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Cartilage resurfacing implies repair to an organized hyaline architecture not evident in simple manipulative techniques used in mature horses. Methods that may enhance the quantity and hyaline characteristics of cartilage repair tissue, while at the same time maintaining the efficiencies of arthroscopic surgery, allow the surgeon to improve the long-term outcome when debriding cartilage lesions. No system routinely provides all of these advantages. Indeed, those with inherent simplicity such as cartilage debridement, forage, and microfracture meet many of the criterion for simplicity, economy, and minimal delay between diagnosis and repair, but provide less assured hyaline cartilage and cartilage durability. Techniques for cartilage repair that strive to improve chondrocyte preponderance and organized matrix architecture include cell and tissue engineered transplantation techniques. Most are better than local debridement or marrow stimulation procedures, but add complexity to the surgery.

LOCAL MANIPULATION
Surgical techniques that rely on simple manipulative procedures intraoperatively include:
- cartilage debridement,
- cartilage re-attachment,
- forage or drilling of the subchondral bone using a drill to provide a uniform diameter perforation through the subchondral plate,
- microfracture or micropick, which uses a tapered surgical awl to perforate the subchondral bone to open marrow spaces,
- any of these techniques are applied during routine arthroscopy.

Cartilage Re-Attachment Using Resorbable Pins
Indications
Under defined conditions where an OCD cartilage flap has not detached on its entire perimeter, the partially attached flap can be replaced and secured with polydioxanone (PDS) pins (OrthoSorb, DePuy).1 Importantly, the OCD flap must be:
- worth re-attaching, which requires a smooth congruous surface with minimal fibrillation
- still in situ within the original defect, with at least some residual continuity with normal surrounding cartilage
- not entirely mineralized

Technique
The joint is examined arthroscopically to determine the suitability for OCD flap reattachment or alternatively, debridement and subchondral bone scarification. Cartilage lesions that have detached from underlying bone and remain partially attached to normal cartilage surrounding the lesion are ideal for reattachment. Several 20 mm length PDS pins are placed with the kit provided. This kit also contains three 40 mm PDS pins which can conveniently be cut in half and the 20 mm pins used to secure the flap every 10 to 15 mm along its length. For drilling, an arthroscopic instrument portal directly over the lesion is developed to allow insertion of the cannula perpendicular to the cartilage surface. The K-wire is secured in the chuck of the drill to allow 19 mm of K-wire to emerge from the end of the cannula. The K-wire is drilled through the loose cartilage and into the subchondral bone the full 19 mm. Repeated entry and withdrawal of the K-wire is vital to make a uniform and appropriately sized hole. The K-wire is exchanged for the pre-cut 20 mm pin, which is pushed down the cannula and into the drill hole. Any excess pin can be clipped off with a biopsy rongeur and the pin flared on the protruding end to form a tack head. Additional pins are placed until the flap is secure. 3 to 10 pins have been required depending on length and width of the OCD flap.

Results
PDS pins have been used to repair OCD lesions in 44 stifles of 27 horses. Resolution of joint effusion occurred in all but 2 horses within 8 weeks of surgery. Radiographic improvement in lesion subchondral bone lucency commenced within weeks of surgery, and many lesions appeared radiographically resolved within 3 months of surgery. One horse was lost to follow-up due to a tendon laceration resulting in euthanasia 8
weeks after surgery. Of the remaining 26 horses, mean duration of follow-up was 15.6 months (range 2 months–12 years). Nine of these were sound and reached their intended athletic potential, 1 horse remained lame, and an additional 6 were sound but remained unbroken or were convalescing. For horses evaluated long-term, an overall success rate based upon continued soundness in performing horses was 95% (19/20). Resolution of the O.C. subchondral defect and contour irregularity was achieved in most horses, and reformation of the subchondral contour was better than that following cartilage flap removal.

**Transplantation Procedures**

The use of supplemental free cells, various vehicles containing cells, or entire tissues such as periosteum or cartilage grafts have been advocated to improve the modest impact that local manipulative procedures have on both the quality and quantity of cartilage repair tissues. Transplantation procedures can be divided into several currently acceptable areas, according to the type of transplant tissue: 1) osteochondral transplantation (mosaicplasty, 2) chondrocyte transplantation, 3) pluripotent stem cell transplantation, and 4) bone marrow aspirate concentrate (BMAC) implantation.

Transplantation of whole tissues and tissue engineered products usually requires arthrotomy approaches which are unsatisfactory in most equine joints. These include chondrocytes cultured on collagen (MACI), polyglycolic acid (PGA), or PGA/polyactic acid (PGA/PLA), or newer synthetic materials such as hyaluronan membranes. This serious practical limitation has tempered interest in using these implants.

**Clinical Results of Chondrocyte Transplantation**

Chondrocyte grafting in fibrin vehicles has been used successfully in the horse since 1995. Clinical resurfacing trials in horses have used a autogenous fibrin or more recently platelet rich plasma (PRP) as a vehicle, laden with 50 ug of IGF-1 and 30 million chondrocytes/ml of fibrin. Clinical application of this growth factor enhanced chondrocyte grafting process in horses has included traumatic cartilage lesions of the third carpal bone, fetlock metacarpal condylar fractures, and O.C.D. or subchondral cystic lesions of the fetlock (22 horses) and stifle (49 horses). Results for stifle OCD and subchondral cyst grafting of the stifle and fetlock metacarpal condylar fractures, and O.C.D. or subchondral cystic lesions of the fetlock (22 horses) and stifle (49 horses). Results for stifle OCD and subchondral cyst grafting of the stifle and fetlock have been generally good. Complete radiographic filling has occurred in more than half of the stifle OCD subchondral defect and contour irregularity was achieved in most horses, and reformation of the subchondral contour was better than that following cartilage flap removal.

**Clinical Applications of MSC Transplantation**

The current cell type of choice is an autologous MSC. Previous clinical work used chondrocyte allografts. However, allograft chondrocytes occasionally resulted in subtle immune reaction. Autologous MSC's avoid this problem, but result in further issues with inadequate chondrogenesis at the time of application. Bone marrow-derived MSC's can be harvested and directed down the chondrocyte lineage. In vivo studies in the horse indicate improved early healing in a femoral trochlear ridge healing model. Methods to induce chondrogenesis in MSC's are becoming better defined, and exposure to TGF-β1, 2, or 3, and Sox5,6 & 9, all induce chondrocytic transformation. Clinical cases are currently grafted with autogenous fibrin or PRP containing 20 to 30 million MSC's/ml of vehicle.

Platelet-enriched Plasma (PRP) as an Anabolic Vehicle - Time to surgery can be shortened by using PRP as a vehicle for stable implantation of MSC's. Fibrinogen requires 72 hours to prepare using cryoprecipitation, which delays the time to surgery after admission to the clinic. However, platelet-rich plasma can be prepared by centrifugation of blood in the surgery suite in 20 minutes, and has sufficient fibrinogen to clot and adhere securely to subchondral bone and cartilage edges. More importantly, PRP is rich in growth factors including PDGF, bFGF, and TGF-β, which drive chondrogenesis in MSC’s. Adding MSC’s also helps control the shrinkage associated with platelet degranulation during clotting. PRP makes a very effective vehicle for delivery of cultured MSC’s (Fig. 1).

MSC Application - At the time of surgery the MSC's are mixed with fibrinogen or PRP and stored at 4°C. The vehicle is clotted with 1000 units of activated thrombin, to provide a two-component system for immediate injection. At surgery, the polymerization process develops immediately upon injection of the two components into the articular defect. Arthroscopic application is routinely performed, using gas insufflation for the few minutes required for fibrin or PRP injection. Alternatively, for short term gas arthroscopy several 60 ml syringes of room air can suffice to dry the cartilage bed and allow injection of the MSC laden fibrin or PRP. The polymerizing liquid nature of fibrin or PRP allow contouring of the cell transplant to the irregularities of many joint surfaces.
Clinical application of MSC grafting in horses has included traumatic cartilage lesions of the fetlock metacarpal condyles and proximal P1, OCD or subchondral cystic lesions of the shoulder, fetlock, and stifle, and third carpal bone lysis, slab fracture, and bone cysts of other carpal bones. Results for stifle OCD and subchondral cyst grafting of the stifle and fetlock have been generally good. Many have been re-operation of previous failed therapies, including simple debridement with or without microfracture and steroid injection.

**Bone marrow aspirate concentrate (BMAC) for cartilage repair**

The development of patient-side centrifugation techniques for intraoperative stem cell isolation and purification for immediate grafting has provided significant advantages in time savings and immediate application of an autogenous cell for cartilage repair (Fig 2).

**REFERENCE LIST**