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Resorbable bone distraction: current status and future directions

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The pioneering work of Dr. Ilizarov defined the theory and practice of clinical bone distraction [1,2]. He laid the foundation for the future application of the principles of bone distraction to craniofacial surgery. In 1992, McCarthy et al began applying the principles of long bone distraction used in orthopedics to the craniofacial skeleton [3–5]. He and his colleagues were able to demonstrate experimentally and clinically that distraction osteogenesis of membranous-derived bone was feasible, defining the scientific basis for craniofacial distraction and guiding early clinical applications. Distraction of the craniofacial skeleton offers many advantages over conventional advancement techniques, including gradual stretching of skin, muscle, and nerves, which minimizes the opposition to bone distraction and decreases the tendency for bony relapse of the advanced bony segments. Important neurovascular structures are slowly elongated, preserving continuity and function. In addition, distraction osteogenesis eliminates the need for bone grafting the osteotomy gaps, saving time and decreasing morbidity. Once the potential of this powerful new technique for "stretching bone" was fully realized, a frenzy of clinical and experimental work was unleashed. The early devices were adaptations of orthopedic instrumentation, used mostly in surgery of the hand, and had to be applied externally. Although these early external devices showed the feasibility of mandibular bone distraction, they had several drawbacks in clinical practice. The external pins that connected the devices to the underlying bone often became loosened, required constant pin site care, and were cumbersome for the patient. In addition, as the distraction proceeded, the pins tended to tract through the skin, leaving unacceptable scars. Multidirectional external devices gave a greater degree of directional control but had the many of the same disadvantages as uniplanar models [6]. These early devices were not applicable to maxillary distraction because of the early design constraints.

Chin, Toth, and several other authors [7–9] reported on various designs for internal distraction devices that could be used both for the mandible and the maxilla. Molina et al [10] further refined a system for internal maxillary and mandibular distraction. Polley and Figueroa [11] in 1997 reported on an ingenuous external distraction system based on a cranial halo device coupled to an orthodontic appliance, which allowed precise midface distraction. Their system also allows for changing of the distraction vectors on an ongoing basis. The distraction process required skilled orthodontic monitoring for optimal results. Unfortunately, though technically appealing, this external system is somewhat cumbersome and may severely limit the patient's activities while applied. All of the internal metal-based distraction systems and most of the external systems require a second operation for removal of the device after the consolidation. Fibrous and bony ingrowth into the distraction mechanism, screws, and plates can make removal of the devices

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difficult. Additional morbidity and expense are also associated with the second operative procedure.

Resorbable materials

Over the last 8 years, there has been increasing acceptance of the absorbable hardware in craniofacial surgery [12,13]. The stimulus for the development and use of resorbable hardware has been multifactorial. Metallic plates and screws can migrate through the skull and become lodged intracranially (Fig. 1). There is potential for interference with normal growth when metallic implants cross suture lines or interfere with growth centers. In addition, metallic implants may not become fully osseointegrated and have to be removed at a later date because of pain, infection, or extrusion. Metallic implants may also become palpable and visible even years after application. Eppley et al [14,15] have investigated the physical characteristics and biologic interactions of resorbable materials in a series of animal models. The basic mechanism of resorption is that of hydrolysis, fragmentation, and phagocytosis of the hydrolyzed microparticles. The time it takes for this process to take place is a function of the composition and mass of the resorbable material. The more polyglycolic acid (PGA) contained in the plate the greater the mechanical strength. Poly L-lactic acid (PLLA) contributes to plate durability. Currently, plate materials are available that can begin to dissolve within 6 weeks and will be completely resorbed within 12 months. Other plate materials having a greater percentage of PLLA can take years to completely resorb. The authors have observed that the longer-lasting materials may fragment into fairly large particles, which can cause local irritation and extrusion. Note that all of these materials lose significant mechanical strength long before they lose volume. The authors have had extensive experience using the LactoSorb system (Lorenz/Biomet, Inc., Indianapolis, Indiana), which resorbs comparatively rapidly. This type of material is ideal for use in children and adolescents because it will not restrict growth along the suture lines or interfere with normal function. Furthermore, LactoSorb tends to fragment in small soft particles rather than large particles that can extrude and cause focal granulomas. The authors have observed that materials that have a long resorption curve can actually cause focal osteitis with underlying bone resorption and remain palpable or visible for years.

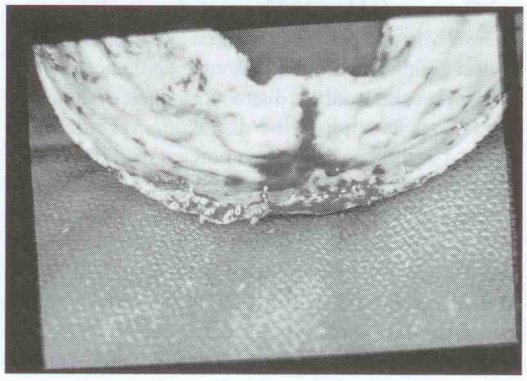

Fig. 1. Operative view of frontal bone flap demonstrating migration of hardware through inner table of frontal bone. Original frontal bone advancement 5 years before this photo.

Cohen et al [16] recently reported on a prototype partially resorbable distraction system using long-lasting material. This system requires a second stage for removal of the metallic expansion device and placement of an interim resorbable stabilization bar. Based on the authors' experience with resorbable plating systems and conventional bone distraction, they began work on a fully resorbable, single stage, bone distraction system approximately 5 years ago. Design ideas from many metallic distraction devices, dental expansion appliances, and resorbable technology to create a new class of distraction devices were incorporated. The initial report in 2002 detailed their experiences with mandibular, maxillary, and orbitocranial expansion in 21 patients [17]. A subsequent report on specific applications in Pierre Robin Sequence was also produced [18]. The authors' experience with 50 patients ranging in age from 5 days to 17 years helped refine the designs of the various resorbable one-stage bone distraction devices and develop surgical techniques to facilitate the device applications and decrease operative time and morbidity.

Resorbable bone distraction devices

The entire family of one-stage resorbable devices has several common mechanical features. These include proximal and distal distraction plates and a connecting steel drive screw. In addition, each steel drive screw can be coupled to a distractor cable of varying length, depending on the application (Fig. 2). The proximal and distal anchoring plates can be easily and precisely bent to the shape of the underlying bone by thermal contouring in a water bath or with a thermal contouring pen (Fig. 3). All the devices can be used with standard 1.5- to 2.0-mm diameter resorbable screws, depending on the underlying bone density and mass. There are two sizes of devices; one used