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Intercondylar eminence fracture treated by resorbable magnesium screws osteosynthesis: A case series

Gigante A.[a,*], Setaro N.[a,*], Rotini M.[a], Finzi S.S.[a], Marinelli M.[b]

[a] Department of Clinical and Molecular Science, School of Medicine, Università Politecnica delle Marche, Via Tronto, 10/A, 60126, Ancona, Italy
[b] Clinic of Adult and Paediatric Orthopaedic, Azienda Ospedaliero-Universitaria, Ospedali Riuniti di Ancona, Ancona, Italy

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A B S T R A C T

Introduction: Tibial spine avulsion fractures are mostly a paediatric injury which appropriate treatment is currently debated in literature. The choice between conservative and surgical treatment is based on the radiographic classification of Meyers-McKeever. The most diffused surgical techniques involve either internal fixation devices (screws) or bone tunnels fixation with resorbable sutures. Today, a third option is represented by resorbable magnesium screws which could combine the best features of the two classical systems. Objective of this study is to investigate the efficacy of these new devices in the surgical treatment of tibial spine avulsions.
Materials and methods: Since 2014 we have seen seven patients with tibial eminence fracture. Patients underwent clinical and radiological examination (MRI, CT scan) before surgery. Only 3 patients that presented with a grade III or IV lesion were treated surgically with internal fixation with magnesium resorbable screws. In post-operative follow-up, functional recovery was evaluated at 1, 2, 4, 6 and 12 months, clinically and by X-ray. Lysholm and IKDC scores were submitted at 1, 2, 6 and 12 months. MRI was repeated at 6 and 12 months.
Results: All three surgical patients showed progressive clinical and functional improvement during the follow-up period. The first case showed a quicker overall recovery rate, which might be due to the lower grade of the lesion. Radiographs and MRI evaluation showed regular healing of the injury. The devices appeared completely resorbed at the 6 months follow-up and replaced by newly formed bone at the 12 months follow-up.
Conclusions: The treatment of tibial spine avulsion fractures with arthroscopic reduction and internal fixation (ARIF) technique by magnesium resorbable screws seems to result in an excellent functional recovery without complications related to fixation devices, which were completely resorbed after 6 months and replaced by newly formed bone after 12 months. This new method could be considered as an alternative option to classic techniques by non resorbable fixation devices or bone tunnel fixation. Further studies are needed in order to evaluate the efficacy of these new devices in a wider group of patients.

Introduction

Tibial spine avulsion fractures are frequently found in children and adolescents aged between 8 and 14. The incidence of these lesions is quite low (3 cases out of 100.000 children) [1], representing from 2% to 5% of the injuries causing knee effusion in paediatric patients [2].

The traumatic mechanism of injury is mostly indirect, due to a combination of external rotation and abduction of the femur with respect to the tibia [3,4]. This is more common during sport activity (ski, soccer, tennis etc.). In adults, the same traumatic mechanism is more frequently cause of ACL injuries [3,5], making tibial spine avulsion fractures quite infrequent during adulthood, although their incidence appears now to be higher than what previously stated [6,7].

Clinical diagnosis of tibial spine avulsion is based on the study of the traumatic mechanism, functional impairment and presence of a quick onset of haemarthrosis. Pain located exclusively or primarily to the proximal tibial ephipysis, near the margins of the patellar tendon, holds an suspicion of the lesion [8–10].

* Corresponding authors.
E-mail addresses: a.gigante@univpm.it (A. Gigante), nicola.setaro@libero.it (N. Setaro).

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Given the low specificity of clinical signs X-ray represents the first diagnostic tool to investigate intercondylar eminence avulsions. CT-scan helps defining the anatomy of the fracture, being a foundamental investigation for pre-operative planning. MRI is the most reliable imaging method to investigate associated meniscal or ligament injuries [8]. Therapeutic approach varies based on the type of lesion involved, according to Meyers-Mckeever [11]. In type I, conservative treatment is indicated. The most common complications of this treatment are stiffness (19%) and residual instability (22%) [3].

On Meyers-Mckeever type II there is no consensus about the most appropriate treatment. Some authors recommended to first try a reduction in hyperextension followed by X-ray; if the reduction is radiologically unacceptable surgical treatment will be needed. Others suggested surgery as first approach [8,10,12–14,11].

In Meyers-Mckeever type III and IV surgery is strongly indicated with the purpose of repositioning the fragment and restoring appropriate ACL tensioning [15–20]. The surgical approach can either be arthrotomic or arthroscopic, while the fixation can be performed by using bone tunnels or internal fixation.

Recent studies underlined the advantages of the arthroscopic approach compared to the more invasive open technique, such as faster functional recovery, reduction in co-morbidity and shorter hospitalization [18,21].

McLennan in the 1980s and Van Loon and Lubowitz in the 1990s were the first to introduce arthroscopic reduction and internal fixation (ARIF) to treat tibial avulsion fractures [22,23,14].

Currently, ARIF is considered the gold standard in the treatment of tibial eminence avulsion fractures. On the other hand, literature is not yet clear on which method of fixation gives the best results [24]. Biomechanical studies showed controversial results, sometimes favouring metal implants or sutures, sometimes showing no significant differences between them [25–29].

Aim of the present study was to evaluate the clinical and imaging results of a case series of patients affected with intercondylar eminence avulsion fractures treated with ARIF by magnesium screws.

Materials and methods

Every patient who came to our attention with a diagnosis of tibial eminence avulsion fracture from 2014 was included in this study.

Inclusion criteria were: patients with traumatic tibial spine avulsion, absence of meniscal or ligament lesions, absence of growth disorders, absence of others bone or cartilage diseases.

Fractures were classified according to the radiographic criteria of Meyers-McKeever [11,30].

Seven patients meeting the criteria were selected: three males and four females, all aged between 11 and 20 years old (mean age 128). Five patients came to our attention after a knee distortion happened during physical activity, while the other two during daily activities. They all reported immediate onset of pain and functional impairment. All patients underwent an accurate clinical evaluation, X-ray examination in 2 projections and MRI to exclude associated lesions. CT-scan was reserved for pre-operative planning in patients with surgical indication.

After clinical and imaging evaluation, we decided to treat four patients conservatively since affected by a grade I or II lesion, while the other three received surgical indication since presenting a grade III or IV lesion (Fig1). This study focused on the patients treated surgically (Table 1).

Surgical technique

The chosen approach was ARIF (arthroscopic reduction and internal fixation).

The patient lied supine with the lower limb slightly elevated and the knee at 110° of flexion. We used standard arthroscopic portals (anterolateral and anteromedial) [23]. Before reduction, arthroscopic evaluation of menisci, ligament structures and articular cartilage was performed: all the structures appeared intact in all three cases. Temporary fragment reduction was obtained with a K-wire, successively used as a guide to introduce a magnesium Herbert screw. The diameter chosen for the screw was about 1/3 of the fragment's maximum diameter to avoid comminution [23,31–34]. In case n.1 we used one 3,2 × 28 mm screw, while in cases n.2 and n.3, given the size of the fragment, we used 2 screws (3,5 mm × 22 mm and 3,5 mm × 24 mm in n.2 and 3,5 mm × 30 mm and 3,5 mm × 32 mm in n.3). The screws were positioned with an angle of 40-50° with respect to the axis of the ACL to obtain the best stability [35]. Moreover, screws placement was performed sparing the growth plate where present: the tip should not be placed at less than 5 mm from the physis [35] and the axis should be closer to horizontally; in this scenario, fluoroscopy was fundamental to avoid transphyseal fixation. At the end of the procedure a final check for range of movement, knee stability and appropriate ACL tensioning was performed. Post-operative X-ray was performed to evaluate the correct positioning of the screws (Fig. 2).

In first post-operative day, an articulated brace blocked at 15° of flexion was positioned. From second post-operative day, patients started isometric exercises with Kinetec system and progressive flexion up to maximum 90°. Partial weight bearing

Table 1
Features of surgical patients.

	Sex	Age	Weight	Height	Sport	Side	Meyers-McKeever
Case n.1	Male	13	63	167	Soccer	Left	III
Case n.2	Female	13	44	152	Dancing	Left	IV
Case n.3	Female	20	64	167	Running	Right	IV

Fig. 1. Pre-operative X-ray assays: case n.1 (A), case n.2 (B) and case n.3 (C).

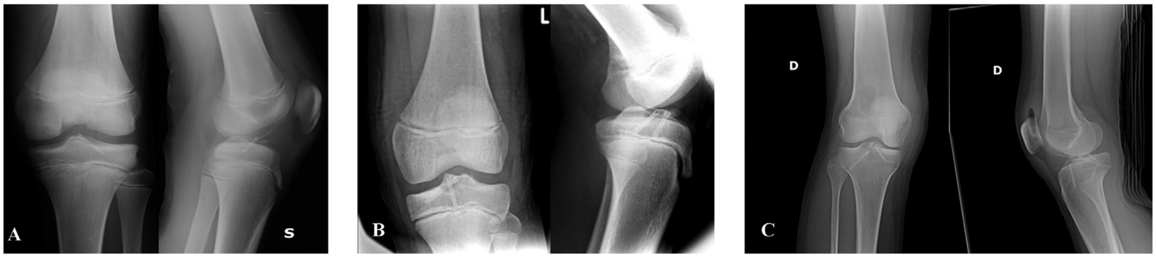

Fig. 2. Post-operative X-ray evaluation: case n.1 (A), case n.2 (B) and case n.3 (C).

started at 15 days post-operatively. Full weight bearing, to tolerance with crutches, was allowed at 30 days after surgery. On the same day patients started isotonic exercises for the quadriceps femoris (cyclette, squat, leg press, leg curl, leg extension, step, stretching) and aquatic rehabilitation.

Features of the screw

We used magnesium screws (*MAGNEZIX*®, Syntellix AG, Hannover, Germany), classified as a MgYREZr metallic alloy (according to DIN EN 1753) for implants, which has a high resistance to traction. Its Young's modulus is E = 41–45 GPa and the screws are countersunk so that there is no prominence on the articular surface. From a mechanical perspective, the screws have yield strength properties higher than 260 MPa, tensile strength properties higher than 290 MPa and elongation to failure properties higher than 8%. In time, this implant is subjected to degradation and absorption by corrosion, unlike polymers which degrade by hydrolysis. The implant is osteoconductive, it is completely and homogeneously replaced by newly formed bone. There are no reported toxic reactions, chemically it is composed by magnesium and zinc and does not induce stress shielding [36].

Results

Pain, function and stability of the knee were evaluated by Lysholm Knee Score and International Knee Documentation Committee (IKDC) score at 1, 2, 6 and 12 months after surgery.

X-ray assays were performed at 1, 2 and 4 months post-operative. MRI was performed at 6 and 12 months to evaluate the resorption of the screws.

In all surgical patients, clinical evaluation at 1-month post-operative showed: negative patellar ballottement, absence of swelling, absence of pain on palpation. In case n.1, active range of movement was limited at maximum degrees by pain; in cases n.2 and n.3 the limitation by pain was present at intermediate degrees.

X-ray follow-up at 1, 2 and 4 months showed no loosening of the fixation devices, maintained reduction of the fragment and progressive bone healing in all cases.

At 2 months, the range of motion of the operated knee was completely recovered and comparable to the contralateral side in case n.1, while in cases n.2 and n.3 there was a persistent functional limitation at maximum degrees of the range of motion.

At 4 months from surgery, all patients showed complete recovery, comparable to the contralateral side. All the patient resumed normal daily activities.

At 6 months the clinical picture was stable and the patients returned to physical activities, without issues or functional limitations. The IKDC and Lysholm scores at 1, 2, 6 and 12 months are reported in Table 2.

MRI at 6 months from surgery confirmed, in all cases, healing of the fracture site and showed the fixation devices completely resorbed (Fig. 3).

At 12 months the clinical picture was stable; in all three cases, MRI displayed complete healing of the fracture, resorption of fixation devices as well as their replacement by newly formed bone (Fig. 4).

Table 2
IKDC and Lysholm scores.

	Case n.1		Case n.2		Case n.3	
	IKDC	Lysholm	IKDC	Lysholm	IKDC	Lysholm
1 month	41.2	80	34.5	66	37.9	67
2 months	70.4	97	62.9	82	65.5	87
6 months	97.7	100	92.1	95	95.4	100
12 months	97.7	100	94.3	97	97.7	100

Discussion

In our knowledge, this is the first case series study in literature reporting the treatment of intercondylar eminence avulsions with ARIF technique and magnesium resorbable screws, therefore no direct comparison with other case series was possible at the time of writing.

Some authors compared the clinical results between absorbable sutures and non-absorbable materials. Coyle et al. and Leeberg et al. published two systematic reviews on tibial eminence fractures in pediatric population, in which better long-term results were obtained with arthroscopic surgery, compared to open surgery; no indication on the best type of fixation was specified [4,21]. Seon et al. found no significant differences between screw and suture fixation in terms of function and stability at a minimum of 2 years follow-up [24]. Sharma et al. found slightly superior clinical results for absorbable sutures in comparison to nonabsorbable materials; a statistically significant difference was found for adults but not for children in knee laxity after a mean of 44 months follow-up. Internal fixation allows for a more stable synthesis and early rehabilitation, reducing the risk of stiffness and range of movement limitation [37]. However, ARIF brought problems such as pain from fixation devices.

This situation might lead to a subsequent surgery for removal of fixation devices. Besides, during paediatric age surgery involves the risk to damage the epiphyseal plate, causing growth disorders of the tibial plate on the coronal and sagittal plane [38–41].

Bone tunnels do not cause pain from fixation devices and there is no need for removal surgery, but they bring a delay in rehabilitation times and a higher risk of stiffness [14,23,42].

In the present study, we evaluated a surgical technique that might be able to combine the advantages of internal fixation with screws and those associated with bone tunnels resorbable sutures.

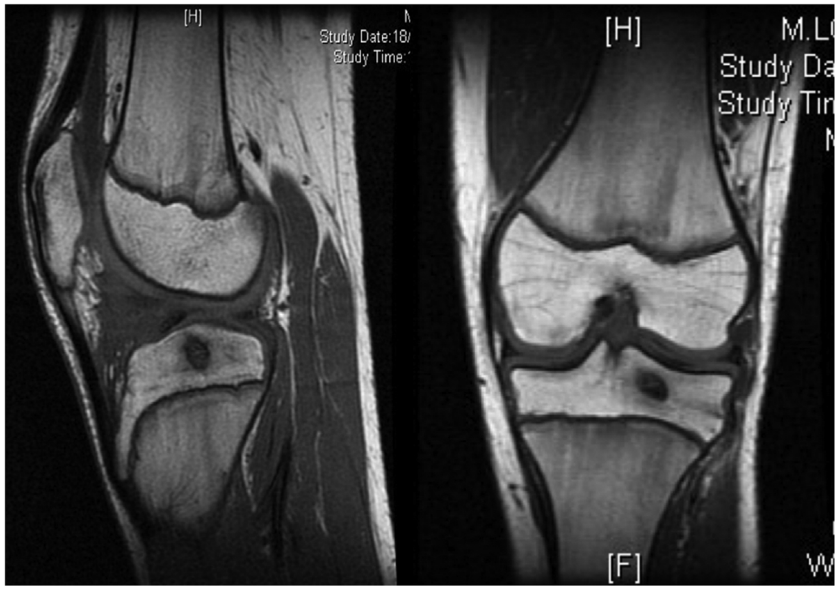

Fig. 3. MRI at 6 months post-op of case n.1.

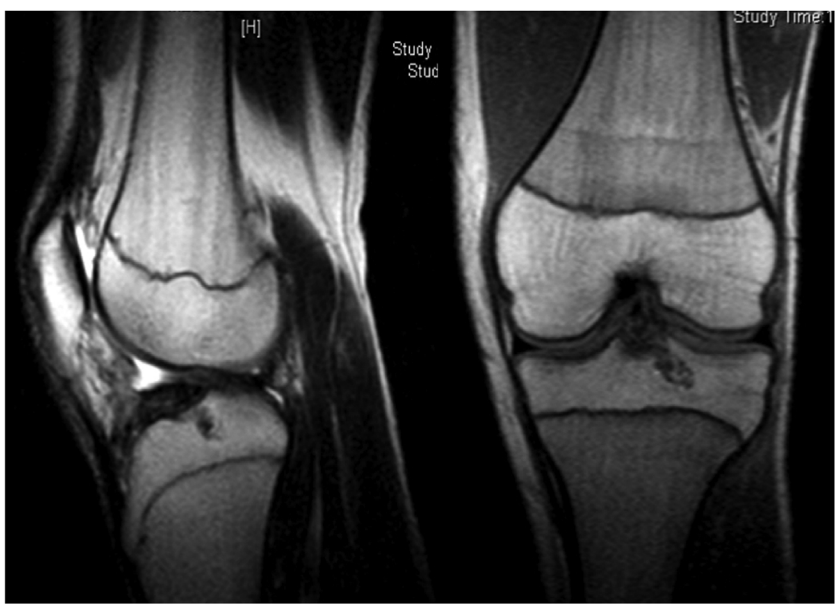

Fig. 4. MRI at 12 months post-op of case n.1.

The results showed that in all 3 patients treated surgically with magnesium resorbable screw, functional recovery has been excellent according to Lysholm score and IKDC, although we observed a slightly slower recovery in two cases. We believe this might be imputable to the more serious injuries (Meyers-McKeever type IV vs Meyers-McKeever type III), but probably also to the higher number of screws used (2 screws instead of 1). Radiographically, in all 3 cases a progressive healing of the fracture site was observed. In addition, MRI at 6 months allowed to assess the complete resorption of the screws and at 12 months the replacement by newly formed bone, avoiding the need to undergo a second procedure to remove the fixation devices as reported by Lukas e Koudela [43].

The choice of magnesium was based on a great number of studies underlining the mechanical, physical and biological properties of this material. Indeed, recent studies demonstrated the clinical feasibility of magnesium screws evaluating its radiological, histological and hematological characteristics [44]. Histological studies showed that the device is completely and homogeneously replaced by bone tissue [44]. Other studies underlined how magnesium screws cause a much lower number of artifacts at MRI, CT-scan and other imaging techniques when compared to conventional titanium screws [45]. Bone response to magnesium is equal or superior to that of other resorbable materials [46]. This metal also promotes healing of the enthesis according to studies on the rabbit [47] Moreover, magnesium appears to have an overall better biocompatibility compared to polymeric screws such as PLLA screws; they also show a higher degree of resistance to corrosion when anodized [48]. Finally, magnesium showed better osteoconductive and osteointegration properties compared to other materials [49]. Mechanical properties are significantly better than conventional resorbable implants.

Strong points of the present study were the homogeneity of both the surgical technique and the device used, together with the same rehabilitation program applied to all three patients.

However, the major limits of this study are the small number of patients, together with the absence of a long-term follow-up (over 12 months).

Conclusions

In conclusion, the treatment of tibial spine avulsion fractures with ARIF technique by the use of magnesium resorbable screws seems to result in an excellent functional recovery without complications related to fixation devices, which were completely resorbed after 6 months and replaced by newly formed bone after 12 months. This new method could be considered as an alternative option to classic techniques by non resorbable fixation devices or bone tunnel fixation. Further studies are needed in order to evaluate the efficacy of this new device in a wider group of patients.

The authors state that there was no conflict of interest; financial, personal or other in the implementation of this study.

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