CLINICAL CASE

The Piezoelectric Osteotomy in Orthopedics: Clinical and Histological Evaluations (Pilot Study in Animals)

L'Osteotomia Piezoelettrica in Ortopedia: valutazioni cliniche e istologiche (Studio pilota su animali)

Ostéotomie piézo-électrique in orthopédie: évaluations cliniques et histologiques

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KEY WORDS

Piezosurgery • Ulnar osteotomy • Head and neck osteotomy • Laminectomy • Clinical histological evaluations • Orthopedic surgery • Dog

PAROLE CHIAVE

Piezosurgery • Osteotomia ulnare • Osteotomia della testa e del collo • Laminectomia • Valutazioni cliniche e istologiche • Chirurgia ortopedica • Cane

MOTS-CLÉS

Piézochirugie • Ostéotomie ulnaire • Ostéotomie de la tête et du cou • Laminectomie • Evaluations histologique cliniques • Chirurgie orthopédique • Chien

Summary

In Orthopedic surgery, the correct execution of each operation requires a meticulous knowledge of anatomy, a well planned surgical procedure and the correct use of specific instruments that allow the necessary level of precision required.

The purpose of this paper is to evaluate the results of a new piezoelectric instrument in orthopedic surgery in cases where there are anatomic difficulties due to the particular fineness of the structure, a lack of intra-operative visibility or due to the adjacency to the spinal cord or vascular nervous tract, where the use of other osteotomy instruments prove to be difficult to control and often risky.

Three orthopedic surgeries were performed on dogs affected by different pathologies using a new surgical device (Mectron Piezosurgery®).

Intra-operative clinical evaluations were undertaken to determine the characteristics of the micro-metric and selective piezoelectric cut, which is effective on bone tissue but inactive on soft tissues. The operating site was blood free with greater intra-operatory visibility than that offered by traditional instruments.

The histological examinations carried out on the cut surfaces of all the osteomitized segments show the presence of live osteocytes. This proves the reduced trauma of the piezoelectric cut.

All the surgeries were followed by an excellent post-operative healing period

Riassunto

In Ortopedia la corretta esecuzione di ogni intervento chirurgico richiede una meticolosa conoscenza di anatomia, l'impiego di una procedura chirurgica ben pianificata e il corretto uso di strumenti specifici che consentono di raggiungere il livello di precisione necessario.

Lo scopo di questo articolo è di valutare i risultati di un nuovo strumento piezoelettrico in Chirurgia Ortopedica nei casi in cui ci siano difficoltà anatomiche dovute alla particolare delicatezza della struttura: ad una mancanza di visibilità intra-operatoria, alla vicinanza del midollo spinale o del fascio vascolo nervoso e dove l'uso degli strumenti tradizionali risulta di difficile controllo nell'eseguire l'osteotomia e pertanto risulta difficile e spesso rischioso per le possibili complicanze post-chirurgiche.

Sono state eseguite 3 chirurgie ortopediche su cani affetti da differenti patologie usando un nuovo apparecchio chirurgico (Mectron Piezosurgery®).

Le valutazioni cliniche intra-operatorie sono state eseguite per determinare che il taglio piezoelettrico, il quale è selettivo e micrometrico, è efficace sul tessuto osseo, ma inattivo sui tessuti molli, inoltre il campo chirurgico esangue ha offerto una maggiore visibilità intra-operatoria da quella che si riscontra con l'uso degli strumenti tradizionali. Gli esami istologici sulla superficie del taglio di tutti i segmenti osteotomizzati hanno evidenziato la presenza di osteociti vitali (nucleati) a dimostrazione della ridotta traumaticità del

Résumé

Dans la chirurgie orthopédique, l'exécution exacte de chaque opération exige une connaissance méticuleuse d'anatomie, une procédure chirurgicale planifiée, et l'usage exact d'instruments spécifiques qui permettent le niveau nécessaire de précision exigé.

Le but de cet article sera d'évaluer les résultats d'un nouvel instrument piézo-électrique dans la chirurgie orthopédique, dans des cas où il y ait des difficultés anatomiques à cause de la finesse particulière de la structure, d'une manque de visibilité ou de la proximité à la corde vertébrale ou aux tissus vasculaires nerveux, où l'usage d'autres instruments de ostéotomie peut se révéler difficile à régler et souvent risqué.

Trois chirurgies orthopédiques ont été exécutées sur des chiens affectés par des pathologies différentes en utilisant un nouvel appareil chirurgical (Mectron Piezosurgery®).

Les évalutations cliniques opératives ont été entreprises pour déterminer les caractéristiques de la coupure piézo-électrique micro métrique et sélective, qui est efficace sur le tissu d'os mais inactive sur des tissus doux.

Le site opére était sans sang avec une visibilité intra-opératoire plus grande par rapport aux instruments traditionnels. Les examens histologiques exécutés sur les surfaces de coupure de tous les segments d'ostéotomie montre la présence d'ostéocytes en vie. Cela prouve le réduit traumatisme de la coupure piézo-électrique. Toutes les chirurgies ont été suivies par une excellente période post-opératoire avec une ab

with an absence of complications and a fast recovery of functions.

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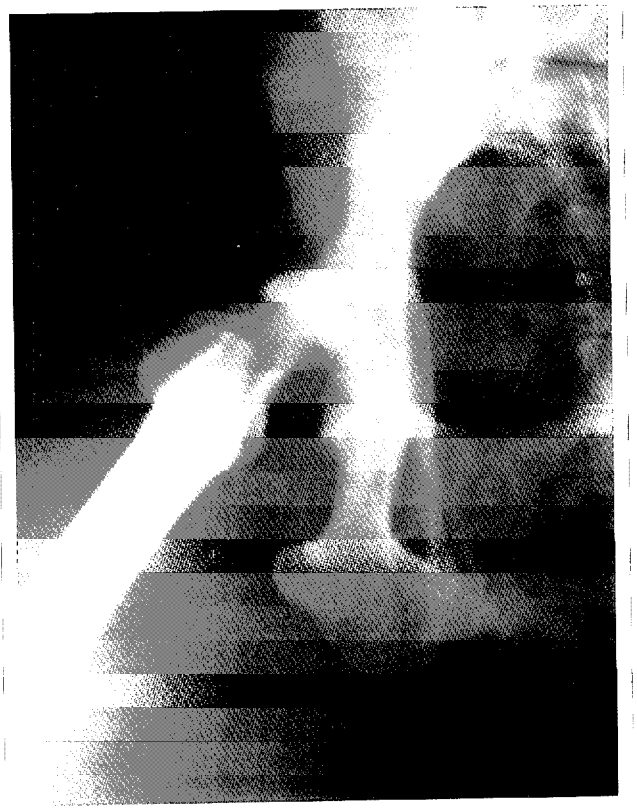
Introduction

Over the last ten years orthopedic bone surgery has begun an unending process researching important technological innovations that have improved clinical results especially in the fields of arthroscopic, prosthetic and vertebral surgery.
Using techniques of great precision improves the clinical results and produces a reduction in morbidity for the patient, especially in osteoarticular regions.
The osteotomies for the treatment of various orthopedic pathologies (of alignment, of centering, of removal etc.) have been performed, over the years, with instruments of increasing precision and of smaller dimensions. The characterizations of the cut have been developed following a gradual evolution of the existing manual instruments (scalpels, gouges, Gigli saws etc.) by motorizing them. Thus, various motorized instruments have been developed (using electric or pneumatic energy) that are able to perform a mechanical cut, taking advantage of the rotation of burs or the oscillation of saws. These instruments however, damage bone tissue due to their mechanical and thermal effects.
Therefore, the Mectron Piezoelectric[30] device was designed to overcome the limits of traditional instruments of bone surgery.
The choice of instrument is correlated to different factors, including the site of the operation, the morphology and densito-mectric characteristics of the skeletal segments, the type of operation and the level of precision needed.
The purpose of this paper is to present a pilot study that evaluates the fundamental characteristics of piezoelectric instruments in orthopedic surgery.

Fig. 1. Cranial-dorsal luxation of the right femur and fracture of the acetebular rime.



Materials and method

Three dogs, with different orthopedic lesions were brought in by their owners to the surgical unit of the Veterinary Faculty and operated on using three different types of osteotomy. The osteotomies were performed on the dogs using a specifically engineered device for simplified bone surgery (Mectron Piezosurgery®).
The Mectron Piezosurgery® device consists of a platform with a very powerful piezoelectric hand-piece with a functional frequency of 25 to 29 KHz and the possibility

Fig. 2. The blood free piezoelectric osteotomy site.

Fig. 3. Osteotomy performed.

Fig. 4. Perfectly smooth surface of respecting the soft tissue the cut.

of a digital modulation of 30 HZ. The inserts move with linear vibrations between 60 and 210µm, providing the hand-piece with power exceeding 5 W and a high powered pump that emits a physiological solution.

Case one

Dalmatian dog, 7 years old, male, weighing 28 kg, was run over by a car three days before the observation.
It was evident that the animal was not putting weight on the right hind limb, which was slightly flexed at the knee and with an extra-rotated paw. During movement the dog did not use the right hind limb.
The examination of the right hemi-pelvis showed an increase in the space between the tuber ischii and the corresponding trochanter with a reduction of the distance between the trochanter and the top of the wing of the ileum. The posterior extension of both hind limbs showed a shortening of the right limb in comparison to the left and was causing pain, exacerbated during passive flexing, extension, adduction and abduction of the right hind limb. Moreover, noises were present due to the contact between the femoral head and the acetabular rime.
The clinical examination and x-ray of the region showed a cranial-dorsal luxation of the femur complicated by a hair-line fracture of the acetebular rime (Fig. 1). The diagnosis indicated the necessity of a femoral head and neck excision to allow the formation of a fibrous false joint [1].
The surgery was performed using a caudo-lateral approach to the hip joint. The ostectomy was performed using piezoelectric instruments. No operating risk or difficulty was noted (Fig. 2).
The osteotomized surfaces were linear, regular with normal appearance and color, without pigmentation (Figs. 3 and 4).
One month after the operation the animal began to lean on the right limb both in a resting position and while stepping or trotting, with a standard post-operative healing period and without any complications.

Case two

Mongrel dog, female, 9 months old, weighing 12 kg. The owner referred to a previous trauma in the right fore limb. The animal had a posture indicating a minor anterior curvature of the radius and an outward rotation of the paw with pain in the carpal region.
The x-ray examination of the foreleg in the fundamental orthogonal projection, showed a previous fracture of the styloid process of the ulna and a premature closure of the distal ulna physis and a valgus deformity of the paw (Fig. 5) [2].
To obtain a realignment of the radius and to avoid further damage to the carpus and elbow, an ostectomy was

Fig. 5. Fracture of the styloid process associated with deformity of the radius.

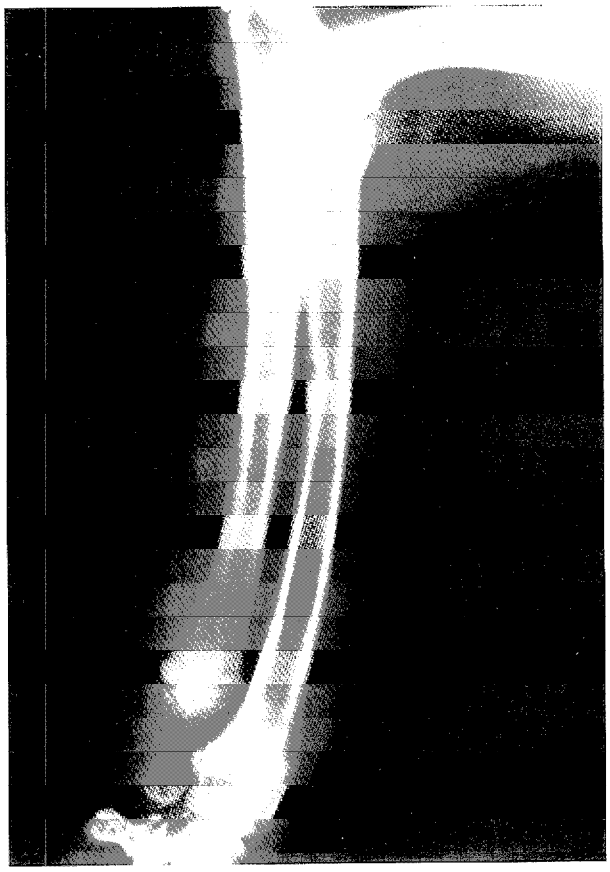


Fig. 6. Osteotomy performed using.

performed exploiting the residual growth capabilities of the radial bone [3]. The ostectomy was performed using piezoelectric surgical instruments and was done quickly and easily (Figs. 6 and 7).

The post-operative healing period followed the normal evolution of the osteotomy of the ulna and, one month after the operation, it was possible to observe a good functional recovery of the affected limb as well as a lengthening of the radius.

Case three

Bulldog, male, 7 years old, weighing 28 kg.

It was brought in for observation for paraparesis and incontinence. The animal presented paraparesis and atony of the posterior quarter without central neurological damage but with polypnea. It had stopped walking and was dragging itself around with difficulty by its posterior limbs. When it was still, it sat with its posterior limbs extended in front of it.

The neurological examination showed a muscular tone and trophism reduced more on the left than the right hind limb.

The examination of the postural reactions showed a reduction of the reflex of the postural reflex extensor.

Fig. 7. Post-operative x-ray of ulnar Mectron Piezurgery® ostectomy.

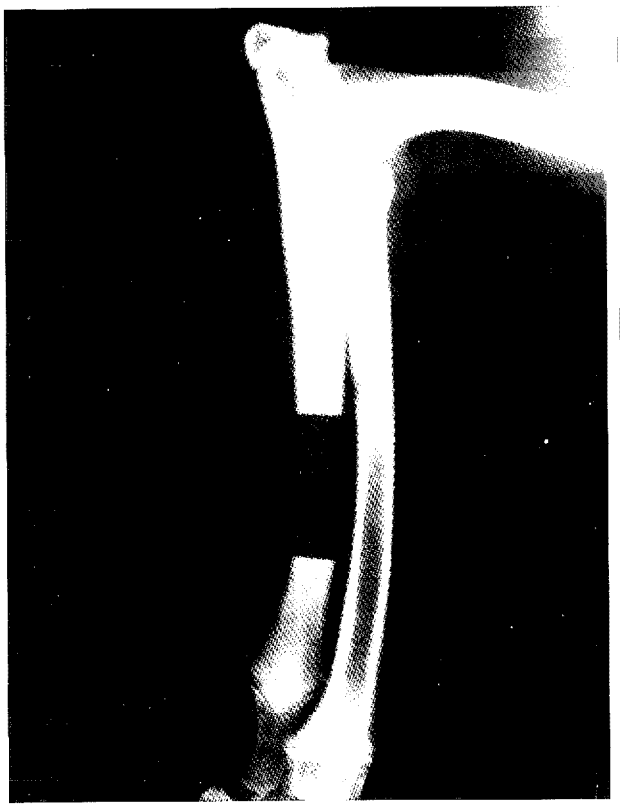


Fig. 8. The X-ray shows lumbosacral compression.

Fig. 9. Intra-operative picture of the laminectomy performed using piezoelectric surgery.

The examination of the spinal reflex showed an increase in the patella reflex in the bilateral form, the presence of deep sensitivity and an absence of the extensor reflex. Still crossed in bilateral form, a reduction in the panniculus, perineal and anal reflex.
The direct radiographic examination showed lumbrosceral syndesmophytis with a reduction of the lumbosocral angle [4-6]. The radiographic exam (myelography and epidurography) showed a lumbosocral compression with Cauda Equina Syndrome [7] (Fig. 8).
A lumbosceral decompression was performed using piezoelectric surgery (Fig. 9) and one week after the operation the animal had recovered the spinal patella reflex and gastrocnemius reflex in both limbs and the recovery of the panniculus reflex.

Results

The parameters used in this study to evaluate the results of the piezoelectric osteotomy technique were the following:
- Clinical evaluations;
- Radiographic evaluations;
- Histological evaluations.

Clinical evaluations

Intra-operative

Characteristics of the piezoelectric osteotomy:
- Simplicity and safety while cutting;
- Precision of the micro-metric cut;
- No bleeding in the operating site with excellent visibility of the anatomical structures;
- The time needed to perform the piezoelectric osteotomy was slightly higher than performing the procedure using rotating mechanical and oscillating instruments.

Post-operative
- Excellent post-operative healing period;
- Absence of complications;
- Fast recovery of functions.

Radiographic evaluations

The presence of the lesion before the operation and the perfect linearity and precision of the osteotomy after the surgery can be demonstrated by the radiographs.

Histological results

Macroscopic results

Perfect integrity of the osteotomized surfaces with a cut that was clean, regular and without imperfections or pigmentation.

Microscopic results

The bone surface that was cut using the piezoelectric device showed no sign of lesions to the mineralized tissues and presented live osteocytes with no sign of cellular suffering [8].

Discussion

The piezoelectric osteotomy differentiates itself from other techniques by its micro-metric and selective cut and by the blood free operating site [9].
Micro-metric bone cut, because the insert works on the bone using mechanical vibrations of between 60 ~ 100 microns, therefore it is a microscopic cut that is made with a frequency of 29,000 times a second producing a cutting speed slightly inferior to that of bone saws or bone burs, but not significant in the economy of the surgical operation. The precision of the cut can in fact, be the determining element in the therapeutic

success of the operation especially in difficult anatomic situations [10].

Selective bone cut, because the piezoelectric device that generates these vibrations uses low frequency ultrasonic waves (22-30 Hz) and therefore performs a selective cut where the insert works only on mineralized tissue whilst being ineffective on soft tissue (to cut soft tissue higher frequency waves need to be utilized).

These characteristics, highlighted in this work, confirm the results obtained in surgery to the maxillary sinus for implant purposes, modifying the success rate (non-perforation of the sinus membrane) from 70% to 95% [11].

A blood free operating site: the inter-operative irrigation is done using a jet of physiological solution that is subject to ultrasonic vibrations, breaking up the liquid into very small particles that, apart from excellently cooling down the bone surface, also make the operating site blood free, offering maximum visibility.

This pilot study was conducted on dogs affected by diverse pathologies in various anatomical zones, with different morphologies. This allowed us to test the effectiveness of the technique and the device, the precision of the cut and above all, through the histological results, to note the absence of negative phenomena.

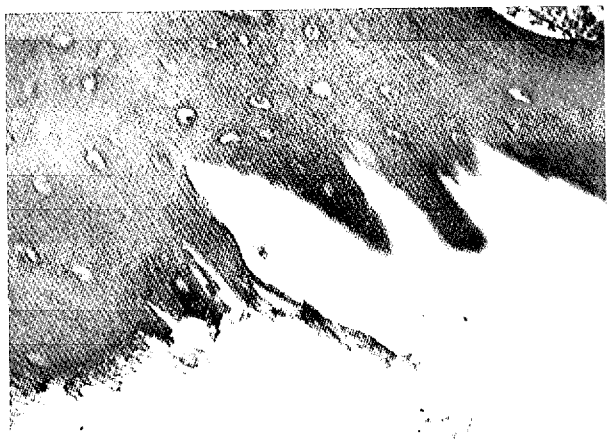
The osteotomy performed for the head and neck excision and for the ulnar osteotomy were simple to perform. The precision and safety of the piezoelectric cut were particularly useful in the lumbosacral laminectomy to allow the decompression of cauda equina, without risk of mechanical soft tissue damage.

The osteotomy was particularly simple to perform on fine bones. The post-operative return of functions to the animal, without neurological damage, confirmed the instruments non-aggressiveness towards soft tissues that were, for experimental purposes, voluntarily brought into contact with the hand piece for several moments (as can occur as an operating error) without any damage.

The distinguishing data of this first applied study using piezoelectric technology in bone surgery is represented by the histomorphologic results obtained from the osteotomized surfaces. This data confirmed the macroscopic data obtained from the osteotomized sites, that is the complete cleanness of the bone surface, without any necrosis, pigmentation, evident phenomena often present in areas osteotomized by other motorized instruments, or areas of irregularity on the bone evident in the manual osteotomy [12,13].

The histological section shows the absolute absence of necrosis with a complete vitality of the osteocytes of normal dimensions and morphology with no evidence of cellular suffering (Fig 10).

Fig. 10. Histological examination of the cut surface of the medulla ossium (magnified X 40) showing present osteocytes with non-coagulated nor damaged nucleus.



Conclusion

The preliminary clinical and histomorphological results of this study confirm the effectiveness of the piezoelectric osteotomy in orthopedic surgery.

The operating site was notable for its unique visibility. This phenomenon is due to the jet of the irrigating physiological solution subject to ultrasonic vibrations. The characteristics of the precision of the micro-metric and selective cut are demonstrated advantageously in the different anatomic situations treated.

The piezoelectric cut is in fact effective only on mineralized tissues, yet inactive on soft tissues, a fact that is particularly relevant to the vertebral osteotomy due to the maximum respect paid to neurological structures. This fact can be added to the results obtained on humans in surgery to the maxilla sinus. The reduced aggressiveness towards bone structures in respect to traditional cutting methods implicates a different surgical dexterity and a slight increase in operating time insignificant to the economy of the operation.

The piezoelectric cut is characterized by osteotomy surfaces that are perfectly linear, smooth and without pigmentation, irregularity or apparent signs of overheating. The microscopic exam shows the presence of live osteocytes with no signs of cellular damage.

This pilot study in orthopedic surgery proves the extreme precision and safety of the piezoelectric cut and therefore, even though it is a new method, confirms the validity and the effectiveness of its use in bone surgery. Although the number of cases treated is small, the results are very promising.

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