Distraction osteogenesis is a process in which new bone is created in a defect of the alveolar ridge by stretching existing bone. The process was originally developed by a Russian orthopedist, Gavriel Ilizarov, for the correction of long-bone deformities. It was later adapted to the maxillofacial skeleton and alveolar ridge. Distraction osteogenesis involves surgically creating a mobile bone segment to which a distraction device is attached. By controlled movement, the bone segment, along with the soft tissues overlying it, are transported into a new position. After a suitable healing period, the distraction device is removed and dental implants can be placed. A case report is presented describing the use of alveolar distraction to augment a vertically deficient alveolar ridge.

INTRODUCTION

The implant surgeon is often confronted by edentulous spans that present with inadequate bone volume. Traditional methods to augment these defects include guided bone regeneration (GBR) and autogenous bone particulate or block grafting. GBR has limited ability to increase bone height predictably, and it carries the risk of infection or graft loss due to membrane exposure. Autogenous bone grafting offers acceptable results but has the added complication of a donor site surgery and its potential morbidity. The development of distraction devices, which can increase alveolar bone volume, offers the implant surgeon an exciting, rewarding modality with which to correct ridge deficiencies.

Codivilla introduced the concept of bone lengthening by callus distraction in 1905 to increase the length of the femur. In 1927, Abbott used a compressed spring to lengthen the tibia. These early cases were accompanied by numerous complications and, as a result, there was reluctance in the medical community to accept these procedure. Beginning in the 1960s, a Russian orthopedic...
surgeon, Gavriel Ilizarov, developed a technique in which long bones could be lengthened predictably. Ilizarov’s principles of distraction osteogenesis form the basis of all such procedures today.7,8 Distraction osteogenesis was first applied to the craniofacial complex in the 1970s and subsequently led to clinical applications that corrected mandibular and maxillary hypoplasia in the 1990s.9,10,11 The devices employed to correct these defects were relatively large with unwieldy extraoral components. In 1996, Block and coworkers described the use of distraction osteogenesis to augment alveolar ridges in a dog model.12 That same year, Chin and Toth employed an intra-oral device to effect alveolar distraction in 5 patients.13 Since that time, a number of authors have reported using intra-oral devices designed to promote alveolar distraction prefatory to dental implant surgery.14–19

This paper presents a case report describing the use of distraction osteogenesis to enhance an alveolar defect in the anterior mandible, thereby permitting the placement of dental implants.

**MATERIALS AND METHODS**

A 24-year-old, healthy male requested fixed prosthetic rehabilitation after traumatic avulsion of mandibular teeth numbers 23 to 28. Clinical and radiographic examination revealed a vertical bony defect in the edentulous region that would compromise fixed implant treatment (Figures 1 and 2). After diagnostic records and patient consultation, distraction osteogenesis was planned to vertically augment the bone before endosseous implant placement.

Under local and conscious intravenous sedation, a vestibular incision was made (Figure 3). Full-thickness reflections were carried apically and crestally to allow proper visualization of the ridge during the osteotomy (Figure 4). An extra-osseous distraction device (KLS Martin, Jacksonville, Fla) was placed over the exposed bone, and proper sizing and functioning of the device were confirmed (Figure 5). After bending the fixation plates so that they became adapted intimately...
to the cortical bone both below and above the sites of the planned horizontal osteotomies, the distractor was affixed with several randomly placed, self-tapping bone screws. This established its location in both the mobile (transport) segment as well as in the inferior (fixed) basal bone (Figure 6). This step allowed orientation of the osteotomy cuts and the simple reattachment of the distractor after the osteotomy had been performed. Care was taken to ensure that the distractor was angled 5 degrees facially from the alveolus. The osteotomy sites were scribed using a small, round bur, and the distractor was removed. The osteotomies were performed using an oscillating surgical saw. To ensure the cuts did not protrude beyond the lingual cortex, the surgeon’s finger was placed against the mucosa overlying the lingual ridge. Using this technique, tactile feedback warned of the proximity of the saw (Figure 7). Final release of the transport segment of bone was performed by placing and twisting an osteotome, after which the bone segment became mobilized (Figure 8). The distraction device was reattached in its original location and stabilized with additional bone screws (Figure 9). Activating the distraction device confirmed mobility of the segment. The device then was returned to its passive or deactivated state, and the soft tissues were closed by primary intention using 4-0 polyglactic sutures in a horizontal mattress configuration (Figure 10).

After 8 days of healing, the device was activated by turning the threaded activating component 0.5 mm every half day, thereby creating a daily 1-mm excursion (Figure 11). A family member performed this after instruction in the use of a universal jointed wrench. After 10 days, a full centimeter of distraction was noted, and the process was halted (Figures 12 and 13). A 2-month consolidation period was allowed to elapse before removing the distractor. During the same procedure, after the distractor was removed, 4 endosseous implants were inserted. At that time, a full-thickness reflection included the removal of the device as well as the uncomplicated placement of the implants (Figures 14 and 15). The distracted bone segment was found to be stable, and the callus was noted to be firm but spongy. Four Steri-Oss (Nobel Biocare, Yorba Linda, Cal) implants were placed with the use of a surgical template (Figures 16 and 17). The soft tissues, which had also proliferated, were then closed with ease. After a 6-month healing period, the implants were uncovered and found to be osseointegrated. A standard restorative protocol followed.

**Discussion**

Successful distraction osteogenesis relies on adhering to several principles: (a) preserving osteogenic tissues; (b) establishing the stability of the distractor fixation plates; (c) observing a latency period; (d) proper rate and rhythm of the distraction process; and (e) allowing for a consolidation period.

Preserving osteogenic tissues (a) is essential at the time of the osteotomy. The viability of the mobilized segment is vital to the success of distraction osteogenesis because the marrow vasculature is disrupted by the osteotomy procedure. One of the greatest sources of blood supply to this bone is the periosteum.20 Thus, procedures that minimize damage to the periosteum are mandatory.21 This is best accomplished using a vestibular incision.16 A vestibular incision leaves a broad band of attached tissue on the facial and crestal bone. In addition, the lingual or palatal tissues are left intact. Preserving these zones allows the greatest amount of periosteum to be preserved. In contrast, the crestal incision, the incision of choice for the most implant procedures, may result in loss of blood supply to the crestal portion of the mobilized segment and, therefore, should be avoided. In addition, consummate care must be exercised during saw-induced osteotomies to protect the attachment and sanctity of the lingual mucoperiosteal flap, since it becomes the major source of vascularity for the mobilized segment.

The stability of the distraction device (b) is critical. Bending and shearing forces result in fractures in microcolumns with local hemorrhage.22 This occurrence would result in the production of fibrocartilage and eventual nonunion of the mobilized bony segment. Distraction device loosening or failure may result in loss of the segment, infection, or, at the very least, relapse of the distracted bone.7 Ilizarov recommended a ring distractor in long bones to allow circumferential fixation during distraction.7 This is not possible, however, in alveolar applications. Devices, which can be affixed to both the mobilized segment and the basal bone, provide the greatest assurances of stability.

The latency period (c) is the time between the osteotomy procedure with the attachment of the distraction device and the start of the distraction process. The latency period allows the formation of a fibrovascular bridge between the mobilized bone seg-
FIGURES 5–10. FIGURE 5. The appearance of the titanium distraction device before placement. Its components include 2 fixation plates, each with counter-sunk screw holes and a smooth vertical sleeve fixed to the lower member (base plate). The upper (distraction) plate is attached to the threaded adjustment post housed within the sleeve, and its upward movement is governed by the hex-topped post. A long-handled wrench turns it clockwise in order to activate the system. FIGURE 6. Before undertaking the osteotomy, the device is affixed temporarily in its planned position. This will permit the scribing of the 3 lines where the osteotomies will be made (2 vertical at the lateral borders of the distractor, and 1 horizontal between the 2 fixation plates). FIGURE 7. The distractor is removed, and the 3 bone cuts are made using a saline-cooled, oscillating saw. The forefinger of the surgeon’s other hand is placed firmly against the lingual mucoperiosteum to guide saw-cut depths and to avoid perforation of the mucosa. This lingual flap is the only source of vascular supply, and its sanctity must be preserved. FIGURE 8. Placing and twisting an osteotome accomplish the final release of the transport segment of bone. FIGURE 9. When the transport segment has been fully mobilized, the distraction device is reattached and stabilized with the aid of additional bone screws. FIGURE 10. Primary closure after the distractor is affixed is facilitated by the simple incision that had been made in the areolar gingiva. This incision design and location offer the fewest possibilities for device dehiscence and for the uncomplicated emergence of the adjustment post.
The literature varies as to the exact time recommended in which to commence distraction; however, a latency period of 5 to 10 days appears to be adequate. Early activation may result in wound dehiscence. Extended latency periods (greater than 3 weeks) should be avoided, as this may allow ossification of the bone segments and prevent bone movement.

The rate of distraction (d) describes the distance at which the bone segment is moved. Studies indicate that 0.5 mm to 1 mm per day is recommended for long bones and maxillofacial bones. Distraction rates below 0.5 mm per day may result in premature ossification of the segment to the surrounding bone, whereas rates greater than 1 mm per day may result in excessive forces, which may become responsible for bone resorption. These excessive forces may create local ischemia in the regenerative zone, which may result in delayed ossification or nonunion of the bony segments.

It has been suggested that the rhythm of distraction also may play a role in the success of the procedure. It is assumed that a continuous distraction rate is ideal. In clinical application, this is not practical and, thus, it has been suggested that the distraction procedure be broken down from one manipulation into 2, 3, or 4 per day.

The consolidation period (e) is the time during which the distraction device is left in place after the desired distraction has been achieved. During this phase, no forces are placed on the bone. The device is left in place to ensure stability while the newly mobilized bony callus undergoes maturation and remodeling. After this time the distractor may be removed (unless it is of a prosthetically treatable design) and implants placed. Ilizarov recommended a consolidation period at least as long as distraction time. The times quoted in the literature for consolidation vary from as early as 3 weeks to as long as 3 months. Prosthetic loading times after implant placement have not been established. Experimental studies indicate that loading may occur as early as 3 months postoperatively in the mandible and as early as 5 months in the maxilla.

The histology of the distraction process has been described. Soon after the distraction process is terminated, the newly distracted bony segment is composed of a fibrous central zone consisting primarily of collagen fibers. This is surrounded by a transition zone that exhibits early bone formation. Immediately adjacent to the transition zone is a region of bone remodeling that borders the surrounding mature bone. After a period of several months, the central collagenous zone is gradually replaced by mature lamellar bone that is clinically indistinguishable from the surrounding environment. Cortical bone formation is present in the distracted segment after 6 months. Complete maturation of the bone has been reported to occur 1 year after the completion of distraction. Histologic studies have revealed that the peripheral, supporting soft tissues, including adjacent musculature, respond to distraction forces by elongation and hyperplasia with resultant soft-tissue growth. Animal studies have suggested that the levels of bone-to-implant contact in mobilized segments are similar to those found in similar situations involving untreated osseous tissues.

Radiographically, immediately after distraction, the callus is present as a radiolucent zone between the distracted segment and its host. This radiolucent zone gradually becomes increasingly radiopaque as the fibrous callus becomes mineralized. Complete osseous infiltration of the radiolucent zone is commonly observed by the sixth month. In segments distracted distances greater than 5 mm, the appearance of radiolucent zones may still be present after 1 year or longer without affecting the success of the procedure or the implants placed.

**SUMMARY**

The case report presented in this article offers details of the successful use of an extra-osseous, intraoral distraction osteogenesis procedure used to correct a large, anterior, mandibular, alveolar de-
height as well as its lack of mineralization. **Figure 14.** At stage I implant surgery (performed after the bone becomes more mature) the distraction device is exposed. **Figure 15.** After removal of the distractor, the bony ridge appears to offer a positive site for placement of endosseous implants. **Figure 16.** Four root-form implants have been seated. The quality of the host bone felt firm to the insertion instruments, and the length of the implants indicates the benefits accruing to distraction osteogenesis. **Figure 17.** A postoperative, radiographic view of the site with its newly placed implants.
The device described in this article is one of many currently available for this purpose. Such devices are classified broadly as either extraosseous or intraosseous. The intraosseous devices can be classified further as either prosthetically adaptable (treatable) or as removable, each which allow placement of dental implants.

The extraosseous devices are attached to the mobilized and basal segments of the bone using bone fixation plates. The plates are connected to each other with a threaded distractor that, when engaged (turned with a wrench), forces the two plates apart. The plates are positioned on the bone prior to osteotomy and are adapted to the cortical surfaces to ensure proper fixation and the subsequent transport of the mobilized bony segment. Several strategically located screw fixation holes must be placed prior to osteotomy. The distraction device is affixed in situ so that the planned osteotomies may be scribed. The device then is removed and the bone cuts completed following their outlines. Following the mobilization of the dynamic segment, the plates are reattached with the original and additional anchoring bone screws. The distractor is designed to permit the threaded activating rod to exit the soft tissues in the alveolar vestibule. After distraction and consolidation, the device is removed, and implants are placed in a classical fashion.

Intraosseous distractors differ from those of extraosseous design in that the former are placed within the mobile bony segment. The distraction component of the device leaves the soft tissues through the alveolar crest similar to a dental implant. It is placed either by using a flapless osteotomy through the crest of the ridge or by elevating a vestibular flap lingually to allow exposure of the alveolar crest. The transport of the mobile bony segment is accomplished when an internal distraction screw exerts force against the basal component. These devices are removed by reverse torque at the time of implant placement. The prosthetically treatable intraosseous devices are similar to the removable devices with the exception that they have a prosthetic platform (such as external hex) that allows the attachment of a prosthesis. In addition, these devices may have roughened surfaces that increase their potential for osseointegration.

The decision as to type of distractor used lies with the clinician. Extraosseous devices offer added stability because they are affixed to both the mobile and basal bony components. They may be more visible and less comfortable to the patient, however, because of their vestibular locations. Conversely, the removable, intraosseous devices, because they are placed in a method similar to root form implant surgery and because they emerge from the fixed gingivae at the ridge crest, have the potential of being more tolerable to patients. In addition, many clinicians have found them to be more technique-friendly in their placement as well as in simplification of postoperative implant placement, due to the channel remaining on removal of the activating post. This is only an advantage, however, if the channel has been left in an acceptable location. Due to their modest sizes, more than a single intraosseous distractor may be required to transport a bone segment, whereas when extraosseous devices (with long bone plates) are employed, usually 1 will suffice. The advantages of the prosthetically treatable distractor are the avoidance of having to remove it and the financial savings in not having to substitute standard dental implants. If the final position of the transported implant is not ideal, however, esthetics and function may become compromised, and if crestal bone loss during the distraction process is experienced, long-term, peri-implant health will become compromised.

**CONCLUSIONS**

Distraction osteogenesis offers the implant surgeon an additional method for optimizing the dimensions of deficient alveolar ridges. The principles to be observed to ensure successful results include: preserving osteogenic tissues, firmly fixing the distractor, respecting the latency period, having an understanding of the rate and rhythm of distraction, and allowing a sufficient period for consolidation. Following distraction, the collagenous callous that was created is replaced gradually with mature, vital bone. A case report describing the use of distraction osteogenesis for the correction of an alveolar defect is presented.

**REFERENCES**


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