



## The Role of Piezoelectric Instrumentation in Rhinoplasty Surgery

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Aesthetic Surgery Journal  
2016, Vol 36(1) 21–34  
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journals.permissions@oup.com  
DOI: 10.1093/asj/sjv167  
www.aestheticsurgeryjournal.com  
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### Abstract

**Background:** In rhinoplasty surgery, management of the bony vault and lateral walls is most often performed with mechanical instruments: saws, chisels, osteotomes, and rasps. Over the years, these instruments have been refined to minimize damage to the surrounding soft tissues and to maximize precision.

**Objectives:** This article will present the evolution of the authors' current operative technique based on 185 clinical cases performed over an 19-month period using piezoelectric instrumentation (PEI).

**Methods:** A two-part study of cadaver dissections and clinical cases was performed using PEI. Evolution of the authors' clinical technique and the operative sequence were recorded.

**Results:** Thirty cadaver dissections and 185 clinical cases were performed using PEI, including 82 primary and 103 secondary cases. An extended subperiosteal dissection was developed to visualize all aspects of the open rhinoplasty including the osteotomies. Ultrasonic rhinosculpture (URS) was utilized in 95 patients to shape the bony vault without osteotomies. To date, 11 revisions (6%) have been performed. There were no cases of bone asymmetry, irregularity, or excessive narrowing requiring a revision.

**Conclusions:** Based on the authors' experience, adoption of PEI is justified and offers more precise analysis and surgical execution with superior results in altering the osseocartilaginous vault. With extensive exposure, surgeons can make an accurate diagnosis of bony deformity and safely contour the bones to achieve narrowing and symmetry of the bony dorsum. Stable osteotomies can be performed under direct vision with precise mobilization and control. As a result of PEI, the upper third of the rhinoplasty operation is no longer shrouded in mystery.

### Level of Evidence: 4



Accepted for publication July 22, 2015; online publish-ahead-of-print November 6, 2015.

In rhinoplasty surgery, management of the bony vault and lateral walls is most often performed with mechanical instruments: saws, chisels, osteotomes, and rasps.<sup>1,2</sup> Over the years, these instruments have been refined to minimize damage to the surrounding soft tissues and to maximize precision. However, the continued lack of precision and the associated uncontrollable fracture lines prompted a search for more precise surgical tools. Subsequently, electric instruments with reciprocating heads were developed to overcome the limitations of manual instruments.<sup>3,4</sup> Power-assisted rasps, burrs, and saws were designed specifically for use in rhinoplasty surgery with good results. However, limitations exist such as the expense, increased operative time, risk of soft tissue injury, more extensive exposure, and difficulty performing

lateral osteotomies. Recently, surgeons have begun using piezoelectric-powered ultrasonic instruments for the management of the bony vault and lateral osteotomies.<sup>5,6</sup> These devices minimize soft tissue injury, because a frequency of 25 to 29 kHz is utilized to cut bone, although a frequency

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greater than 50 kHz is necessary to cut neurovascular structures. Piezoelectric inserts have the ability to selectively act on bones and/or hard cartilage, without injuring soft tissues: skin, mucosa, and flimsy cartilages such as the upper lateral cartilages (ULCs) and lower lateral cartilages. Importantly, the fracture lines created by PEIs are very accurate and eliminate the risk of radiating fracture lines encountered with traditional instrumentation. This paper will present the evolution of our current operative technique based on 185 clinical cases performed over an 19-month period from June 2013 to December 2014.

Piezoelectric surgery is based on piezoelectric vibrations generated by an electrically supplied piezoceramic transducer, which can then be utilized to cut bone through various tips (herein after referred to as *inserts*) (see <http://sites.synthes.com/na/piezoelectric/Overview/Pages/Piezoelectric-System.aspx> for a review of the inserts and the operating components). Essentially, an electric current passes across the ceramic, resulting in an oscillation of ultrasonic frequency that is then amplified and transferred to a vibrating insert.<sup>7,8</sup> Bony tissue is emulsified and removed by suction irrigation without thermal or mechanical injury to the surrounding tissue. The ultrasonic frequency is set at a low level, which causes the metallic insert to oscillate for cutting hard tissues (bones, stiff cartilages), while leaving soft tissues (vessels, nerves, mucous membranes) untouched. The insert's tip vibrates within a range of 60 to 200  $\mu\text{m}$ , allowing a very precise bone incision. Water irrigation is provided through a distal port of the working tip through a hydraulic circuit inside the handpiece. A peristaltic pump enables differential water flows. A foot pedal allows the surgeon to control all the parameters (power, mode, and irrigation). For simplification of the text, we will refer to piezoelectric surgery as PE and the various piezoelectric instruments as PEIs, which will include the numerous inserts: saws, rasps, burrs, and scalpels.

PE is suitable for all bony surgery, but it is particularly valuable when access is restricted and/or the bones are near delicate soft tissues (vessels, nerves, skin, mucosa, dura, and pleura). It allows the surgeon to perform osteotomy, osteotomy, and osteoplasty. PE is well established clinically, with review articles detailing its evolution over the past 20 years.<sup>9</sup> Initially, PE was utilized in dental and oral surgical procedures such as excision of cysts, third molar extraction, preparation of implant sites, creation of an opening into the maxillary sinus, and elevation of endosteum. Subsequently, PE was utilized in maxillofacial surgery with extension to maxillary LeFort I osteotomies, mandibular sagittal split osteotomies, and cranial bone harvesting.<sup>10</sup> PE is particularly useful in craniofacial surgery, because it allows extensive osteotomies without injury to the underlying dura and adjacent neurovascular structures.<sup>11</sup> Concurrently, applications have been found for the use of PE in otological surgery (stapedectomy and chain replacement as well as facial nerve decompression) and hand

surgery (osteotomy and hardware removal).<sup>12,13</sup> Histologic examination of bony cut surfaces shows that coagulative necrosis does not occur.<sup>14</sup>

The first application of PEI in rhinoplasty surgery was reported by Robiony<sup>5</sup> in 2004 and published in 2007. The initial publication reported on the use of a piezo scalpel for performing lateral osteotomies through a percutaneous approach. The vibrating scalpel was passed continuously along the ideal osteotomy line, resulting in a continuous osteotomy as opposed to a perforating osteotomy. A greenstick transverse fracture was then performed to achieve the desired movement. Several months later, Robiony<sup>15</sup> published a preliminary report on additional applications in rhinoplasty surgery including management of the bony vault as well as medial and lateral osteotomies. Hump removal was performed en-bloc, with an incision of the cartilaginous hump being made along the proposed profile line using a scalpel followed by a piezoelectric saw to remove everything cephalic to the keystone junction. Medial osteotomies were performed as vertical cuts at the junction between the septum and the nasal bone, and lateral osteotomies performed through the aforementioned percutaneous technique. In 2013 Cochran and Roostaeian<sup>6</sup> reported five cases of lateral, continuous low to low osteotomies using a PE aspirator through an intranasal lateral approach.

In 2010, Pribitkin et al<sup>16</sup> reported on their experience using PEI for dorsal hump removal in 60 patients. In addition to management of the bony vault, deepening of the radix/ glabellar area was performed as indicated. Importantly, they were able to smooth the mobilized nasal bones following osteotomies without the risk of disrupting critical soft tissue attachments. They also reported the use of PEI for septoplasty, turbinectomy, and anterior nasal spine resection. In 2011, Greywoode and Pribitkin<sup>17</sup> expanded their retrospective clinical study to dorsal reduction in 103 patients with additional emphasis on anterior nasal spine resection (10 patients) and glabellar deepening (3 patients), plus routine use in smoothing mobilized nasal bones and sculpting convexities of the nasal bones. Then in 2013 these same authors updated their series to 150 patients and provided a detailed description of the use of PE for septoplasty and inferior turbinoplasty.<sup>18</sup> They stated that over 100 turbinectomies had been performed without any significant bleeding, synechia, or bone necrosis.

## METHODS

### Initial Experience

The lead author (O.G.) began using PEI for rhinoplasty surgery in February 2013. At first, a VarioSurg machine (Nakanishi, Inc., Tochigi, Japan) was utilized with standard available inserts that had been designed primarily for dental and maxillofacial surgery. Later, a Piezotome M+

duo (Acteon Group, Mérignac, France) and a piezoelectric system (Synthes International, West Chester, Pennsylvania, USA) were utilized. Initially, surgery of the bony vault was performed using the standard soft tissue elevation techniques over the central part of the nose. Bony cap removal was achieved through sonic fragmentation of the bony cap above the cartilaginous vault using a rasp for small humps, thin bones, or in cases of thin skin. A blade or scraper was utilized for larger humps. Medial oblique osteotomies were easily performed using a saw. In all cases, smoothing the bones after hump removal or osteotomies was performed with the diamond rasp. Attempts to perform a lateral osteotomy through the usual lateral subperiosteal tunnel were unsatisfactory, because the existing saws were too short and their shape too cumbersome. Thus, lateral and transverse osteotomies continued to be performed with standard osteotomes. Next, we attempted to do external percutaneous osteotomies using PE instruments with small angulated saws for both lateral and transverse osteotomies. Although the technique did work, the PE instruments were considered less than ideal because: 1) the inserts were less adaptable than a 2 or 3 mm osteotome, 2) the skin opening was larger than a simple stab incision using a percutaneous 2 mm osteotome, 3) the skin had to be protected to avoid burn injury caused by friction, and 4) they had a greater time requirement. Therefore, a new set of inserts were developed specifically for rhinoplasty surgery. It consisted of longer instruments, which allowed lateral osteotomies and transverse osteotomies to be performed after having dissected a lateral subperiosteal tunnel. Those instruments were also designed to perform septal surgery.

## Cadaver Studies

While these clinical cases were being conducted, the lead author (O.G.) began an ongoing study in cadavers to assess the effectiveness of PEI for rhinoplasty surgery between July 2013 and February 2014. All cadavers were acquired through affiliations with the Medico Legal Institute in Hamburg, Germany and the Semmelweis University in Budapest, Hungary. Cadaver dissections were not performed on patients with previous nasal surgery. During the cadaver dissections, the technique was either to remove the nasal skin completely or to perform a complete subperiosteal exposure of the bony vault from maxilla to maxilla. Visual assessment of the bones was completed, noting the asymmetries and heights of the bones. The bony cap was then removed using PEI. The amount of time it took to expose the underlying cartilaginous vault was recorded, and the overlap of the osseocartilaginous vault measured (Figure 1). Bony cap removal continued on the lateral sidewall, where the removal depended on the shape of the hump; the wider the hump, the more lateral the extent of bone removal. After exposure and bony cap removal, it was noted that a large amount of cartilage was preserved. Spreader flaps

were performed noting whether or not the ULCs needed to be dislocated from the overlying nasal bones. Complete osteotomies (lateral-transverse-medial oblique) were performed, and the stability of the nasal wall (whether or not there was collapse into the nasal cavity) was recorded. The amount of medial movement was observed as well as the ability to independently and concurrently rotate the nasal sidewall. Finally, sculpting of the bony sidewalls was performed even on mobilized bones.

## Clinical Technique

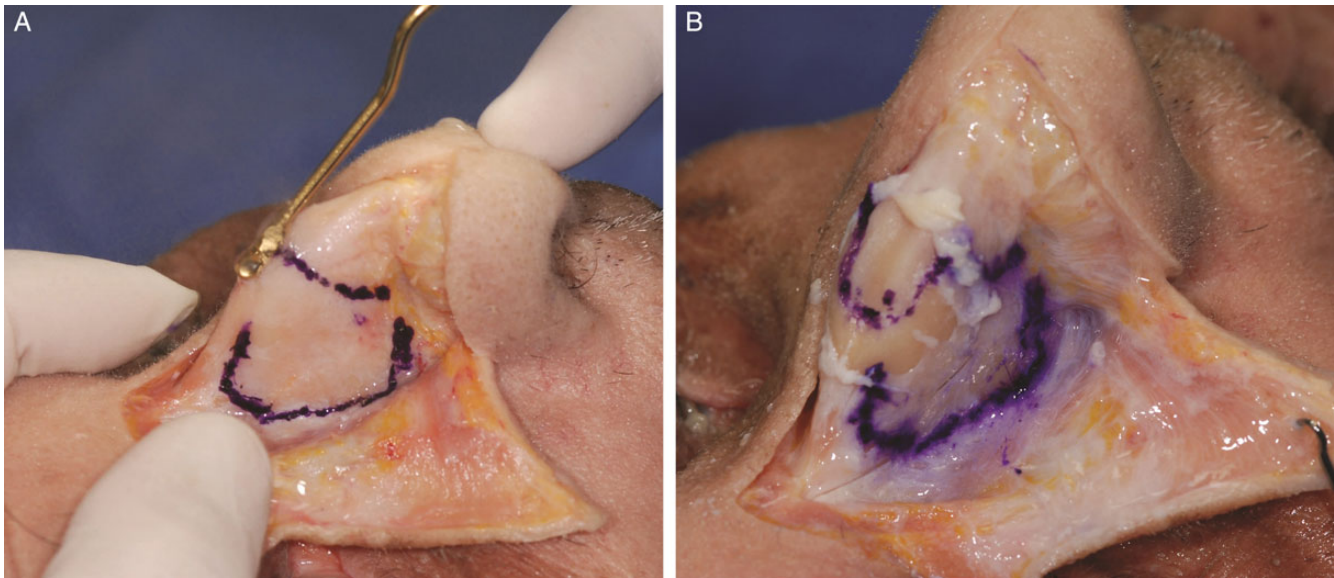
From June 2013 to December 2014, all patients presenting for rhinoplasty were included in the current study. Informed consent was given by all patients, although IRB approval was not obtained, because the study was performed in the authors' private practice. The current clinical technique and the methods detailed below have evolved over the past 18 months.

### Extensive Exposure

Based on our cadaver dissections, we began to extend exposure of the bony vault in our clinical cases. A full subperiosteal dissection of the bony vault was performed longitudinally from the keystone junction up to the cephalic part of the radix and transversely from one ascending frontal process of the maxilla to the other side. Usually, the lateral pyriform aperture ligaments (from the lateral part of the ULC to the pyriform aperture) are elongated or trimmed, depending on their strength, to allow complete access to the nasal bony wall along the pyriform aperture. This extended dissection permitted the use of short angulated saws to achieve a continuous complete osteotomy under direct vision, which resulted in complete mobilization of the lateral bony wall. In June 2013 we performed our first open rhinoplasty with extended soft tissue elevation, allowing a complete visual assessment of the entire osseocartilaginous vault. It should be noted that no dissection of the lining was performed under the bones, which keeps the posterior support intact.

### Hump Removal

After exposure, hump removal is the first part of every reduction rhinoplasty. The bony cap was removed to lower the dorsal profile line, to narrow the lateral keystone area (especially when osteotomies were not performed), and to remove any bone that would prevent a harmonious reshaping of the ULC when using spreader flaps. Bone removal was performed with a diamond burr if the hump was small or if the skin was thin, and it was performed with a scraper or blade if the hump was larger or if the skin was thick. Whichever instruments we utilized, an open roof never occurred, because the underlying cartilages and mucosa were unharmed through PEI. The bone work was performed first to set the width and shape of the bony segment of the nose



**Figure 1.** The clinical sequence of this 68-year-old male cadaver began with bony cap removal. (A) The cadaver after removal of the skin, and (B) after bony cap removal with the Piezo.

before opening the middle third. Submucosal dissection of the bones was *not* performed, because the mucosa would act as an internal splint for the mobilized bones. By using this sequence, the cartilage vault was managed independently from the bony pyramid *after* the bone was corrected.

### Osteotomies

Osteotomies were indicated only if the bones were too wide either laterally or dorsally on preoperative assessment or dorsally after hump removal. In most cases, we prefer the following sequence. First, a low to low *lateral osteotomy* was performed as low as possible. The fracture line was initiated from the pyriform aperture just above the insertion of the inferior turbinate and continued along the nasofacial angle with an angulated saw. Then, a *transverse osteotomy* was performed. The length and shape of the transverse cut depended on the cephalic orientation of the lateral osteotomy, and also on the intended motion on the nasal bone. Finally, a *medial oblique osteotomy* was performed from the cephalic extent of the hump removal in an oblique direction beginning at the desired dorsal aesthetic line and connecting to the transverse osteotomy. This osteotomy wasn't usually performed when the radix was narrow; rather, in this case, medializing the bone with a blunt periosteal elevator introduced in the lateral osteotomy was enough to narrow the bony pyramid. Next, the completeness of the osteotomy was confirmed using a blunt periosteal elevator, and the bone flap was mobilized medially. The bone flap can be moved more caudally or more cephalically, depending on the pattern of the bony pyramid.

From our initial experience, it became clear that bone mobilization is composed of two vectors: a horizontal

vector and a rotational vector. When the combination was a low to low lateral osteotomy plus a longer transverse osteotomy and a medial oblique osteotomy, then the movement was predominantly a horizontal movement of the lateral wall. In case of a more "triangular pattern" osteotomy composed of a low to high lateral osteotomy, followed by a very short transverse osteotomy and a medial oblique osteotomy, then the main movement was rotation of the mobilized bone. Both motions could be combined. A rotation was desired when the lateral wall is flat and needs to be verticalized. Otherwise, a horizontal translation of the bone was utilized to narrow the bony pyramid. No overlapping of the bones occurred medially, because the bones meet end to end and were very stable. Once the osteotomies were completed, the bony edges could be smoothed with a diamond burr. Visually one could evaluate the bones and then assess them digitally through the skin. Usually a burr was utilized to smooth the dorsal edge of the medial oblique osteotomy. Finally, additional smoothing with a burr or a rasp could be performed at the end of the surgery, even when the skin has been sutured in the case of open approach, to reduce any irregularity palpated during the final checking.

### Ultrasonic Rhinosculpture

Bone reshaping procedures with associated narrowing and remodeling are designated as *ultrasonic rhinosculpture (URS)*. In cases in which the bony vault required only a slight reduction (1-3 mm), a true osteoplasty of the bony pyramid was possible by shaping the different parts of the nasal bones and osteotomies were not required. The bony cap was removed, followed by a superficial osteotomy



performed with the more convex side burred down more than the opposite side. In very asymmetric cases, the bony cap was removed first from the medial and lateral keystone area. If the convexity was more lateral where the bones were thick, then osteotomy with saws or burrs was favored. If the convexity was more medial where the bones were thin, vertical and horizontal cuts were performed in a criss-cross pattern to straighten the convexity without removing a significant amount of bone.

### **Middle Third Reconstruction**

Reconstruction of the middle third was directly related to the amount of dorsal reduction. If the profile line was good after treatment of the bony pyramid, then we did nothing to the middle third. Slight narrowing could be achieved using a 4, 0 mattress suture placed at the cephalic end of the ULC. If this suture increased the height of the arch slightly, then the ULC could be partially released from its junction with the bones. If the profile line needed to be lowered less than 1 mm, and/or if the dorsum was too broad, then the cartilaginous hump could be tangentially shaved to lower it or to reshape it. In all other cases of middle third lowering, a split incision was made vertically on both sides of the septum, separating the septum from the ULC. All the septal work was then performed and the dorsal height lowered. After removal of the bony cap both in the central and lateral keystone areas, it became possible to fully mobilize the ULC inwards without having to dislocate it from the bone. Also, it was possible to place more sutures in the cephalic end of the ULC. Spreader flaps were created by folding the ULC over and suturing them with 4-0 sutures. If the ULC were too flimsy or too stiff, spreader grafts could be utilized. When spreader grafts were performed, they were overlaid with bent ULC to achieve a curved shape for the reconstructed dorsum.

### **Septoplasty**

Long saws were developed to allow very precise cuts on the exposed septum. Spurs were easily corrected by tangential trimming in a sagittal direction. A big advantage of piezo-assisted septoplasty was safe treatment of *high* septal deviations. A small strip of perpendicular plate was removed safely, without using the twisting motion of the septum. Also, there was much less risk of a radiated fracture to the skull base. Once the bony excess of the septum was removed, the remaining part could be medialized.

### **Perioperative Care**

All patients were given a preoperative antibiotic dose of a first-generation cephalosporin as well as a 5-day oral course of antibiotics postoperatively. A standard splint was applied at the end of the operation for 5 to 7 days, and taping was done every night for 3 weeks.

## **RESULTS**

### **Cadaver Results**

The following important findings from the cadaver studies are illustrated in Supplementary Video 1, which can be viewed at [www.aestheticsurgeryjournal.com](http://www.aestheticsurgeryjournal.com). Thirty cadaver dissections were performed (18 male, 12 female), with an average age of 68 years in the cadavers (range, 21-87 years).

- (1) Direct visual assessment of the bones showed that in nearly all cases ( $n = 28$ , 93%), the lateral nasal bony walls were asymmetric with a more convex side and a more concave side. Measurements of lateral nasal bone length were available in the rhinoplasty literature.<sup>19</sup> The average time for wide exposure took an extra 4 minutes on average, compared with a standard rhinoplasty approach.
- (2) During hump removal, it was easy to remove only the bony cap without injuring the underlying cartilaginous vault and/ or the mucosa more cephalically. Thus, a true open roof never occurred with the use of PEI. Injury to the cartilaginous tissues was virtually impossible with PEI. The overlapping of the bone over the ULC ranged from 6 to 20 mm in longitudinal length with an average of 12 mm. The time required to remove all the bone over the cartilaginous hump ranged from 2 to 5 minutes, with an average of 3.2 minutes depending on the height of the hump and its cephalic extent.
- (3) Bony cap removal continued on the lateral sidewall depending upon the shape of the hump; the wider the hump, the more lateral the extent of bone removal.
- (4) Because bone removal was easy and accurate over the medial and lateral keystone areas, the result was more extensive exposure of the underlying cartilaginous vault than is common with the use of either osteotomes or rasps. Because the ULCs were more visible, it was easier to shape them and they allowed shaping with greater precision. This extensive exposure of the cartilaginous vault allowed easier creation of spreader flaps without the need to dislocate the ULC from its bony attachment. Also, mattress sutures could be placed much more cephalically, because the bone had been removed from the lateral sidewalls. Spreader flaps were more stable, because more cephalic sutures could be added compared with traditional techniques.
- (5) The stability between the ULC and the bone was intact even after extended bony hump removal. Preservation of fixation occurred, because all the connections between the posterior periosteum of the bone and the anterior perichondrium of the ULC were not damaged. Even when pushing as hard as possible on the ULC with a forceps, no gap between the ULC and the bones was observed.

- (6) When a complete osteotomy (lateral-transverse-medial oblique) was performed, the bony wall remained extremely stable without collapse into the nasal cavity in all cadavers (Figure 2). This essential finding led us to begin performing an extended subperiosteal dissection of the bony pyramid in clinical cases. The first purpose of this extended dissection from one ascending branch of the maxilla to the other was to assess the whole length of the fracture line, and to be sure that a complete osteotomy was performed when indicated. Very quickly, this extended dissection became part of the routine dissection, allowing a very accurate assessment of the asymmetry, shape, and tailored treatment of the bones.
- (7) The underlying periosteum and mucosa were never injured in any cadavers after we performed osteotomies using an ultrasonic saw.
- (8) Controlled medial movement (transversed inwards) and rotation of the lateral wall was possible (Figure 3). These two movements could be performed independently or more frequently combined. This combination of bone movements was nearly impossible to assess and to control when osteotomies were executed without direct visualization. When performing lateral osteotomies, the inclination of the saw had an impact on the bone mobilization. The more angled the saw blade, the easier it was to move the bone inward. In contrast, a very horizontal cut increased the stability of the bones and made it more difficult to move the bones inward.
- (9) Sculpting of the lateral bony wall was possible, either before the osteotomies or even on mobilized bones. This sculpting was performed with a burr or saw by removing a slice of bone where it was the most convex. In thin bones, the convexity could be treated with crisscross cuts to eliminate the convexity.

## Clinical Results

From June 2013 to December 2014, the senior author (O.G.) performed PEI in 185 patients including 82 primary rhinoplasty cases and 103 secondary rhinoplasty cases. These patients ranged in age from 17 to 60 years (average, 27 years), with 105 females and 80 males. Average follow-up was 13 months, with 128 patients having 12 months of follow-up or more (range, 3 weeks to 20 months). The current techniques are demonstrated in Supplementary Video 2, which can be viewed at [www.aestheticsurgeryjournal.com](http://www.aestheticsurgeryjournal.com).

URS is defined as shaping of the bony vault with incremental osteotomies performed by scraping, rasping, or burring. URS was performed in 96 patients. Modification of the bony vault was achieved without any osteotomies. Indications for URS included patients with a normal bony width at the base plus a mild-to-moderate width of the bony vault, a mild-to-moderate osseocartilaginous hump (1-3 mm), or a localized

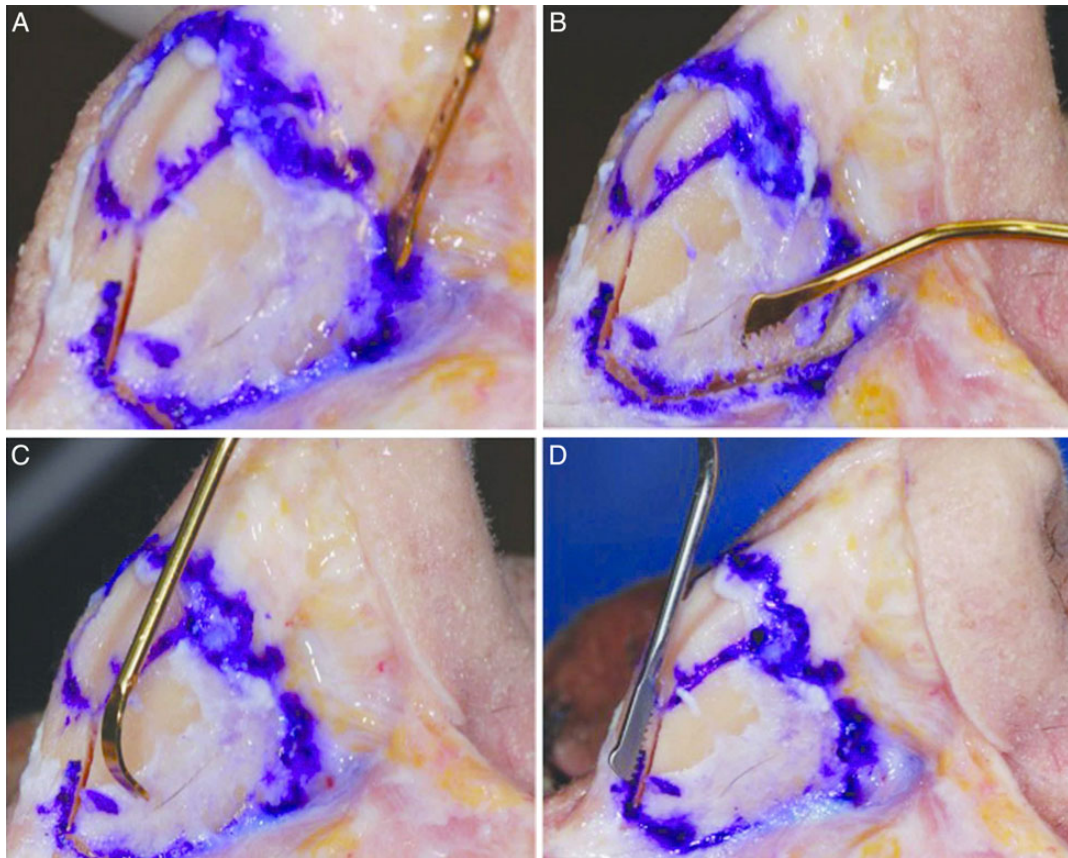
convexity (asymmetries and irregularities). In 24 cases, rasping of the remaining bony excess was performed through a closed approach. In 17 of these cases, the patients were undergoing primary rhinoplasty through an open approach and the excess was noted after closure of the transcolumellar incision. It is easy to place a piezo rasp through the infracartilaginous incision and under the skin sleeve to perform fine-tuning at the end of the procedure. This group also included seven secondary patients who had traditional osteotomies by another surgeon, but had remaining localized bone excess and/or convexity. In these patients, a small tunnel was made using an endonasal, intercartilaginous approach to treat the bone excess.

In 89 cases, an osteotomy was performed on at least one side when the bony base width was judged to be too wide from the lateral to the medial canthus. A partial osteotomy consisting of a low to low osteotomy following the nasofacial groove, and a transverse osteotomy (without medial oblique osteotomy), was performed when the bones were too wide, but with a narrower upper bony pyramid, ie, narrow radix. Bony mobility was assessed with a blunt periosteal elevator, and when the inward displacement of the bone was judged sufficient, the medial part of the transverse osteotomy and the medial oblique osteotomy were postponed until after any septal work was completed. Depending on the opening of the cartilaginous vault and its management, the spring effect of the upper part of the ULC on the bones was reassessed, especially at their cephalic part. The medial portion of the transverse osteotomy and the medial osteotomy were completed if the bony vault was still too wide.

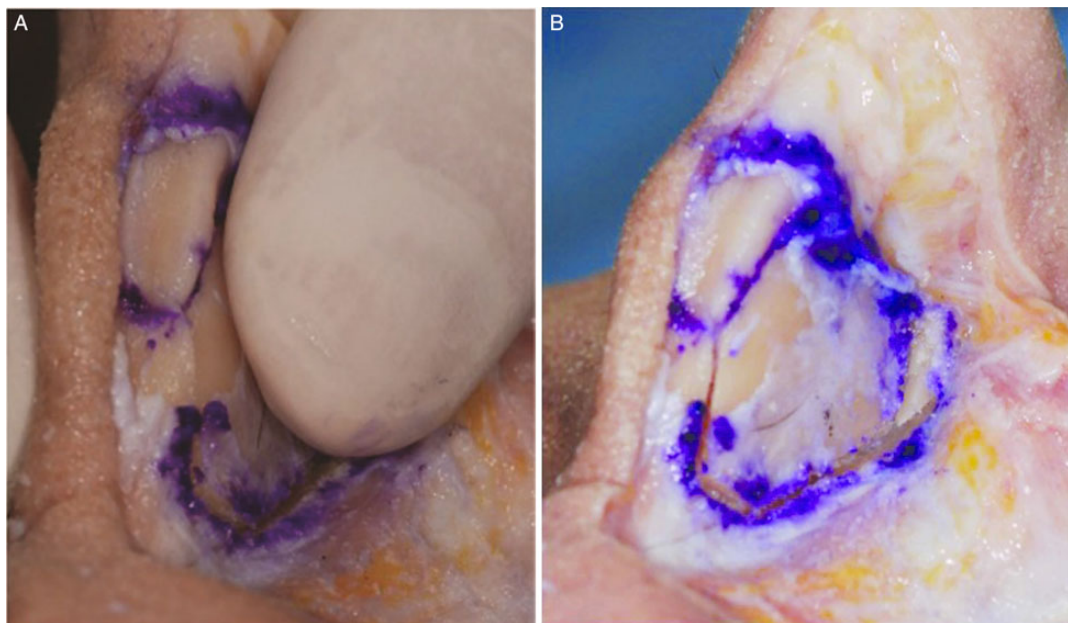
In 105 patients, the bony part of the septoplasty was completed using PE saws. In particular, it was utilized in patients with high septal deviation of the perpendicular plate of the ethmoid bone. Most frequently, a strip of bony and cartilaginous septum was removed at the turning point of the deviation, and the rest of the septum was then moved medially. When there was severe deviation of the bony septum, a larger piece of ethmoid and/or vomer was trimmed. In cases of a bony septal spur, the spur was trimmed tangentially with a piezo saw, keeping the lower part of the vomer in place if it was in the midline.

For 59 patients, a drill hole was made in the anterior nasal spine using a PE drill to facilitate relocation or stabilization of the caudal septum. In 14 patients, the premaxilla was reshaped by doing osteotomy or rasping on the pyriform aperture. An anterior nasal spine reduction was performed in 8 patients.

To date, there have been 11 revisions (6%) with 2 (1%) requiring additional radix reduction, 4 (2%) for middle vault asymmetry, and 5 for tip and alar rim asymmetries (2.5%). There were no cases of bone asymmetry, bone irregularity, or excessive narrowing requiring a revision. There were also no cases of soft tissue damage from PEI, nor did any patients have abnormal swelling from the



**Figure 2.** The osteotomy sequence in this 52-year-old male cadaver. (A) The osteotomy begins at the pyriform aperture, (B) followed by the low osteotomy, (C) then the transverse osteotomy, and (D) finally the optional medial oblique.



**Figure 3.** After the osteotomy sequence of the same 52-year-old male cadaver shown in Figure 2, manual pressure with palpation or a periosteal elevator is utilized to assess mobility and to create movement. (A) Manual pressure and (B) medial movement of the nasal bone without collapse into the nasal vault.



extended exposure. In four patients (2%), one of the bones was considered to be not stable enough after performing osteotomies. This meant that even if it was not collapsing in the airway, the fragment was felt to be unstable. In those cases, drill holes were made so that the bony fragment could be secured to the stable central segment. This was not considered to be a result of PEI; rather, wide exposure may have contributed to the “instability” of this segment. The time spent performing osteotomies and osteotomies has varied. However, we have become more efficient, because we have a better understanding of the instruments and adoption of inserts designed specifically for rhinoplasty surgery. URS with hump removal and osteotomies now takes approximately 10 minutes on average. The complete sequence of hump removal plus bilateral osteotomies and final touch-ups with osteotomies and bone polishing, takes approximately 20 minutes on average. Representative clinical examples from our study are shown in Figure 4-6, and Supplementary Video 3, the latter of which can be viewed at [www.aestheticsurgeryjournal.com](http://www.aestheticsurgeryjournal.com).

## DISCUSSION

The adoption of new techniques in rhinoplasty surgery can be simple or complex. For example, switching from closed to percutaneous osteotomies is essentially a change in instrumentation and approach rather than principles.<sup>20</sup> The current clinical report is more complex and even disruptive of many rhinoplasty principles. For example, a new component is extensive elevation of the skin envelope combined with complete osteotomies. Traditionally, a complete osteotomy resulted in transection of the underlying periosteum and mucosa, thereby increasing the risk of the nasal bones falling into the pyriform aperture. As a result, limited skin elevation and greenstick fractures were recommended (Sheen, a rhinoplasty surgeon). In contrast, complete osteotomies performed with PEI preserve the underlying periosteum and mucosa, resulting in greater stability and optional methods of mobilization. This discussion will focus on the major changes in our rhinoplasty operation after we started using piezoelectric instruments.

### Preoperative Analysis and Operative Planning

Bony vault preoperative analysis has become of paramount importance in planning the rhinoplasty, because more options are available. We have found semibasilar and helicopter views more important for bony analysis than the frontal view. Because bone shape and asymmetry can be difficult to assess on frontal views, analysis and planning based on frontal views can be misleading. Palpation is also of paramount importance in planning the surgery: bone size (length, width), shape (concave, straight, concave) and asymmetries are easily assessed by palpation and can confirm visual assessment. We do this by

having the patient lay on the examination table so that we can palpate the nasal bones between our thumb and index finger.

At least four changes in operative technique and sequence are readily apparent. First, extensive elevation of the soft tissue envelope permits greater visibility and assessment of the bony vault before and after surgical modification. Second, one can utilize the concept of URS to correct asymmetries of the bony vault directly by changing the thickness of the nasal bones both dorsally and laterally as well as their intrinsic convexity. The operating surgeon is no longer limited to varying the level, angulation, or number of osteotomies to achieve symmetry. Third, removal of the dorsal hump is staged with removal of the bony cap first without altering the underlying cartilaginous vault. The delay in modifying the cartilage vault until after the osteotomies allows maximum preservation of the cartilage. Fourth, complete osteotomies with intact underlying periosteum/mucosa permit more precise mobilization and stabilization than previously possible. It is only after the lateral bony wall has been mobilized that the cartilaginous vault is altered. Thus, one sees a dramatic change in operative planning and sequence compared with current methodology.

### Extensive Exposure

To utilize the short PEI for the lateral osteotomies, the surgeon must elevate the skin envelope subperiosteally from one frontal process of the maxilla across the nasal bridge to the opposite side. Dissecting far laterally and cephalically as well as releasing the pyriform aperture ligaments are the two keys for optimal bone treatment with PEI. One of the principal advantages of this extensive exposure is the ability to visually assess the bony vault before and after osteotomies, with the latter performed under direct visualization. Previously, the bony vault was shrouded in mystery because of limited exposure. Traditionally, narrowing the bony vault was often accomplished using a low-to-high lateral osteotomy followed by a manual transverse fracture into the open roof. The surgeon simply assumed that the osteotomies and the fracture lines were symmetrical. However, no attempt was made to see the fracture lines or even the bony dorsum. The result of uncontrolled osteotomies is shockingly asymmetric, because the two fracture lines have different angulations and are located at different points. In our cadaver studies, fracture lines occurred at the intrinsic weak point of the lateral walls and took the path of least resistance into the open roof, which may or may not coincide with the aesthetic goal. Once observed, a controlled, medial oblique osteotomy placed at the desired point and angulated to account for the intrinsic asymmetry of the two bony lateral walls undoubtedly offers greater control and aesthetic correction of asymmetry. Once the nasal bones are directly visualized with complete exposure, the surgeon can no longer ignore the preexisting deformity, nor accept the limited improvement.





**Figure 4.** This 32-year-old woman underwent ultrasonic rhinosculpture (URS). This patient complained of a broad nose and undefined tip. Following complete exposure of the osseocartilaginous vault, an open URS was performed. First, approximately 1 mm of the bony cap was removed, and the upper lateral nasal walls contoured. Next, the lateral nasal walls were sculpted to narrow the width and to reduce convexity, all without osteotomy. A component cartilaginous hump reduction was performed with removal of 2 mm of dorsal height. Next, dorsal reconstruction was achieved using spreader grafts. The upper lateral cartilages (ULCs) were folded over and fixed with 4-0 polydioxanone (PDS) sutures. A 1 mm caudal septal trim was also performed. The tip deformity was treated by cephalic trim, a columellar strut, and tip sutures. The results are shown preoperatively (A, D, G), 6 days postoperatively (B, E, H), and 1 year postoperatively (C, F, I) after URS without osteotomies. Note the lack of bruising and swelling at 6 days even with the extensive exposure from maxilla to maxilla.



**Figure 5.** This 35-year-old woman underwent osteotomies with piezoelectric instrumentation (PEI). This patient complained of a hump and a nose that appeared masculine. She had a high, C-shaped septal vertical deviation towards the left. Structural open rhinoplasty was performed with septoplasty and repositioning of the remaining bony septum. Bilateral complete osteotomies (medial oblique, transverse and low to low) were performed after bony cap removal and a component 3 mm cartilaginous hump reduction was performed with dorsal reconstruction through spreader flaps. Cephalic trim, a columellar strut and tip sutures were utilized to treat the tip. The results are shown preoperatively (A, D, G), 6 days postoperatively (B, E, H), and 1 year postoperatively (C, F, I) after PEI with osteotomies. Note the lack of bruising and swelling even with the extensive exposure from maxilla to maxilla as well as osteotomies at 6 days.





**Figure 6.** This 42-year-old man with an asymmetric developmentally deviated nose (ADDN) who underwent PEI. This patient with severe facial asymmetry complained of a twisted nose that was slightly too long. He had no history of nasal trauma or surgery. Speculum examination revealed a significant S-shaped septal deviation with a cephalic convexity towards the right and a caudal convexity toward the left. First, the bony cap was removed utilizing the open approach. Complete osteotomy on the right vault was performed as well as sculpting of the sidewall. The middle vault was reconstructed with spreader grafts and the caudal septum was trimmed 2 mm and relocated to the midline. Cephalic trim, a columellar strut, and tip sutures were utilized to treat the tip. The results are shown preoperatively (A, C, E) and 1 year postoperatively (B, D, F) after PEI with osteotomies.



An extensive subperiosteal undermining can also be performed through a closed approach, and long instruments have been developed for such a purpose and to perform septal work. The technical difficulty with long instruments is to maintain efficiency; long instruments work well on thin bones, such as the vomer and the ethmoid, but they are time consuming for osteotomies and importantly, the bones cannot not visualized.

## Ultrasonic Rhinosculpture

Ultrasonic rhinosculpture (URS) is an important new surgical approach, with dramatic application in both primary and secondary rhinoplasty. URS was employed in the majority of our cases (52%, 96/185). URS involves direct shaping of the bony vault to achieve the desired aesthetic goal without osteotomies. In primary rhinoplasty, the bony pyramid may be slightly wide or asymmetric. Using conventional techniques, the former would require medial oblique osteotomies and the latter asymmetric lateral osteotomies. Alternatively, URS permits removal and thinning of the nasal bones along the dorsum, thus narrowing the dorsal width. In asymmetric cases, the convex lateral bony wall can be directly thinned until the asymmetry is minimized. Focal bony convexities are easily removed. Compared with conventional techniques, URS proved extremely valuable in secondary cases with residual bony asymmetry, insufficient narrowing of the bony pyramid, or remaining convexity (localized bone excess). A significant number of secondary patients complain of a wide bony dorsum due to previous verticalization of the lateral bony walls after aggressive lateral osteotomies. One is able to directly contour the upper bony walls and achieve significant narrowing of the cephalic dorsal lines.

## Bony Hump Reduction

Anatomically, the dorsal hump comprises a bony cap covering the cartilaginous vault.<sup>21</sup> With the recent introduction of spreader flaps, preservation of the underlying ULCs has become paramount.<sup>22</sup> Removal of the bony hump with an osteotome often leads to damage of the underlying cartilaginous vault or creation of an "open roof" extending 6 to 10 mm cephalic to the keystone junction. In contrast, PEI permits graded removal of the bony cap without creating an open roof or damaging the underlying cartilage. The result is the ability to extend spreader flaps cephalically in the bony vault, resulting in a more natural dorsal reconstruction. In addition, incremental controlled osteotomies can be performed laterally onto the nasal bones to narrow the dorsal width. Equally, any sharp edges or spicules after osteotomies can be easily eliminated using PEI even on mobilized bones. As noted by Gruber,<sup>23</sup> removal of the bony cap with maximum preservation of the cartilage is a critical first step in creating spreader flaps. In cadaver dissections the

cephalic extension of the cartilaginous hump beyond the keystone junction averaged 8.9 mm (range, 4-14 mm).<sup>20</sup> In our combined clinical experience, we have seen only one case in which the cephalic end of the cartilaginous hump was identified and mucosa seen extending cephalically within the open roof after bony cap removal. Admittedly, this was an extreme case with a very large dorsal reduction (11 mm). Our explanation of the difference between anatomical and clinical findings is "patient selection," ie, all clinical patients having a reduction rhinoplasty have a "hump," which implies a significant cartilaginous vault component. An additional explanation may be the ossification of cartilages with aging, which means that there is a shorter length of the cartilaginous vault during cadaver dissection on older cases.

Another significant advantage of removing the bony cap with PEI is that the fibrous junction between the ULC anterior perichondrium and the bone's posterior periosteum is kept intact. Thus there is no gap between the bones and the ULC when spreader flaps are performed, and consequently no step off in the keystone area after having reconstructed the dorsum with spreader flaps. Traditionally, dislocating the cephalic part of the ULC from the bones in the central area of the dorsum was a source of instability and frequently a bony-cartilaginous gap, especially when the ULCs are dissected in a subperichondrial plane. The spreader flaps can now extend the full length of the open roof and not stop at the keystone junction. Rather than fixing just the middle third of the dorsum, one can now do a full-length reconstruction of the dorsum.

## Osteotomies

The role of osteotomies in rhinoplasty surgery, both their objectives and types, has been recently reviewed.<sup>24</sup> Currently, the most popular technique would appear to be a medial oblique osteotomy, then a lateral osteotomy, then a transverse greenstick fracture. In contrast, our sequence would be a lateral osteotomy, then a transverse osteotomy, and finally an optional medial oblique osteotomy.

A very low lateral osteotomy can be performed under direct vision at the nasofacial groove with the angulated saw. The saw can be oriented to affect the amount of mobilization. The transverse osteotomy begins at the cephalic end of the lateral osteotomy and extends toward the dorsum, with the orientation depending on the degree of bony movement desired. Finally, the medial oblique osteotomy is performed from the cephalic extent of the bony hump removal in an oblique direction at the desired dorsal aesthetic line to the anterior termination of the transverse osteotomy. Previously, our indication for the medial oblique osteotomy was to control the dorsal line, and it was performed before the lateral osteotomy. Now it is performed to narrow the upper part of the bony vault, and the bony dorsal aesthetic lines are further modified by sculpting the bones. These movements

are much more precise and performed with visual inspection to assure that the bone moves in a specific direction to a specific extent. Even crisscross osteotomies can be performed to treat a significant bony convexity when the bones are thin. This osteotomy allows control of the bone curvature in a horizontal and vertical axis, contrary to the double-level osteotomy, which treats only the vertical convexity. Overall, the surgeon has much more control over the bony vault.

## Summary of Advantages and Disadvantages

As currently employed in rhinoplasty surgery, PEI has distinct advantages and disadvantages compared with hand-held and power-assisted instruments. PEI has 12 distinct advantages. First, there is minimal if any damage to the surrounding soft tissues and no significant risk of osseonecrosis compared with power-assisted instruments.<sup>14</sup> Second, extensive exposure allows the surgeon to more accurately analyze and surgically correct deformities of the osseocartilaginous vault. Indication, execution, and evaluation of osteotomies are no longer performed blindly, which allows far greater precision. Third, bony cap removal can be performed atraumatically, which minimizes damage to the underlying cartilaginous vault and maximizes its use as spreader flaps for reconstruction of the dorsum high into the bony vault. Fourth, PEI is utilized to remove the lateral edges of the bony vault with optional extension onto the lateral side wall. This extension has two powerful effects: 1) it allows the cephalic dorsal lines after hump reduction to be determined by cartilage rather than by the bony lateral wall; and 2) it allows shaping of the cephalic cartilaginous vault with sutures, thereby reducing the need for medial oblique osteotomies to modify and narrow the dorsal bony vault. Fifth, lateral bony wall asymmetry can be directly addressed by URS rather than merely by breaking the bone. Sixth, all types of osteotomies can be performed more precisely without risk of radiating fracture lines, which occurs with osteotomes and chisels. Seventh, osteotomies and rasping can be performed on brittle or thin bones as well as on mobilized lateral bony walls without the risk of disruption. Eighth, complete osteotomies can be performed with stability, because the underlying periosteum and mucosa are not damaged, and avoiding this damage is very difficult with conventional techniques. Ninth, there is no assistant required to assist the surgeon in executing osteotomies, thus eliminating both force and assistant variations from mallet strikes. Tenth, PEI can be utilized on the septum to reduce bony spurs and deviations, thus preserving more of the bony septum. Eleventh, PEI can be utilized safely on the turbinates, pyriform aperture, anterior nasal spine, and premaxilla. Finally, the extended dissection allows the surgeon to easily stabilize unstable bones by drilling holes in the bones and suturing them to the central dorsum.

The disadvantages of PEI include the cost, increased operating time, and a learning curve. In contrast to power-assisted instruments that are routinely available in most surgical centers, PEI has to be purchased. The initial cost of the system is approximately \$10,000 and the inserts are \$100 each, although reuse up to 10 times is possible. Initially, the increase in operating time is probably 30 minutes because of the need for elevating the soft tissue envelope and having controlled visualization of the osteotomies. With experience, the surgeon can execute these steps quicker, and the precision of the surgical steps performed with the PEI leads to fewer adjustments later in the operative sequence. As with the adoption of any new technique, there are modifications in the operative technique and a learning curve for the instrumentation. Fortunately, the inserts are similar to standard power-assisted instruments with rasps, burrs, and saw blades. Rather than using reciprocating heads, the inserts are pressed against the bone, leading to vaporization and then aspiration of the bone. Surprisingly, tactile feedback is similar to that of conventional instruments. One example is the harvesting of rib grafts, in which the surgeon can feel a distinct difference in resistance between the central rib and the thicker outer rib surface. As with the introduction of the endforehead technique, the surgeon has the option of converting to more familiar conventional instruments during the procedure without compromising the final result.

Potential limitations of this paper include the limited follow-up, because only 128 out of 185 patients had more than 12 months of follow-up. Also, the technique evolved over time and therefore was not completely consistent. Finally, the instrumentation also changed and evolved over time.

## CONCLUSIONS

Based on our experience, the adoption of PEI is easily justified, because it offers more precise analysis and surgical execution with superior results in altering the osseocartilaginous vault. With extensive exposure, one can make an accurate diagnosis of bony deformity and safely contour the nasal bones to achieve narrowing and symmetry of the bony dorsum. Stable osteotomies can be performed under direct vision with precise mobilization and control. Therefore, the upper third of the rhinoplasty operation is no longer shrouded in mystery.

## Supplementary Material

This article contains supplementary material located online at [www.aestheticsurgeryjournal.com](http://www.aestheticsurgeryjournal.com).

## Disclosures

Dr Daniel receives royalties from Springer Publishing, Dr Kosins is a consultant for ZO Skin Health, Inc., and Dr Gerbault has nothing to disclose.

## Funding

The authors received no financial support for the research, authorship, and publication of this article.

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