Piezoelectric Surgery for Dorsal Spine

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■ BACKGROUND: **Laminoplasty and laminectomy are 2 common surgical procedures used in treating degenerative and neoplastic diseases of the spinal canal. Routinely used instruments, such as the Kerrison rongeur and high-speed drill, can result in potentially serious complications, such as dural injury and thermal and mechanical damage to neurovascular structures. We adopted piezoelectric bone surgery, which permits a selective cut of mineralized tissues, to perform posterior procedures on the thoracic spine, where the relationship between bone and the spinal cord is critical. The aim of this article was to evaluate the use of piezoelectric surgery for performing dorsal spine laminectomy and laminoplasty.**

■ METHODS: **The Mectron piezosurgery device was developed for cutting bone with microvibrations that are created by the piezoelectric effect. This instrument allows a safe and precise bone cut, and it is characterized by no heat generation, thus avoiding thermal injury to bone and soft tissues. We used this device to perform 8 laminoplasties for tumors of the dorsal spine and 2 laminectomies for thoracic spinal stenosis in 10 patients.**

■ RESULTS: **There were no procedure-related intraoperative complications, such as dural injury or damage to neural structures.**

■ CONCLUSIONS: **The piezoelectric device showed excellent results in terms of safety and precise bone cutting properties when performing posterior surgical procedures in the dorsal spine, where thermal injury produced by the conventionally used drill may damage the spinal cord closer to bony elements.**

INTRODUCTION

Laminoplasty and laminectomy are 2 common surgical procedures used in treating degenerative and neoplastic diseases of the spinal canal. The instruments routinely used for osteotomy are the high-speed drill and the Kerrison rongeur. Some risks and potentially serious complications are associated with these instruments, such as dural injuries in patients with a narrow spinal canal and thermal and mechanical damage to neurovascular structures.[1] Piezoelectric bone surgery is a recent innovative technique that permits a selective cut of mineralized tissue while sparing soft tissues.[2,3] This technology has been developed in the last 20 years and has been extensively used in dentistry and maxillofacial surgery. Application has recently spread to many other fields, such as ear, nose, and throat surgery; orthopedic surgery; and cranial and spine surgery.[3,4] In this article, we present our technique to perform posterior spinal procedures with piezoelectric bone surgery. We note the advantages of this technique in the thoracic spine, where the canal is relatively narrow and the relationship between bone and the spinal cord is critical.

MECTRON PIEZOSURGERY DEVICE

The Mectron piezosurgery device (Mectron Medical Technology, Carasco, Italy) cuts bone with microvibrations that are created by the piezoelectric effect with trauma to the surrounding soft tissue minimized. The principle of piezosurgery is ultrasound transduction obtained by piezoelectric ceramic contraction and expansion. The produced vibrations are amplified and transferred onto the device's insert. When applied with slight pressure to the bony tissue, the insert has a mechanical cutting effect exclusively on mineralized tissue, without damaging soft tissue even in case of accidental contact.[4] The system consists of a platform with a piezoelectric device that generates ultrasonic vibrations with variable frequencies of 24–36 kHz and a series of inserts of different forms with a range of linear vibration of 60–200 μm. The insert that we used for spinal procedures, MT1-10, is a small (10 mm long), thin (0.55 mm wide) 5-pointed bone saw,

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- Laminectomy
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- Piezoelectric surgery
- Thoracic spinal stenosis

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Figure 1. Piezosurgery hand piece with the piezoelectric scalpel (MT1-10 insert). (Courtesy of Mectron Medical Technology, Carasco, Italy.)

with a sharp surface, made of medical iron (**Figure 1**). Moreover, the piezosurgical device is coupled with a peristaltic pump for irrigation using a jet of cold physiologic solution (0.9% saline solution) that discharges from the inserts with 5 different flow rates. Irrigation removes debris from the cutting area, thus providing ideal visualization of the depth of the osteotomy, and ensures the precision of the cut.[3,4]

OPERATIVE TECHNIQUE

The laminae are exposed out to the facet joints. A narrow groove with the shape of the bone opening is performed on the surface of the laminae, "drawing" the shape of a laminotomy. Afterward, the osteotomy is deepened to the dura of the spinal roots, which is not affected by the vibrations of the cutting device. During the procedure, the bone is cut by carefully moving the insert back and forth with little pressure.

When the inner cortex of the bone is actually passed and a sense of loss of resistance is felt, the blade of the instrument is moved into a second position to complete the entire perimeter of the bone window. Thereafter the complex of spinous processes, laminae, and interspinous ligaments is lifted away as a whole with care to avoid angling it in the spinal cord. At the end of a laminoplasty procedure, the laminae are returned as close as possible to their original position and fixed with titanium miniplates and self-taping screws or silk sutures (**Figure 2**). Conversely, in laminectomy procedures, the bone is not repositioned to allow for adequate spinal decompression.

PATIENTS

We have used the Mectron piezosurgery device in 10 patients; we performed 8 laminotomies with laminoplasty for tumors and 2 laminectomies for thoracic spinal stenosis in the dorsal spine. We have retrospectively reviewed all the surgical records associated with these operations. There were no procedure-related intraoperative complications, such as major bleeding or neural damage owing to lesion of the spinal cord or spinal nerve roots, in any of the surgeries. In addition, there was no evidence of accidental dural tear or postoperative cerebrospinal fluid fistula. The following cases demonstrate our ultrasound-based surgical technique. Informed consent was obtained from patients.

Case 1

Dorsal laminoplasty was performed for spinal meningioma (anterior) (**Figure 3**). A 53-year-old woman presented with touch hypoesthesia in the dorsal surface of her third and fourth right toes in 2012. The level of sensory deficit was stable until March 2017, when the touch hypoesthesia ascended to the groin level. Whole-spine magnetic resonance imaging showed an intradural extramedullary mass lesion occupying the anterior part of the spinal canal and displacing posteriorly the spine, which appeared extremely thinned in axial sections. To avoid producing thermal or mechanical damage to the spine, which was strongly compressed against the dura, a laminoplasty extending from C7 to D1 was performed with the piezoelectric device. The tumor, which pathologic examination revealed to be a meningioma, was completely removed avoiding neural damage. At discharge, the

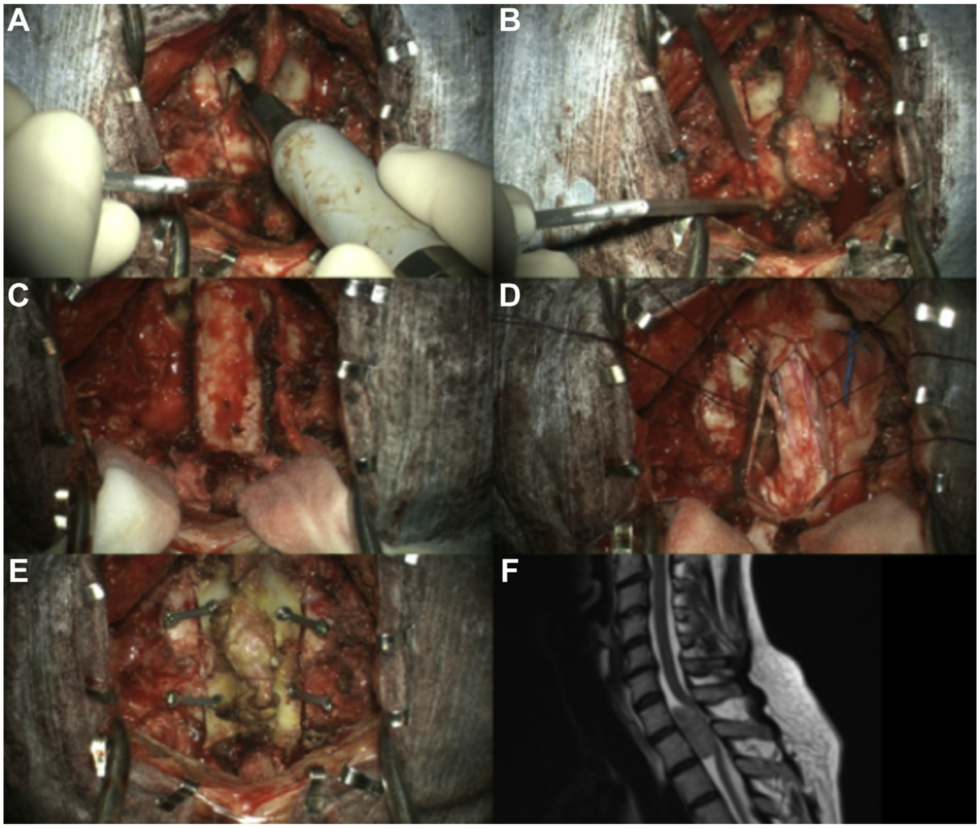

Figure 2. A laminotomy with the piezoelectric device is performed under magnified vision to remove a dorsal meningioma. A sulcus with the shape of the bone opening is performed on the surface of the laminae, "drawing" the shape of a laminotomy (**A**). Thereafter the complex of spinous processes, laminae, and interspinous ligaments are lifted away as a whole (**B** and **C**). After complete tumor removal (**D**), the laminae are approximated to their original position and fixed with titanium miniplates (**E**). Pre-operative MRI (**F**) is showed.

patient did not exhibit neurologic worsening; resolution of touch hypoesthesia was observed.

Case 2

Dorsal laminectomy was performed for thoracic spinal stenosis (**Figure 4**). A 76-year-old man was referred to our department with progressive development of burning dysesthesias in the lower limbs and paraparesis so severe that he was unable to walk without assistance. Neurologic examination detected sensory ataxia and a marked muscular hypotrophy within the lower limbs. Whole-spine magnetic resonance imaging and computed tomography highlighted a thoracic spinal stenosis owing to hypertrophy of articular facets and of ligamentum flavum and signs of myelopathy (intramedullary hyperintense spot on T2-weighted sequences) at T10-11. Moreover, there was cranial migration of a calcified herniated discal fragment at the level of T10. The prevailing posterior compression was concordant with sensory ataxia as the main feature of the neurologic picture. Therefore, we decided to perform a T10-11 posterior laminectomy with the piezoelectric device. Postoperatively, the patient's motor strength and coordination of lower limbs improved. At 2 months after surgery, he has recovered the ability to walk unaided, and pain and sensory disturbances have resolved.

DISCUSSION

The risk of injuring soft tissue structures such as the dura mater, epidural venous plexus, nerve roots, and the spinal cord is well known when performing a laminoplasty or laminectomy and may result in unexpected neurologic deficits and cerebrospinal fluid fistula. A literature review reported that the overall risk of complications across spinal surgeries is 16.4% with the risk of producing dural tears in 1.6%–9% of the procedures.[5] This problem is particularly enhanced when the surgical field is narrow and when performing revision surgery. It is mostly related to the drilling of bone and to osteotomies performed with high-speed drills, rotating burrs, and threadwire saws in close vicinity to meningeal sheaths, neural tissues, and blood vessels.[6] With regard to dorsal spine surgery, the complications of bone drilling may be even more serious owing to the close relationship between the spinal cord and bony structures. As a consequence, we decided to use the piezosurgery device for dorsal spine surgery.

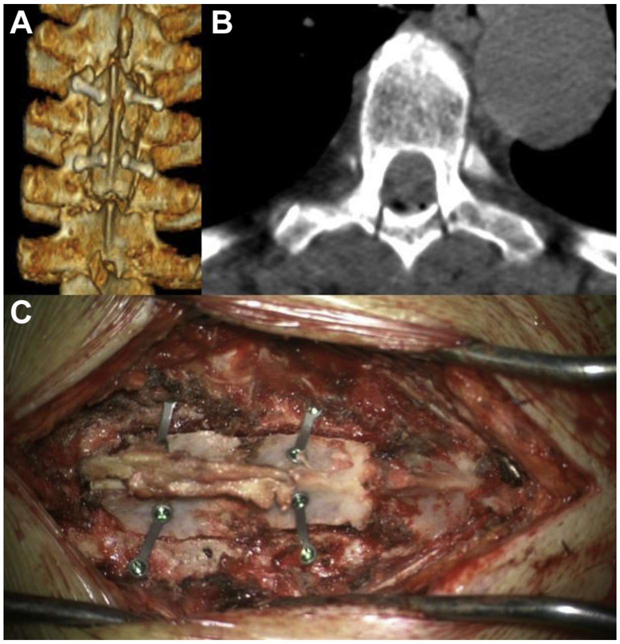

Figure 3. A dorsal meningioma at the level of T5-6 is removed through laminotomy. At the end of the procedure, the laminae are put back into their original position and fixed with titanium miniplates. Three-dimensional reconstruction (**A**), post-operative computed tomography (**B**), and intraoperative result (**C**) are showed.

The use of the piezoelectric device for spinal surgery presents several advantages. The micrometric vibrations of the insert and the absence of macrovibrations permit a safe and precise cut and allow for the maintenance of a blood-free site because of the physical phenomenon of cavitation.[3] The cavitation effect creates bubbles from the physiologic solution, the subsequent implosion of which generates a shock wave that causes a microcoagulation effect.[7] The width of the cut is very small and precise (approximately 2-mm defect, as measured on postoperative computed tomography images) resulting in good congruence when replacing the laminae. When using traditional motorized instruments for bone surgery, the mechanism of action is based on the conversion of electric or pneumatic energy into mechanical energy, with subsequent heat production. Piezoelectric surgery is characterized by no heat generation, thus eliminating thermal injury, thermal bone necrosis, and soft tissue damage and providing faster postoperative regeneration of the bone and greater safety. Moreover, the osteotomy is very accurate because the strength required by the surgeon to effect a cut is far lower compared with that required with a drill, a craniotome, or rongeurs, thus allowing for better control of the instrument.[3] Finally, the reimplantation of the laminae is easier and faster because there is less bone erosion.

Experimental studies on animal models have shown the safety, the cutting precision, and the protection of anatomic structures as characteristics of the piezoelectric device when applied in spine surgery procedures.[8] Furthermore, other authors have reported their experience with ultrasonic bone scalpels[1,6,9-14] in various spinal procedures in human subjects and have achieved favorable results in terms of safety and clinical efficacy. With regard to the use of the Mectron piezosurgery device in spinal surgery, it has been reported with success in cervical laminoplasty for the treatment of cervical spondylotic myelopathy,[12] lumbar laminotomy for tethered cord in children,[14] and removal of retrovertebral body osteophytes in anterior cervical discectomy.[15] To the best of our

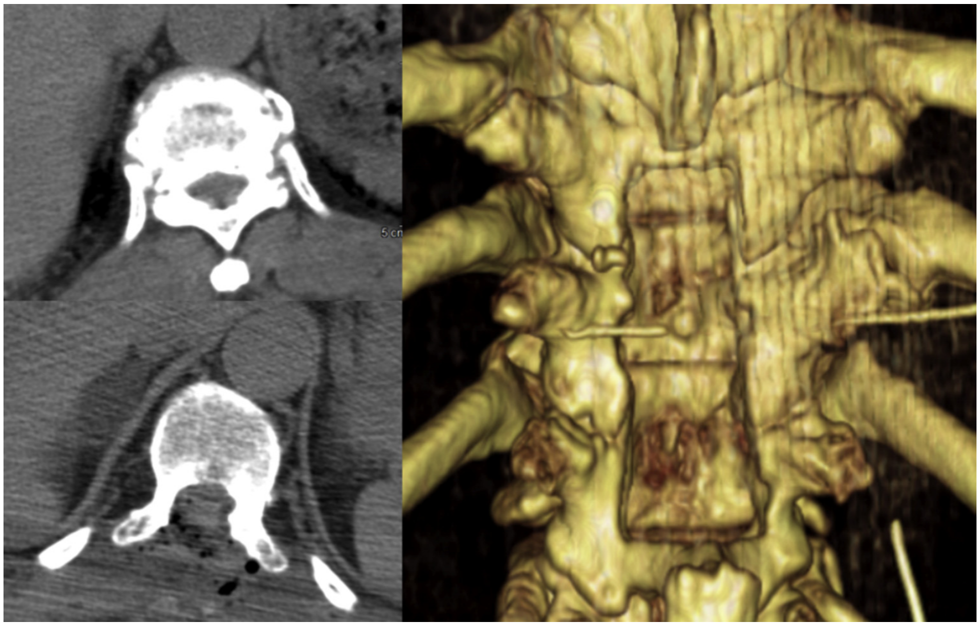

Figure 4. A laminectomy is performed to relieve thoracic spinal stenosis. Preoperative and postoperative computed tomography images with three-dimensional reconstruction are shown.

knowledge, this is the first description of surgical procedures on the dorsal spine with this instrument.

The main disadvantage of available ultrasonic bone scalpels when used for performing spinal surgery has been reported to be the generation of heat from the instrument, which is comparable to the heat produced by the high-speed drill[9] and may cause heat-related dural defects and thermal injury to soft tissue structures and to the underlying spinal cord[16-18]; previous studies reported dural tears with use of bone ultrasonic scalpels in 1.6% to 18% of patients.[19] By contrast, heat production by the Mectron piezosurgery device is greatly reduced, as the optimized modulation of the vibrations' amplitude and the high-flow irrigation system avoid overheating of the bone during osteotomy, while maintaining optimal cutting capacity.[20-22] This results in better soft tissue—sparing properties, less risk of producing a dural injury, and greater safety for patients. Histologic examinations performed on the cut surfaces of bony fragments obtained during piezosurgery with the Mectron device showed no signs of the coagulative necrosis typically seen when using ultrasonic devices and classic drills, confirming that this instrument is able to cut bone without producing necrosis.[22] Moreover, bone healing appeared to be improved.[7] Another advantage of this instrument for spine surgery is the angled and lightweight configuration of the handpiece, which allows the surgeon to comfortably and precisely handle the device under microscopic magnification, without no obstacles to the surgeon's view, such as straight and bulky handpieces.

Although this case series demonstrates the utility of this instrument, it is limited to a small number of patients, and no control group was included. A larger study is needed to compare the rate of complications between the Mectron piezosurgery device, other ultrasonic scalpels, and conventional techniques for osteotomy. Finally, the cost of this device is significant, and thus its use might be limited to larger centers, perhaps shared among different departments (maxillofacial surgery; orthopedic surgery; ear, nose, and throat surgery; neurosurgery).

CONCLUSIONS

The piezoelectric device showed excellent results in terms of safety and precise bone cutting properties when performing posterior spinal surgical procedures such as laminectomy and laminotomy. It proved of particular value for procedures in the dorsal spine, where the canal is narrower and thermal injury produced by the conventionally used drill may damage the spinal cord closer to bony elements.

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