Piezoelectric osteotomies in craniofacial procedures: a series of 15 pediatric patients

Technical note


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During the previous decades the advancement of the frontoorbital complex has become a routine procedure in pediatric craniofacial surgery. The procedure has proven to be valuable for symmetrical adjustment of the orbital and intracranial volumes and for improvement of facial appearance. As in the case of other complex osteotomies of the anterior skull base, frontoorbital advancement surgery can entail a variety of severe complications, including hemorrhage and sepsis, as well as ophthalmic and neurological damage. Technically, frontoorbital advancement is performed through an osteotomy of the supra- and periorbital craniofacial skeleton involving the frontonasal, ethmoid, frontal, frontozygomatic, sphenoid, and temporal bones. To separate the frontoorbital complex from the bones of the cranial base, saws, drills, and chisels are usually used, thus requiring extended exposure of the osteotomy sites to ensure a safe, precise osteotomy and to avoid any damage to adjacent soft tissues. In recent years a new device has been introduced for use in periodontal and maxillofacial surgery that splits bone by using microvibrations of ultrasonic frequency created by piezoelectric effects. The aim of the present study was to investigate the usefulness of this appliance for frontoorbital advancement in pediatric craniofacial surgery.

Materials and Methods

In 2004, 15 consecutive patients with syndromic or nonsyndromic craniosynostosis were treated with frontoorbital advancement (Table 1). The mean age of the patients was 11.3 months. Before the osteotomy, a narrow exposure of the osteotomy sites was performed using a periosteum elevator. The frontoorbital segment was osteotomized with an ultrasonic osteotome (Piezosurgery; Mectron Medical Technologies, Carasco, Italy). The device consists of an electronic base unit with a display for ultrasound adjustment and is operated using a foot switch. A peristalsis pump for irrigation is integrated into the base unit (Fig. 1), which is connected by a cord to a pencil-like handpiece in which the working ends are inserted. The surfaces of the variously shaped working ends are coated with titanium; some tips are additionally coated with diamonds to improve bone-cutting activity (Fig. 3). In contrast to conventional sawing or drilling devices that function macrometrically, this appliance...
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Table 1: Clinical data of study patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (mos), Sex</th>
<th>Diagnosis</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>6, M</td>
<td>scaphocephaly</td>
</tr>
<tr>
<td>2</td>
<td>9, M</td>
<td>scaphocephaly</td>
</tr>
<tr>
<td>3</td>
<td>7, M</td>
<td>scaphocephaly</td>
</tr>
<tr>
<td>4</td>
<td>34, F</td>
<td>Crouzon syndrome</td>
</tr>
<tr>
<td>5</td>
<td>13, M</td>
<td>trigonocephaly</td>
</tr>
<tr>
<td>6</td>
<td>11, M</td>
<td>plagioccephaly</td>
</tr>
<tr>
<td>7</td>
<td>7, F</td>
<td>plagioccephaly</td>
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<tr>
<td>8</td>
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</tr>
<tr>
<td>9</td>
<td>14, F</td>
<td>trigonocephaly</td>
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<td>10</td>
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<td>12</td>
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<td>11, M</td>
<td>plagioccephaly</td>
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<tr>
<td>14</td>
<td>7, F</td>
<td>Crouzon syndrome</td>
</tr>
<tr>
<td>15</td>
<td>9, F</td>
<td>plagioccephaly</td>
</tr>
</tbody>
</table>

Fig. 1. Photograph of a piezoelectric osteotome, including drainage and peristalsis pump system for irrigation.

Fig. 2. Photograph of the osteotome handpiece with working tips.

Uses ultrasound vibrations to cut through bone micrometrically. After an electric stimulus, certain ceramic crystals inside the appliance begin to oscillate. The frequency of these oscillations is transferred to the working end, resulting in vibrations of ultrasound frequency. The applied frequency varies between 25 and 30 kHz and is optimized to cut mineralized tissues selectively. Damage to soft tissues by ultrasound at this frequency is physically impossible. Although soft tissues are not affected by slight touches with the instrument, the working end becomes hot and requires copious irrigation to avoid heat damage. All ultrasonic osteotomies were performed under intense and continuous irrigation with a sterile 0.9% sodium chloride solution that was cooled to 4°C before application. The oscillating amplitude varies between 60 μm and 210 μm.

For frontoorbital advancement, all osteotomies required for mobilization of the supraorbital bone bar were performed using the piezoelectric osteotome (Fig. 4). Additionally, shaping and molding of the osteotomized bar before replantation and osteosynthesis was done using ultrasonographic osteotomy.

Results

In all 15 patients, ultrasonographic osteotomy was precise and easy, and movement and pressure of the osteotome against the bone surfaces was uncomplicated. In contrast to the application of chisels, only low pressure was necessary to cut precisely through the cranial bones. In contrast to procedures using burs or saws, the initiation of the osteotomy did not involve the risk of accidental dislocation of the osteotome and had no effect on the course of osteotomy. In contrast to procedures with conventional reciprocating saws using macrovibrations, no contrasting actions were required to perform the osteotomies. Depending on the applied working tip, the width of the resulting osteotomy gap was approximately 0.5 mm. When the frontal bone bar was removed, a selective osteotomy of the inner table with no damage to the outer table was performed to reshape the frontal bone bar. Continuous and intense irrigation of the osteotomy site was required to cool the adjacent bone and to remove the osteotomized bone particles. The exposure of bone surfaces at the osteotomy sites was less extensive than that required for conventional osteotomy techniques. This aspect reduced surgical trauma and operation time; however, because of the increased time required for piezoelectric osteotomy, total operation time remained fairly constant.

No damage to adjacent soft tissues was observed, and within the observation period of 12 months, postoperative bone formation was uneventful in all patients.

Discussion

In previous decades many technical modifications were introduced into pediatric craniofacial surgery to increase precision and reduce morbidity, including resorbable osteosynthesis materials, image guidance devices, and endoscopic approaches. From a technical viewpoint, however, the manner in which osteotomy was performed remained unaffected and continued to involve the use of various types
of saws, burs, or chisels. Conventional osteotomy techniques always required extensive protection of adjacent soft tissues because cutting was not limited to bone and could easily affect other tissues when applied improperly. In particular, complex osteotomies located at technically or anatomically challenging sites require adequate surgical exposure to ensure the safety of adjacent structures, resulting in an extended operation time. In contrast, the ultrasonic vibrations of the piezoelectric osteotome did not cause visible damage to adjacent soft tissues, even when these tissues are only slightly touched by the instrument. Our observations were paralleled by previous histological and clinical reports confirming little or no soft-tissue damage after ultrasound-aided osteotomies were performed. The preservation of intact soft tissues through this technique allowed for less extensive soft-tissue dissection at the osteotomy sites and contributed to a reduction in surgical trauma.

Another aspect of conventional osteotomies is that usually a firm physical pressure of the saw or bur has to be applied on the osseous surface for safe guidance; this can limit precise handling of the instrument. Because of the risk of an initial dislocation, surgeons must always pay particular attention at the beginning of an osteotomy with saws or burs. In some delicate situations, the rotational spin of burs and the thickness of saws may even preclude a precise osteotomy from being performed at the intended ideal lines. The precision of osteotomies performed with drills or saws is limited by the manual pressure required to guide the instrument while avoiding damage to both soft and hard tissues. In contrast, the handling of the piezoelectric device is virtually effortless, requiring very little manual pressure to guide the osteotome precisely; even curved osteotomies can be easily performed.

As has been discussed in other reports on piezoelectric surgery, the importance of adequate cooling when using the ultrasound osteotome must be stressed. Because the microvibrations generate local heat similar to that found in conventional osteotomy techniques, copious irrigation is required, usually with a sterile 0.9% solution of sodium chloride cooled to 4°C. During prolonged use of the device,
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heat generation also affects the handpiece of the instrument, thus requiring short interruptions to allow it to cool down. In contrast to the findings of other reports, we found that piezoelectric osteotomies in bones thicker than those found in children’s craniofacial skeletons is technically possible. In thicker bones, the speed of an ultrasound osteotomy is decreased when compared with conventional techniques, but, again, it allows precise handling and increases the safety of the procedure. Ultrasound osteotomies have been performed successfully during orthognathic mandible surgery in adults and contributed to the intraoperative safety of the inferior alveolar nerve.  

Conclusions

A new device that uses ultrasound vibrations to cut bone was used for osteotomies in pediatric craniofacial surgery. It differs from conventional instruments used for osteotomies in its easy and precise handling and its tissue selectivity, cutting only bone and producing no visible damage to soft tissues. In our experience the instrument performed well and allowed precise cuts to be made with a light touch. We therefore conclude that piezoelectric osteotomies may prove useful in future applications in pediatric craniofacial surgery.

Disclaimer

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References


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