).

The patient returned 4 weeks later for the second surgery, and the last stage of the CARS procedure was performed under local anesthesia. A crestal incision was made at the edentulous site on the maxillary right canine with intrasulcular incisions around the buccal aspect of the right lateral incisor and the right first premolar. A full-thickness flap was then elevated without any vertical incisions. An osteotomy was made, and the implant (4.1 × 10 mm, BLT SLActive Roxolid, Straumann) was placed following the specific implant protocol (Fig 5a). A periapical radiograph was then taken. The flap was then repositioned and adapted, and tension-free closure was achieved and stabilized by interrupted resorbable 4/0 chromic gut sutures. The implant was successfully restored 9 months after
implant placement (Figs 5b and 5c). The patient returned for follow-up every 3 months for 15 months (Fig 5d). During this time, 2 years after implant placement, the implant and bone levels remained stable, with excellent function of the restoration (Figs 5e to 5g).

Case 2

A 29-year-old woman presented to the Ashman Department of Periodontology and Implant Dentistry at NYUCD missing a maxillary left central incisor (Figs 6a and 6b). The CARS technique was performed 4 weeks prior to implant placement. All procedures were performed using the same steps and materials used in Case 1, except the current patient received GBR simultaneously with implant placement.

The implant (4.1 × 10 mm, BLT SLActive Roxolid, Straumann) was placed at the central incisor site, and a GBR procedure was performed on the buccal aspect using bone graft material (Bio-Oss, particle size 1 cc, Geistlich) and a resorbable membrane (Bio-Gide, Geistlich) with tacks. Healing was uneventful (Fig 6c). The implant was successfully restored 12 months after placement and was followed for an additional 12 months (up to 2 years postplacement), and stable bone and soft tissue levels were seen at 24 months postplacement (Figs 6d and 6e).

Results

In the 16 cases followed, all implants were successfully placed and restored (6 to 21 months after implant placement), and were followed for an additional 24 months after loading. To date, all 22 implants have functioned well with no failures or complications. Appendix Table 1 summarizes the placement, procedure, time of loading, and follow-up information of all 16 consecutive cases treated with the CARS technique (all Appendix Tables can be found in the online version of this article available at quintpub.com/journals). Patients 8 and 1 represent the first and second case reports, consecutively.

Discussion

The present study introduces a new technique for horizontal ridge augmentation of atrophic ridges that can be used for single or two adjacent edentulous sites in the anterior
Fig 5  Case 1. (a) Clinical view of the implant placed 4 weeks after the first surgery. (b) Occlusal and (c) periapical radiographic views of the final screw-retained crown at 1 month postloading. (d) Occlusal view at 1 year postloading. (e) Occlusal, (f) facial, and (g) periapical radiographic views at 2 years postloading.

Fig 6  Case 2. (a) Occlusal and (b) frontal views of the missing maxillary left central incisor. (c) Occlusal view after the CARS technique, GBR, and implant placement. (d) Clinical and (e) periapical radiographic views of the final screw-retained crown at 24 months postplacement.
maxilla, in cases where the mesiodistal space is narrow for alveolar ridge-splitting, with a minimum narrow ridge width of 2 mm. It can also be used in the anterior mandible with the same minimum bone width. In 2018, Hu et al published a modification of the alveolar ridge-splitting technique recommending the three-stage alveolar ridge-splitting technique. The CARS technique is a modification of the alveolar ridge-splitting technique. The goal of the CARS technique is to create an intraosseous bony defect produced by designed cuts in the residual alveolar bone, which then becomes the future implant site after creating a greenstick fracture of the patient’s native bone based on those customized cuts. The created intraosseous bony defect will contain a fresh blood clot rich in cells that can stimulate the osseous tissues healing and bone formation according to the regional acceleratory phenomenon and the buccal gap distance. The addition of a bone graft can prevent the collapse of the created space. These advantages and changes in the technique do not require the periosteum supply to be maintained on the transported segment, as recommended in the original ridge-splitting technique.

The CARS technique can simplify alveolar ridge augmentation surgical techniques, enhance the results of GBR, enable a more predictable and prosthetically oriented implant placement, be less invasive, and possibly minimize patient morbidity. However, it may require two to three staged procedures (but when conditions are optimum, the CARS technique can be done in one stage). In addition, the trephined bony segment could fracture, which occurred in one case in the present study. The fractured segment was repositioned and allowed to heal, and the implant and restoration were then successfully placed and continued to function well with 24 months of follow-up.

Currently, a wide range of surgical procedures are available for ridge augmentation. However, it is difficult to demonstrate that any one of these can offer better outcomes than another. A comparison between GBR, block grafts, ridge-splitting, and the CARS techniques is presented in Appendix Table 2. The ridge-splitting and the CARS techniques create intraosseous defects with horizontal and vertical incisions, respectively. These intraosseous defects have demonstrated more predictable outcomes than extraosseous ones. Moreover, the CARS technique improves both soft and hard tissue morphology. However, all techniques are operator-sensitive and require surgical skill. Training for the CARS technique presents an easy learning curve with the use of 3D models, which can be printed from the patient’s CBCT scan file. Comparison with other augmentation procedures demonstrates that the CARS technique requires a smaller flap size, reducing surgical time and patient morbidity, thus potentially decreasing patient discomfort.

Conclusions

Within the limitations of this case series, it can be concluded that the CARS technique may present another option for horizontal alveolar ridge augmentation in the anterior maxilla in cases of atrophic alveolar ridges. Further research with a greater number of patients and case-controlled comparison studies are necessary to determine the success and advantages of the CARS technique compared to those conventionally used for horizontal ridge augmentation.

Acknowledgments

An application for patent has been filed to protect the novel instruments and techniques described in this article. The authors declare no conflicts of interest.

References

### Appendices

#### Appendix Table 1  Case Details of All 16 Patients with Implants Placed Using the CARS Technique

<table>
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<td>Bio-Oss</td>
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</table>

CARS = Customized Alveolar Ridge-Splitting; F = female; GBR = guided bone regeneration; M = male.
All Bio-Oss (Gesitlich) filling material used small particle sizes (1 cc).
*FDI numbering system.

#### Appendix Table 2  Comparison Between GBR and Block Grafts, Ridge Splitting, and CARS Techniques

<table>
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<th>GBR and block graft</th>
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<th>CARS</th>
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<td>Horizontal cutting</td>
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<tr>
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<td>Operator-sensitive</td>
<td>Operator-sensitive (easy learning curve with 3D models)</td>
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<td>Incidence of use</td>
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<td>High</td>
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CARS = Customized Alveolar Ridge-Splitting; GBR = guided bone regeneration; TBD = to be determined.