Surgical repair of an unicortical condylar fracture in a Thoroughbred racehorse using a bioabsorbable screw

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Abstract

Surgical repair of unicortical fractures of the distal condyles of the third metacarpal/metatarsal bones (MCIII/MTIII) has been described. In the present case, a bioabsorbable screw was used to stabilize a unicortical fracture in the palmar aspect of the medial condyle of MCIII in a National Hunt Thoroughbred racehorse. The clinical, radiographic and magnetic resonance (MRI) findings before and after surgery were recorded. Eighteen weeks after surgery, the lameness had resolved and the bone surrounding the fracture had recovered its normal architecture. One year after surgery, the horse was in training, showed no recurrence of the primary lesion and was considered a "racing prospect" by the trainer.

The use of a bioabsorbable screw in this case was associated with a successful outcome and is worthy of further investigation.

Keywords: horse, bioabsorbable screw, condylar fracture, MRI, osteointegration.

Introduction

Unicortical condylar fractures of the distal condyles of the third metacarpal/metatarsal bone (MCIII/MTIII), an early stage of the more commonly recognized complete/incomplete (bicortical) condylar fracture, are common injuries in racehorses. In literature they are defined as short fractures, fissures, or incomplete fractures and often originate to the palmar/plantar aspect of the bone in the area where the sesamoid bones articulate with the condyle [1–3]. In the literature, the pathogenesis of these fractures involves progressive, fatigue related disease of the mineralized cartilage and subchondral bone and often originates in the palmar/plantar aspect of the medial or lateral condylar groove [4]. Surgical treatment is generally recommended in order to stabilize the fracture and thereby prevent its further propagation and encourage healing. Brown *et al.* [5] suggested that the placement of a single lag screw in unicortical condylar fractures may be useful for reducing the recovery period. While complications associated with the use of metal screws in this location are uncommon, it is known the risk of osteolysis around the implant, which although not always clinically relevant, can determine unwanted changes in the material properties of the bone [6]. Bioabsorbable implants, including bone screws, are increasingly used in human orthopaedic surgery [7–9]. These implants can be classified into several categories depending on their composition. Some are made from synthetic polymers, such as polyglycolic or poly L-lactide acid (PLLA), poly-d-lactate, or polyetilene. Others are composed of ceramics, while others are made of a composite of bioceramic and polymers. The use of bioabsorbable implants in the horse was first reported by Field *et al.* in 1993, who evaluated the mechanical properties of bioabsorbable screws in bones from horse cadavers. They concluded that bioabsorbable screws used to stabilise a fissure created from the sagittal ridge to middle-diaphysis of the distal third metacarpal/metatarsal bone were inferior to those made of stainless steel in achieving stability of the repair construct [10]. Wall *et al.* [11] reported successfully using bioabsorbable screw to bridge the physis of long bones in foals as a means of correcting angular limb deformities. Pyles *et al.* [12] investigated the efficacy of using a bioabsorbable screw to repair an induced fracture in the proximal sesamoid bone, while Mageed *et al.* [13] reported using bioabsorbable screws to treat a splint bone fracture. All the aforementioned studies used implants made of polymers. This case report describes the successful management of a unicortical fracture in the distal condyle of MCIII using a composite bioabsorbable screw. This implant has been shown to retain high strength during fracture healing, is absorbed, has osteoconductive properties and binds well to surrounding bone matrix [14].

1. Case Report

1.1 Case history

A 2-year-old National Hunt Thoroughbred racehorse (520 kg bodyweight) was admitted for investigation of right forelimb lameness that developed acutely after the morning workout.

2.2 Clinical findings

The horse was grade 3 lame (AAEP scale 1-5)[15] on the right forelimb. It showed pain when the right fore fetlock joint was flexed although the joint was not swollen. No intra-articular medications of the injured fetlock joint were performed prior to diagnosis.

2.3 Diagnosis

A radiographic examination of the right fore fetlock was performed. A radiolucent line, compatible with a unicortical condylar fracture of the palmar aspect of the medial condyle of MCIII (Fig 1A) was identified on the dorsodistal-palmaro proximal oblique (flexed dorsopalmar) projection. In order to confirm the diagnosis, a standing magnetic resonance imaging (MRI) (Hallmarq[1], Tesla 0.27) examination was performed. The horse was sedated with detomidine (0.02 mg/kg i.v.) and butorphanol (0.06 mg/kg i.v.) and MRI of the metacarpophalangeal joint was performed including the following sequences: palmar-sagittal aspect using gradient T1, T1 HR (High Resolution), T2* (T2-star), FSE (Fast Spin Echo), T2 FAT-SAT (Fat Saturation); in sagittal aspect with T1 FAT-SAT and in dorsal aspect using T1, T1 HR and FAT-SAT. The MRI images confirmed the presence of a 1cm fissure in the sagittal plan located in the palmar cortex of the condylar groove of the medial condyle. The fissure was associated with bone resorption, fluid signal around the fissure and sclerosis of the surrounding bone (Fig 1B-F).

Surgical repair of the fracture was planned, using a bioabsorbable screw (Osteotrans-OA[2]). The screw is made of forged composite materials, which include unsintered hydroxyapatite, embedded in poly L-lactide acid. Since the holding power required for stabilization of a unicortical condylar fracture is likely to be much less than that required for a complete fracture, the authors were confident that this screw would offer adequate mechanical support and chose to take advantage of the osteoconductive, binding and bioabsorbable properties of the composite screw.

2.4 Surgical treatment

The horse was pre-medicated with procaine penicillin 22,000 IU/kg i.m. and flunixin meglumine 1.1 mg/kg i.v. The surgery was performed with the horse conscious, standing, under local analgesia. Detomidine (0.02 mg/kg i.v.) and butorphanol (0.06 mg/kg i.v.) were used for sedation. Perineural anaesthesia of the distal limb was performed through a high-4-point nerve block, using a total of 60 ml mepivicaine 2%, [16]. After aseptic preparation of the surgical site, the limb was draped with a sterile sock to accommodate movement during surgery. The site of entrance of the drill bit was identified on dorsopalmar and mediolateral radiographic projections with a hypodermic needle and a stab incision was made in the skin overlying the medial epicondylar fossa. The screw was placed in lag fashion according to the technique recommended by the AO/ASIF. A 4.5 mm glide hole was drilled to just cross the fissure line. A 4.5/3.2 sleeve was inserted to guide a 3.2 mm drill bit, which was used to create the hole across the lateral segment of the bone. The depth of the hole was measured and then the hole was tapped using a 4.5 mm tap. In order to ease the compression between the head screw in the lag hole a countersink was used; then a bioabsorbable screw of 4.5 mm diameter and 50 mm length was inserted (Fig 2A). Bioabsorbable screws are weaker than steel and so particular care was taken when incrementally tightening the screw. In order to achieve optimal compression in an unweighted position, the leg was raised during tightening of the screw (Fig 2B, 2C). Dorsopalmar and mediolateral radiographic projections were performed to assess the position of the screw (Fig. 2E, 2F). The skin was routinely closed with non-absorbable monofilament suture (Ethibond nylon n. 3.5) and the limb was bandaged.

2.5 Post-operative care

The horse was discharged from hospital 24 hours after surgery and antimicrobial and inflammatory treatment (procaine penicillin 22,000 IU/kg i.m. and flunixin meglumine 1.1 mg/kg i.v.) was continued twice daily for 3 days. The bandage was changed every 4 days until suture removal 12 days post-surgery. No complications were observed.

2.6 Outcome and rehabilitation program

After 4 weeks of stall-rest the horse was not lame when examined; thus, a rehabilitation exercise protocol of 15 minutes walking-machine daily for 8 weeks followed by 20 minutes trotting daily for more 6 weeks was scheduled. Radiographs, taken 12 weeks after surgery (Fig 3A) indicated healing of the fracture and no reaction around the screw head. Another MRI examination was performed 18 weeks after surgery, before the horse's workload was increased.

2.7 MRI follow-up

Decrease in the length of the fracture line was associated with resolution of the high intensity signal in the subchondral bone in the STIR sequence. No bone resorption around the screw was apparent (Fig 3B-F).

2.8 Long-term follow up

The horse was monitored closely for one year during which its workload was progressively increased. The horse is free of lameness, the fetlock joint retains full range of mobility and no recurrence of the primary lesion has been observed. The trainer considers that the horse is a “racing prospect”.

2. Discussion

Unicortical condylar fractures are associated with more long-standing, localised bone disease, caused by repetitive stress and, if not recognized, can progress to complete fractures or catastrophic injuries. Unicortical condylar fractures of MCIII/MTIII can be treated conservatively [3,17]. However, cases require stable confinement for at least 8 weeks with or without a cast. Immobilization may decrease bone metabolism, which may also reduce healing process [1,18,19]. The placement of a cortical bone screw in lag fashion to achieve compression across the fracture line will encourage bone healing, leads to a faster recovery of the athletic function, and minimizes the potential risk of re-injury [2,3,5]. Loosening of screws used to stabilize a fracture will result in movement of fragments relative to each other leading to delayed fracture healing. It is essential that the osteosynthesis through internal fixation guarantees a stable interface between fracture margins; moreover, interfragmentary compression is also important in fixation of incomplete fractures [20]. As demonstrated in differents studies, the screw used in the present case exhibits an impact strength that increases remarkably between 20-28 weeks compared to the initial values, while it decreases at 36 weeks after surgery [7]. The compression strength, calculated as maximum force/compressive area ($S_c=F_{max}/A$), changes least and remains in the region of 110 MPa. The compression strength values originate from the compactive polymer which accounts for over 70% of the volume of the composite, while the crystal morphology of multi axial orientation allow remarkably high bending strength [7,20]. Across the fracture line a screw must also provide an initial mechanical bending strength of at least 200 MPa [20], that is higher than natural cortical bone; the bioabsorbable screw used in this report assures a bending strength of 270 MPa for six months [20]. Although the aforementioned study was performed on cortical bone of humans [20], other studies about mechanical properties of cortical bones of equine cannon bones showed similar values, with an average bending strength ranging from a median of 226 MPa in the lateral and medial quadrants and 195 MPa in the caudal quadrant [21]. Moreover, a study reported that the bioabsorbable composite screws stimulate new bone formation 2 weeks after surgery without fibrous tissue formation between bone and screws; it is demonstrated that the surrounding bone directly binds the unsintered hydroxyapatite particles that are partially exposed at the screw surface improving adhesion and osteointegration that are advantageous for initial fracture stabilization [14]. This osteoconductive activity of the bioabsorbable screw may contribute to the early positional stability in the bone [8], and for these reasons they are considered suitable for bone fracture fixation [20]. Several reports in humans demonstrated comparable results in the treatment of ankle fractures and lateral malleolar fractures fixation using unsintered hydroxyapatite/poly L-lactide acid or metallic screws and the time of fracture union were inferior to those of metallic screw [9]. Kuroyanagi *et al.* [8] treated tibial condyle fractures in humans, with no breakage of bioabsorbable screws and maintenance of the joint surface at final follow-up in all patients. The histological analysis showed the formation of new bone around the implant at 2 weeks; at 8 weeks bone lamellar construction was visible, and at 25 weeks the bone surrounding the composites became normal trabecular bone [8]. The bioabsorbable material gradually deteriorates and the osteoconductivity of unsintered hydroxyapatite promotes the growth of new bone in the region [22]. The absorption mechanism of bioabsorbable screws is not yet fully clarified, certainly it is slow. When it is implanted in the bone, body fluids enter into it via interface between unsintered hydroxyapatite particles and acid matrix reaching the centre of the bioabsorbable screw [22]. The degradation depends on several factors like shape and size of the screw as well as vascularity of surrounding tissue and implantation site [20]. In addition, it is known that the solubility of unsintered hydroxyapatite is enhanced under acid conditions [23]. There is no information about the average time needed to the complete absorption of bioabsorbable screw in horses; it can be assumed that the time required for complete absorption can be similar to that studied in animal models, in which it has taken three years for screws to be phagocytized completely by macrophages [22,24]. The biomechanical trials, the advantages of unsintered hydroxyapatite/poly-L-lactide acid and the proven effectiveness in human long bone fractures repair, have convinced the authors that it was possible to treat unicortical condylar fracture with this specific bioabsorbable screw in horses. While use of conventional metal screws for this surgery is well-established, they do have some disadvantages. For instance, metal screws generate artefacts on computed tomography and MRI and so limit application of these diagnostic modalities post operatively. Furthermore, metal screws sometimes need to be removed which involves a second surgical procedure, with possible complications [6,9]; even when everything goes smoothly, it may sometimes be necessary to remove the screw because its presence reduces the horse value and may prevent the sale. Therefore, the concept behind this surgery is that in selected cases (incomplete fractures) the use of bioabsorbable screw may be beneficial, providing an adequate stabilization and allowing the fracture healing. The MRI, performed 18 weeks after surgery, demonstrated not only bone healing, but most importantly the restoration of more normal bone signal. Although no information about the efficacy of this specific composite screw for fracture fixation in horses is available in the literature, in the present case the fracture line, clearly recognizable on radiographic examination (figure 2B), was no longer visible after screw insertion (figure 2F), suggesting compression through the implant. Moreover, the absence of signs of callus on MRI can demonstrate that a good fracture stabilization was achieved. However, although reports in humans suggests the use of absorbable implants also in displaced fractures [8], it must be taken in consideration that human patients are prohibited from bearing weight for 6 weeks after surgery, which is impossible in horses. For these reasons, bioabsorbable screws are not suitable for unstable or comminuted fractures [20].

This study has some limitation; firstly, only one case was included and no comparison with conservative treatment or metallic screw fixation was possible; secondly, the literature available on biomechanical features and the use of this bioabsorbable screw refers to human surgery and/or animal models.

3. Conclusion

To the authors' knowledge, this is the first study reporting outcome of a unicortical condylar fracture treated with a unsintered hydroxyapatite/poly-L-lactide acid screw in a horse. Despite only one horse treated, clinical, radiographic and MRI follow up are encouraging. This kind of screw can be chosen for its mechanical properties, as well as for its osteointegration and osteoinduction capabilities. Further studies are needed; however, bioabsorbable screw offers a promising alternative to treat unicortical condylar fracture and may potentially be used for other orthopaedic surgical treatments as the next-generation material.

Manufacturers' address:

[1]Hallmarq Veterinary Imaging Ltd, Unit 5 Bridge Park, Guildford, Surrey, U.K

[2]Takiron. CO.LTD. Distributor: M.I.T, Localita' I Vaccari, 29122 Piacenza, Italy.

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poly-L-lactide screws in a minipig fracture model: preliminary report. J Biomed Mater Res 2002;63:679–85.

Legend to figures

Figure 1

A: Flexed dorsopalmar radiographic projection with small radiolucency in medial parasagittal region (red arrow). B-E: MRI transverse STIR-FSE (B-C), T2-FSE (D) and T2-W-FSE (E) sequences through palmar condylar region of the third metacarpal bone showed cortical fissure (red arrow) and extensive signal hyperintensity in the surrounding cancellous bone (yellow arrowheads) of medial condyle. F: T1-W-GRE sequence of sagittal plane, showed extensive signal hypointensity in the surrounding bone (yellow arrowhead).

Figure 2: Images during surgery.

A: Bioabsorbable cortical screw of 4.5 mm diameter diameter composed of hydroxyapatite (HA) and radiolucent poly L-lactide acid (PLLA).

B: Dorsopalmar radiographic projection with small radiolucency in medial parasagittal region (yellow arrowhead)

C: A 3.2 mm glide hole was created after the fracture line, across the distal cortex.

D: The tap is inserted. The condylar fracture is still visible (yellow arrowhead)

E: The hole was performed in palmar position.

F: The screw was inserted (yellow arrowheads).

Figure 3

A: Dorso-palmar radiographic projection of the metacarpophalangeal joint 12 weeks after surgery.

B-E: MRI of the metacarpophalangeal joint in distal-transverse plane STIR-FSE (B), T1-W-GRE (C) and T2-W-FSE (D, E) sequences showed a healing of the condyle fracture with no sclerosis of the surrounding bone. The screw was implanted in palmar position (yellow arrowheads). F: MRI T1-W-GRE sequence of sagittal-lateral plane showed the screw inserted in palmar position (yellow arrowhead), with healing of fracture and no hyperintensity signal around the screw.