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Treatment of full thickness focal cartilage lesions with a metallic resurfacing implant in a sheep animal model, 1 year evaluation

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SUMMARY

Background: Full depth focal cartilage lesions do not heal spontaneously and while some of these lesions are asymptomatic they might progress to osteoarthritis. Treatment for these lesions is warranted and the gold standard treatment at younger age remains biological healing by cell stimulation. In the middle-age patient the success rate of biologic treatment varies, hence the surge of non-biological alternatives. Our objective was to evaluate the efficacy and safety of a metallic implant for treatment of these lesions with respect to the long-term panarticular cartilage homeostasis.

Methods: The medial femoral condyle of 16 sheep was operated unilaterally. A metallic implant was inserted in the weight-bearing surface at an aimed height of 0.5 mm recessed. Euthanasia was performed at 6 or 12 months. Implant height and tilt was analyzed using a laser-scanning device. Damage to cartilage surfaces was evaluated macroscopically and microscopically according to the Osteoarthritis Research Society International (OARSI) recommendations.

Results: Thirteen sheep were available for evaluation and showed a varying degree of cartilage damage linearly increasing with age. Cartilage damage of the medial tibial plateau opposing the implant was increased compared to the non-operated knee by 1.77 units ($p = 0.041$; 95% CI: 0.08, 3.45) on a 0–27 unit scale. Remaining joint compartments were unaffected. Implant position averaged 0.54 recessed (95% CI: 0.41, 0.67).

Conclusions: Our results showed a consistent and accurate placement of these implants at a defined zone. At this position cartilage wear of opposing and surrounding joint cartilage is limited. Thus expanded animal and human studies are motivated.

Introduction

The treatment of a focal cartilage lesion grade 3–4; according to the International Cartilage Research Society (ICRS) score[1] remains a clinical challenge[2]. These lesions are often associated with other sports injuries[3] and the increased activity levels at older age coupled with a demand on higher quality of life puts this pathology on the rise[2]. Because cartilage injuries show a decreasing healing capacity with age[4,5] and a focal cartilage lesion left untreated might progress to osteoarthritis[6–9], treatment is warranted. Various types of biological treatments have proven valuable but are either technically demanding, require sophisticated laboratory resources or proved less effective with increased age[10–12].

In the last decade a novel surgical strategy has been proposed[13–15] using focal knee resurfacing metal implants (FKRM). The most commonly described indication is for the symptomatic middle-aged (35–60 years) active patient where biological treatments have failed or shown to be less effective[16]. This method can be regarded as the final attempt at joint preservation in the younger

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patient. In the middle aged, FKRM could develop into a primary procedure when the disease is incipient or the patient is too young to warrant the established end-stage treatment (total or partial knee joint arthroplasty). Although it is attractive to provide immediate stability to these cartilage lesions with a metallic implant, the scientific evidence supporting this treatment modality is still limited.

The concept of resurfacing a full thickness focal cartilage lesion in the knee with a metallic implant articulating against the opposing tibial cartilage (unipolar) requires three fundamentals to succeed. First, the implant must bond to the host bone. Second, the surrounding cartilage should not be damaged but rather adhere to the implant. Third, it is imperative that the opposing cartilage withstands the new biomaterial over time. We used a monobloc Co–Cr implant double coated with titanium and hydroxyapatite to optimize osseointegration. While other groups have used rather large titanium anchor screws or bolts[13,14] to obtain fixation, we chose a slender press-fit peg for primary fixation in order to minimize bone defects that could aggravate potential revision surgery.

In a pilot study we demonstrated a strong relationship between implant positioning and opposing cartilage wear, showing encouraging results when implants were seated in an adequate position[15]. Others have acknowledged this fact, and aim at inserting the implant either flush or somewhat below the surrounding cartilage surface, although the postoperative implant position was not reported[13,14]. In our pilot study we also observed a significant implant position imprecision when using a first generation aiming device. Hence, both a reliable instrumentation for accurate positioning and a technique for detailed evaluation of obtained results are of utmost importance.

For the present study the second generation double-curved implant was used with a third generation positioning device (Fig. 1). Implant position was verified using a refined laser measurement protocol (Fig. 2). The primary outcome measurement in order to evaluate the efficacy and safety of the implant was the histological cartilage condition of multiple surfaces within the knee. We studied the feasibility of accurate and consistent implant positioning, and hypothesized that damage at 1-year to opposing tibial cartilage would be minor assuming that an ideal, somewhat recessed, position was obtained.

Materials and methods

Animals

Sixteen healthy female sheep (Swedish landrace) from the same breeder were used. Mean age and weight of the sheep were 4 years (evenly distributed; range 2–6) and 82.5 kg (range 70–99), respectively. Animals that did not meet these characteristics, or presented general disease or lameness as determined preoperatively at veterinary examination were excluded. Animals were housed at the Department of Clinical Sciences, Swedish University of Agriculture Sciences (SLU) in Uppsala, Sweden, and kept indoors in stables in groups of three the first weeks and thereafter in an outdoor stable. Food was given twice a day and water was freely available. They were well acquainted with the person handling them, and observed daily to monitor general condition, signs of pain and lameness (grade 0 was normal gait and 1–4 was mild, moderate, major and severe lameness respectively)[17]. Euthanasia was randomly performed at 6 months (7 animals) or after 12 months (6 animals) using an overdose pentobarbital (100 mg/ml) after securing blood samples. Three animals were lost for follow-up (see below). The knees were prepared for further investigations as described below. Animal Ethics Committee, Uppsala Sweden, approved the protocol.

Implant

The implant (diameter 7.5 mm) had a double-curved (radii 19 and 12 mm) articulating surface modeled after computer tomography (CT) scans of a "standard" sheep knee, and was manufactured from implant-grade cobalt-chrome by a computer aided design and manufacturing (CAD/CAM) process. Implants were coated with commercially pure titanium (60 μm) on which a layer of hydroxyapatite (HA; 60 μm) was plasma sprayed (Plasma Biotal Ltd., GBR). The articulating surface was then polished to a roughness (R_a) < 0.03 μm. The monobloc implant (Fig. 1a) had a 10 mm peg (diameter 2 mm) introduced into an undersized (diameter 1.8 mm) drill hole in the bone for primary interference fit. Implants were manufactured and provided by Episurf AB, Sweden.

Anesthesia

The animals were anaesthetized by an intravenous injection in the jugular vein of xylazine (Rompun® vet, Bayer Animal Health, Denmark) 0.11 mg/kg and ketamine (Ketaminol® vet, Intervet, Sweden) 2.2 mg/kg and then intubated. The anesthesia was maintained with isoflurane (IsoFlo® vet, Orion Pharma Animal Health, Sweden) 1.5–3% in 100% oxygen. After anesthetization, blood samples were taken from the cephalic vein. The animals were given antibiotics, cefuroxime (Cefuroxim, Farmaplus, Norway) 22 mg/kg IV and analgesic, carprofen (Rimadyl® vet, Orion Pharma Animal Health, Sweden) 4 mg/kg SC, buprenorphine (Temgesic®, Schering-Plough, Sweden) 0.01 mg/kg IM and glucopyrrolate (Robinul®, Meda, Sweden) 0.25 ml/10 kg SC.

Surgery

Surgery was performed on one knee; randomly prepared closed envelope determined the side. All operations were carried out under aseptic conditions by the same surgeons (HNS, NMC and LR). The medial femoral condyle was exposed through a medial parapatellar 5–6 cm incision through skin and subcutaneous tissue. After inspecting the knee the operation was carried out using a set of specially designed instruments: First, a centralizing aiming guide with a built-in guiding tube, adapted to the contour of the weight-bearing condylar surface was applied and fixed to the condyle by means of three pins engaging the metaphysis outside the articulating cartilage (Fig. 1b and d). Through the guiding tube, sitting perpendicular to the articulating surface, a specially designed drill was used to cut the cartilage and the underlying bone. According to previous studies[15], we aimed to position the implant at a level 0.5 mm recessed below the surrounding cartilage (Fig. 1c). A testing device with identical articulating contour as the final implant was used iteratively to control the position in height relative to the surrounding cartilage. The level of the implantation depth was incrementally increased by 0.01 mm by turning the guide tower clock-wise one step until a satisfactory level was achieved before finally inserting the implant. Finally, the joint capsule was sutured using polydioxanone (PDS®, Ethicon), subcutaneous tissue and skin were closed in a similarly using poliglecaprone 25 (Monocryl®, Ethicon). No surgical complications occurred during the operations. The sheep were extubated in their stables under continuous observation and regained consciousness within 1 h post surgery.

Laser measurements of implant position

The medial femoral condyle with the implant was used for analysis. A negative print was taken of using an alginate plaster (Hydrogym; Zhermack, Italy), which was subsequently scanned using a high precision (<1 μm) laser-scanning device (www.