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TOTAL REPLACEMENT OF THE METATARSOPHALANGEAL JOINT IN THE HORSE

A SINGLE PILOT STUDY

P.W.Th. Stolk¹, M.C. de Waal Malefijt², P. Buma², and A. Barneveld¹

SUMMARY

In this paper the successful replacement of an equine metatarsophalangeal joint by a human total condylar knee prosthesis is reported. In the period of observation following implantation of the endoprosthesis the experimental animal showed almost no lameness when exercised at walk, bearing weight on the operated limb. Flexion and extension of the joint were markedly reduced. The clinical and histological observations clearly support further investigation into the equine metatarsophalangeal joint replacement by an endoprosthesis.

INTRODUCTION

Degenerative joint disease (DJD) of the metatarsophalangeal (fetlock) joint is a frequent cause of lameness in the horse. Although many therapeutic measures exist, the final results following medical treatment of the more severe cases of DJD of the fetlock joint are often very disappointing. In selected cases of severe DJD of the fetlock joint surgical arthrodesis may be considered, though return to soundness following complete ankylosis of the joint can never be expected (1).

In humans suffering from osteoarthritis modern surgical techniques presently allow a wide variety of affected joints to be replaced by an endoprosthesis to maintain at least partial joint function. As yet, in veterinary medicine the technique of total joint replacement has been limited to osteoarthritis of the canine hip joint. To our knowledge the use of an endoprosthesis in the equine species has never been reported in literature.

One of the major factors associated with long term failure of an endoprosthesis is instability of the prosthetic components (2). Micromotion at the cement-bone or prosthesis-bone interface of cemented or cementless implants respectively, invariably induces lysis of bone around the prosthetic components and may, therefore, lead to a reduced anchorage of the endoprosthesis, a process commonly known as aseptic loosening (3).

In this single experiment we performed a cemented prosthetic replacement of the fetlock joint in a healthy experimental horse using a human total condylar knee prosthesis. The aim of this experiment was 1) to study the technical feasibility of total replacement of the equine metatarsophalangeal joint by a human prosthesis with maintenance of at least partial articular function and 2) to histologically study the bone at the cement-bone interface of the implant.

MATERIALS AND METHODS

Experimental design

After the left metatarsophalangeal joint of an experimental horse had been replaced by a human total knee system a fibreglass cast was put around the lower limb to support and

protect the surgical site during recovery from anaesthesia. Six weeks later the cast was replaced by a supportive bandage for a week. The horse was exercised at hand for a period of more than 24 weeks and 170 days after implantation of the prosthesis the animal was euthanized to allow further histological examination of the juxta-articular bones.

Experimental animal

A healthy 8 year old female Dutch Warmblood Horse (body weight 520 kg) was used for this study. The animal had no clinical and/or radiographical evidence of any chondro-osseous disease.

Prosthesis

For the fetlock joint replacement we used a human 52 mm (LM) cruciate ligament sacrificing Insal/Burstein® total knee system (Johnson & Johnson). This device consists of an ultra-high molecular weight polyethylene tibial component and a cobalt-chromium alloy femoral component. For anchorage of the prosthesis an antibiotic loaded polymethylmethacrylate bone cement (Simplex, Howmedica) was used.

Anaesthesia and pre-operative medication

One hour prior to the induction of anaesthesia the following drugs were administered intravenously: gentamicin sulphate¹ (4 mg. kg BW⁻¹), ampicillin sodium² (12 mg. kg BW⁻¹), flunixin meglumide³ (1 mg. kg BW⁻¹) and dexamethasone sodium phosphate⁴ (80 µg. kg BW⁻¹). After premedication with detomidine hydrochloride⁵ (12 mg. kg BW⁻¹), anaesthesia was induced with a mixture of guaicol glycerine ether⁶ (100 mg. kg BW⁻¹) and thiopentone sodium⁷ (5 mg. kg BW⁻¹), the trachea was intubated and anaesthesia was maintained with halothane in a mixture of oxygen and nitrous oxide. Throughout the procedure alveolar ventilation was assisted using IPPV. During anaesthesia 9 litres of lactated Ringer's solution were given intravenously. The total anaesthetic duration (including pre-operative preparation, surgery and transportation to the Department of Radiology for post-operative examination) was 325 minutes.

Surgical technique

With the horse in right lateral recumbency an Esmarch bandage was applied to the limb, and the fetlock region of the left hind limb was surgically prepared. A 15 cm straight midline incision over the dorsal side of the fetlock joint was made. The joint was opened by extending the incision just medially to the common digital extensor tendon into the joint

¹ Gentamicine® (AUV, Cuijk, the Netherlands).

² Ampicilline® (Alfasan, Woerden, the Netherlands).

³ Finadyne® (AUV, Cuijk, the Netherlands).

⁴ Dexadreson® (Intervet, Boxmeer, the Netherlands).

⁵ Domosedan® (AUV, Cuijk, the Netherlands).

⁶ Gujatal® (Aesculaap, Bostel, the Netherlands).

⁷ Nesdonal® (Rhône Mérieux, Amstelveen, the Netherlands).

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Figure 1. Intra-operative view after completion of the resection of the distal third metatarsal bone and the first phalanx.

cavity. This allowed the latter tendon to be reflected laterally and, following maximal flexion of the fetlock joint, the distal part of the third metatarsal bone and the proximal first phalanx were completely exposed.

With the help of guiding tools (PFC, Johnson & Johnson) and 8 mm thick bone slab was removed from the distal epiphysis of the third metatarsal bone.

Using resection guides the distal metaphysis and the remnant of the distal epiphysis of the third metatarsal bone were precisely shaped to fit the femoral component of the prosthesis (IBPS size 1, Johnson & Johnson).

Subsequently, a bone slab of approximately 8 mm thickness was removed from the proximal first phalanx. This could only be performed after dissecting part of the insertion of both collateral ligaments from the bone slab. A cavity of approximately 25 mm depth (length 15 mm, width 10 mm) was then created in the centre of the cut surface of the first phalanx to fit the stem of the tibial component of the human knee prosthesis (Figure 1). After thorough cleaning of all bony surfaces and soft tissues the femoral and tibial components were secured using bone cement. When the cement had set the articular surfaces of both sesamoid bones appeared to be in contact with the posterior side of the femoral component. Also, during passive flexion and extension the joint showed a smooth tracking pattern and

there were no indications for any (sub)luxation. Both the joint capsule with its fascia and the subcutis were sutured together using a continuous suture (Vicryl® 2-0), whilst the skin was sutured using a continuous intracutaneous suture (Monocryl® 2-0).

The range of motion of the newly created fetlock joint ranged from approximately -45 degrees flexion to approximately 10 degrees hyperextension whilst pre-operatively these values were -90 degrees and 30 degrees, respectively.

After the correct position of both components of the prosthesis had been confirmed radiographically, a supportive fibre-glass cast⁸ was applied around the lower limb, with the cannon and pastern segments aligned (i.e. 0 degrees), and the animal was allowed to recover from anaesthesia.

The total surgical duration was 175 minutes.

Post mortem examination

The joint containing the prosthesis and its adjacent bones were fixed for two weeks using a 4 percent phosphate-buffered formalin solution.

To allow histotechnical processing the prosthetic components were removed by separation at the prosthesis-cement interface. Using a water-cooled saw the third metatarsal and first phalangeal bones were sectioned in slices of approximately 4 mm thickness. After radiographical examination the slices were either decalcified in a 20 percent EDTA solution to allow routine histology or embedded without decalcification for the preparation of sawing sections of 20-40 µm thickness. All sections were embedded in PMMA.

⁸ Articast® (Beiersdorf, Almere, the Netherlands).

⁹ Pro-Dynam® (Leo Pharmaceutical Products, Weesp, the Netherlands).

RESULTS

Post-operative period and medication

Approximately 30 minutes after recovery from anaesthesia the horse could walk from the recovery unit to its box, bearing weight on the operated limb. In the post-operative period medication consisted of trimethoprim sulfadiazine sodium (30 mg.kg BW⁻¹ b.i.d) and phenylbutazone (4 mg.kg BW⁻¹ b.i.d.).

On the days immediately following surgery, the horse was allowed to walk around in its large box (dimensions: 4 x 4 metres) and whilst walking it bore weight on the operated limb. Five days after surgery (=D5) it was decided to reduce the daily NSAID medication to a single dose. At D7 it was decided to inspect the surgical site and to change the protective cast under general anaesthesia. The clinical findings were: some subcutaneous swelling of the fetlock area, no (sub)luxation or joint laxity and primary healing of the skin wound. Passive motion of the artificial joint now ranged from -45 degrees (flexion) to 0 degrees (i.e. bone segments aligned). At D14 the NSAID medication was discontinued. To allow further inspection of the limb the protective cast was changed at D28. The subcutaneous swelling had now

disappeared; the other clinical findings were similar to those on D7. During the changing of the cast at D42 radiographs were made of the prosthesis and its adjacent bones. In the absence of any radiological and/or clinical contra-indications it was decided to substitute the supportive cast for a supportive bandage. Thus, a new supportive fibreglass cast was applied to protect the prosthesis during the process of recovery from anaesthesia, whilst the following day (D43) the cast was removed and a supportive bandage in the standing, non-sedated animal was applied. At D50 the supportive bandage was removed and the animal's exercise was subsequently increased to walking at hand on a tarmac surface twice a day for approximately 15 minutes. During these walking exercises visual inspection showed no marked difference between load bearing of the operated limb and the contralateral limb. Also, stance times of the operated and contralateral limbs were equal, though hyperextension of the metatarsophalangeal joint at load bearing was reduced from approximately 30 degrees pre-operatively to approximately 10 degrees post-operatively. At D170 radiographic examination showed no periosteal new bone formation in the joint (Figure 2).

At D173 the animal was euthanized to allow macroscopic and histological examination of the joint and its juxta-articu-

Figure 2a en b. Dorsoplantar (left) and lateromedial (right) radiographic views of the in situ endoprosthesis (170 days after implantation).

lar bones. To the best knowledge of the authors the horse had shown no signs of discomfort at any time during the period of observation following the implantation of the prosthesis.

Pathology

Macroscopic findings

Dissection showed moderate periarticular dense connective tissue formation. The joint capsule with its synovial layer appeared slightly thickened. No intra-articular granulation tissue was found. Both the femoral and tibial prosthesis compounds appeared to be firmly anchored into the metatarsal and first phalangeal bones respectively. The distal articular sides of both sesamoid bones showed loss of cartilage with no apparent subchondral bone reaction.

Histological findings

At the cement-bone interface of the tibial component of the prosthesis the cement surrounding the central stem had penetrated into the adjacent dense trabecular bone over a distance of approximately 2 mm. No signs of bone resorption at the cement-bone interface were noticed nor were there any signs of fractures of the cement. The bone directly facing the cement appeared to be viable, except for trabeculae that were completely surrounded by the cement. It appeared that following the insertion of the tibial component of the prosthesis new bone had been formed on the existing trabecular bone. Underneath the tibial plateau of the prosthesis local areas of cement were found, but most sections showed dense connective tissue formation at the cement-bone interface (Figure 3). At the cement-bone interface of the femoral component of the prosthesis the abnormalities were slightly more pronounced: bone resorption, dense connective tissue formation and dynamic bone remodelling were noticed in particular at the axial and abaxial sides of the medial resection plane of the third metatarsal bone.

Fluorochrome labelling showed no marked necrotic zones and a low-intensity bone remodelling at the cement-bone interfaces of both prosthetic components, indicating that the bone had fully accepted the endoprosthesis and that no rejection had taken place.

DISCUSSION

Prior to implantation of the prosthesis in the experimental animal 9 pilot studies were carried out on cadaveric equine metatarsophalangeal joints in order to obtain surgical experience. The ethical committee of the university gave full approval to carry out the experiment.

Throughout the observation period of this pilot study the clinical findings clearly indicated that there was full anchorage between the endoprosthesis and the third metatarsal and first phalangeal bones. Also, in the absence of any laxity and/or subluxation of the joint it is concluded that the collateral ligaments as well as the flexor and extensor tendons had fully regained their normal function following the joint replacement. However, the histological findings at the cement-bone interface of the femoral component indicated that this part of the endoprosthesis could not have been completely stable and it is highly likely that micromotion of the prosthesis was responsible for the histological findings. As yet, the cause for this phenomenon is not clear.

Both sesamoid bones showed marked loss of articular carti-

Figure 3. Dense connective tissue formation (dark) between the cement (left) and the trabecular bone (right) underneath the tibial component of the prosthesis.

lage at their distal ends. This was not a surprising finding as there appeared to be a marked mismatching between the shape of the articular surfaces of the sesamoid bones and that of the plantar part of the condyles of the femoral component of the human prosthesis. This indicates that for future use in the equine species the femoral component of the prosthesis should be redesigned to fit precisely the specific shape of the articular surface of the sesamoid bones. Furthermore, it is most likely that this mismatching of shapes is (at least partially) responsible for the reduction in hyperextension of the fetlock joint following operation.

Another important factor in the post-operative reduction of the range of fetlock joint motion might be the prolonged period of post-operative joint immobilisation. This probably allowed the formation of peri-articular dense connective tissue, causing marked stiffness of the joint. In human prosthetic replacement it is common practice to start passive movement of a replaced joint as soon as two days post-operatively to reduce reactive tissue formation and, thus, to obtain maximal joint flexion and extension. However, in the present case the joint had deliberately been fully immobilized for a period of six weeks to allow complete healing of the peri-articular soft tissues (including the insertion of both collateral ligaments). Therefore, in future cases the period of post-operative cast immobilisation may have to be limited.

From the clinical experience and the macroscopic and histological post-mortem examinations it is concluded that further investigation into equine metatarsophalangeal joint replacement by an endoprosthesis is fully warranted.

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