ASPECTS OF CURRENT MANAGEMENT

A clinical review of cartilage repair techniques

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Chondral injuries involving the knee are common. In a recent study of 993 consecutive arthroscopies scored using the International Cartilage Repair Society (ICRS) knee evaluation form,1 articular cartilage pathology was found in 66% of patients, while 11% had localised, full-thickness lesions which might have been suitable for cartilage repair procedures. Another review, of 31 000 arthroscopic procedures, found articular cartilage lesions in 63%2 and another reported the incidence of localised chondral and osteochondral lesions in 1000 consecutive arthroscopies to be 19%.3 Debate still persists about the best treatment for symptomatic chondral defects. Here, we discuss the efficacy of the different surgical techniques that may be used to address these lesions.

Natural history of cartilage injuries

The natural history of cartilage injuries is not well understood, but a knowledge of it may help to identify which patients are suitable for treatment. Chondral injuries noted at the time of anterior cruciate ligament reconstruction do not appear to affect clinical outcome at a mean of 8.7 years.4 Although these defects were small and, in a young population, it may be difficult to extrapolate these findings to patients presenting with symptomatic lesions. In a long-term follow-up of a small group of young patients noted to have chondral defects at arthroscopy, there was a high rate of radiological evidence of osteoarthritis (57%), although most patients had few symptoms.5

What can we learn from osteochondral defects? Linden6 published a long-term follow-up study on osteochondritis dissecans of the femoral condyles and evaluated 76 knee joints (58 patients) at a mean of 33 years after diagnosis. Of the 23 patients who were children at the time of diagnosis, only two (9%) had mild osteoarthritis at follow-up. In contrast, osteoarthritis affected 81% of those with adult-onset osteochondritis dissecans, approximately ten years earlier than for primary osteoarthritis.

From this limited information, it is perhaps reasonable to suggest that only symptomatic, chondral defects should be treated as there is no evidence to suggest that patients with asymptomatic lesions will become symptomatic in the future. Osteochondral defects in adults may warrant more aggressive attention because of the high incidence of early-onset osteoarthritis.

Debridement

Cartilage in and around a symptomatic chondral defect is abnormal. Mechanical overloading results in increased matrix metalloproteinase production7,8 which has a damaging effect on the opposing surfaces and surrounding cartilage. Simple excision of this damaged cartilage has been shown to improve symptoms for five years or more.9 Hubbard9 recommended selection of patients on the basis of a chondral defect combined with local tenderness. His aim at debridement was meticulous removal of all unstable cartilage and to abrade the calcified layer sufficiently for new tissue to form in the base. In this prospective randomised trial, only isolated medial femoral condylar defects were selected and arthroscopic lavage was used as the control. The debridement group had significant improvement when compared with lavage as measured by the Lysholm score.10 Results gradually deteriorated over the five-year period.

Studies of debridement in osteoarthritis, as opposed to discrete chondral defects, reach conflicting conclusions.11,12 Opinion is divided as to whether arthroscopic debridement has any place in the treatment of established osteoarthritis although this debate does not apply to the treatment of localised, symptomatic chondral defects.

Microfracture

This procedure was introduced by Steadman et al13-18 20 years ago and is a technique in which accurate debridement of all unstable and damaged articular cartilage is performed, down to
the subchondral bone plate while maintaining a stable perpendicular edge of healthy cartilage. An arthroscopic awl is used to make multiple holes in the defect 3 to 4 mm apart, and ensuring the subchondral plate is kept intact. After this microfracture, the defect is filled with so-called super clot, said to be the optimal environment for pluripotential marrow cells to differentiate into stable tissue. The rehabilitation protocol is an important part of the microfracture procedure. Early mobility of the joint with continuous passive motion is advocated in conjunction with reduced weight-bearing for an extended period.

Microfracture is a modification of the Pridie drilling technique. Microfracture, drilling and debridement (abrasion) may all be considered as marrow stimulation techniques, where the chondral lesion is exposed to material moving from the bone cavity through the subchondral plate. This layer is unsealed by removing the lower, calcified layer of articular cartilage and by making holes which penetrate the subchondral plate. Advantages of microfracture over drilling might include reduced thermal damage to subchondral bone and the creation of a rougher surface to which repair tissue might adhere more easily. It is also easier to penetrate a defect perpendicularly with a curved awl during an arthroscopic procedure as compared with a drill. There are currently no published studies which compare microfracture with drilling.

According to Hunziker, marrow-stimulation techniques have acceptable clinical results up to five years and decline thereafter, although Steadman et al recently published outcomes of microfracture to show that at seven years 80% of patients rated themselves as improved. They also found that patients aged less than 35 years improved more than those aged between 35 and 45 years. The patients in this study were retrospectively selected from a larger group and had relatively small chondral defects, with a mean size of 2.8 cm², although no histological results were presented. However, Knutsen et al described 20 biopsies after microfracture and noted that 11.4% had predominantly hyaline cartilage and 17.1% a mixture of fibrocartilage and hyaline cartilage within them. There is much interest in microfracture as a treatment of chondral injuries in professional sports players. In a series of 25 National Football League American football players, Steadman et al reported that 76% of players returned to their sport by the next season although this reduced to 36% at a mean follow-up of 4.5 years.

**Mosaicplasty**

Mosaicplasty, or osteochondral cylinder transplantation, was first described in 1993 and is a technique that has been widely advocated. In this procedure, osteochondral plugs are taken with a cylindrical cutting device and used to fill an articular cartilage defect. Plugs are usually taken from the peripheries of both femoral condyles at the level of the patellofemoral joint and introduced as a mosaic to fill the defect. Different sizes of plug can be used in order to maximise filling of the defect. The technique is usually undertaken as an open procedure, although it is possible to perform it arthroscopically.

Advantages of this technique are that defects can be filled immediately with mature, hyaline articular cartilage and that both chondral and osteochondral defects can be treated in the same way. However, donor site morbidity is a concern and Hangody and Fules recommend that the area to be treated is limited to between 1 and 4 cm². There are also technical difficulties in restoring the surfaces of both cartilage and bone to produce a smooth, convex joint surface. The thickness of the donor cartilage may differ from that of the area to be treated and reconstitution of the important subchondral layer may not occur. In addition, lateral integration rarely occurs raising the concern that synovial fluid may penetrate through the subchondral layer and cause cyst formation. Perpendicular access to the cartilage surface by cylinder cutters is required for this technique and this makes treatment of defects of the tibial plateau difficult. Bentley et al advised against using mosaicplasty on the patella.

The largest single series of mosaicplasty to date is that of Hangody and Fules who reported the results of operations on 597 femoral condyles, 76 tibial plateaux and 118 patellofemoral joints at up to ten years post-operatively. Good or excellent results were reported in 92%, 87% and 79% of patients who underwent mosaicplasty of the femoral condyle, tibial plateau and patellofemoral joint respectively. This paper does not give the mean time to follow-up and did not discuss the survival of osteochondral grafts in those patients with the longest follow-up.

**Perichondrial grafts**

This technique, which was described by Homminga et al, uses autologous strips of perichondrium fixed to the subchondral bone with fibrin glue. The long-term results for 88 patients with a mean follow-up of 52 months showed good results in only 38% using the Hospital for Special Surgery score. In a histological analysis of 22 biopsies taken after perichondrial grafting, tissue with a hyaline morphology of over 50% was found in only six biopsies (27%).

**Carbon fibre**

Fine spaces between the fibres of carbon-fibre rods direct the regeneration of tissues onto the surface of a joint. Good clinical results have been reported for both chondral and osteochondral defects. Carbon-fibre matrix is more commonly used in the patella but was reported by Meister, Cobb and Bentley to give good results in only 41%. No systematic histological study has been reported but, in failed implants, poor quality fibrous tissue with carbon fibre fragmentation is seen over the pads. The main disadvantage of carbon rods is the introduction of a non-absorbable material deep to the subchondral bone.

In early osteoarthritis, Brittberg, Faxen and Peterson had 83% success in 37 patients who were studied prospec-
tively. This may, therefore, be the best indication for the use of carbon fibre, where there are degenerative changes present and when knee replacement would be the next form of treatment.

**Osteotomy**

Osteotomy is usually reserved for early unicompartamental osteoarthritis. Three studies are of relevance when studying articular cartilage healing.

Wakitani et al\(^{38}\) observed that cartilage healing principally occurred only when cartilage loss was down to bone. In this study, osteotomies were performed and the knees were arthroscopically reassessed a year later. A better Outerbridge score\(^{39}\) was found in those joints where there was full-thickness cartilage loss before osteotomy.\(^ {38}\) This might appear strange but is consistent with the effect of debridement where bone can heal but cartilage does not.

Schultz and Gobel\(^ {40}\) looked at four groups of patients who underwent a Coventry-style tibial osteotomy. All had a follow-up arthroscopy and biopsy which demonstrated thicker tissue and improved histology when Pridie drilling or abrasion arthroplasty was combined with the osteotomy.\(^ {40}\) An improved walking distance and knee extension in these groups was also claimed.

Wakitani et al\(^ {41}\) cultured autologous bone marrow stem cells to add to the tibial plateau after osteotomy in 12 patients and compared these with a control group of 12 patients who received an osteotomy alone. Cultured stem cells were suspended in a collagen gel and covered with a patch of periosteum. Better histology was obtained at a year but there was no significant clinical benefit in the short term compared with the control group.\(^ {41}\) Evidence from Peterson et al\(^ {42}\) in Gothenburg, using autologous chondrocyte cell implantation in isolated chondral defects, predicted good long-term results at seven years for those who had good results at two years after surgery. Combined cell therapy with osteotomy may be a logical way to develop better long-term results in unicompartamental arthritis.

**Periosteal grafts**

Periosteum has the potential for both chondrogenesis and osteogenesis\(^ {43}\) and its use has been described in a number of publications.\(^ {44-51}\) Lorentzon et al\(^ {49}\) reported promising results in treating patellar lesions in a study of 26 patients with a mean follow-up of 42 months. They showed that 17 patients had excellent and eight had good results. Only one patient had a poor outcome. Interestingly, they combined grafting with drilling of the defect bed and thus allowed marrow elements to contribute to the repair.\(^ {49}\) To date, these clinical results are comparable with other techniques for patellofemoral lesions. Alfredson and Lorentzon\(^ {48}\) reported on the post-operative benefits of continuous passive motion in a study of 57 patients with patellar defects who were treated with periosteal grafts. Of the 38 patients who used continuous passive motion post-operatively, 76% had an excellent or good result at a mean follow-up of 51 months. Of the 19 patients who did not have continuous passive motion post-operatively, 53% had an excellent or good result at a mean follow-up of 21 months.\(^ {44}\)

One study from Finland reported good clinical results with periosteum after four years.\(^ {47}\) However, by 12 years after treatment all the patients had a poor clinical result. Calcification of the grafts has been mentioned as a problem in the long term. In a recent paper in the Chinese literature,\(^ {51}\) periosteal grafting in association with a silicon membrane, which was removed at six months, was described as a treatment for large cartilaginous defects in 37 patients. The follow-up was a mean of 10.5 years (7 to 15). The lesions treated were secondary to congenital hip dysplasia (16 patients), post-traumatic osteoarthritis of the hip (six), septic arthritis of the hip (one), ankylosing spondylitis (two), intra-articular knee fractures (six), osteoarthritis of the knee (four), and septic arthritis of the knee (two). In this heterogeneous group of patients with significant pathology, the clinical results at follow-up were described as excellent in 11 patients, good in 18 and poor in eight.

**Autologous chondrocyte implantation**

The technique of autologous chondrocyte implantation (ACI) was first performed by Peterson et al\(^ {52}\) in Gothenburg in 1987 and was the first application of cell engineering in orthopaedic surgery. Cartilage is harvested at an initial arthroscopy, and culture-expanded autologous chondrocyte cells are injected into a chondral defect underneath a patch of periosteum.

Brittberg et al\(^ {53}\) presented the results of 23 patients with a mean follow-up of 39 months. Good or excellent clinical results were reported in 70% of cases (88% of femoral condylar defects). Of the biopsies from treated femoral condylar lesions, 11 of 15 had a hyaline-like appearance. A more recent publication from the same group showed durable results up to 11 years following the treatment of osteochondral lesions.\(^ {52}\) Encouraging results of ACI have also been reported by other authors.\(^ {54-57}\)

In studies where histological analysis has been performed,\(^ {58}\) it is apparent that ACI is capable of producing tissue which is hyaline-like in some specimens. However, the best repair tissue is not morphologically or histochemically identical to normal hyaline cartilage, and fibrocartilage may be found in a proportion of samples.

A variation of the ACI technique using culture-expanded bone marrow stem cells has the advantage of not requiring an additional arthroscopic procedure in order to harvest articular cartilage. This technique has been used in conjunction with high tibial osteotomy.\(^ {41}\)

**Randomised clinical trials**

Horas et al\(^ {50}\) presented a prospective, comparative trial looking at two-year outcomes of 40 patients randomised to either ACI or osteochondral cylinder transplantation. Each group consisted of 20 patients. No significant difference was found in the Tegner\(^ {59}\) and Meyers scores,\(^ {60}\) although
Lysholm scores\(^{10}\) at six, 12 and 24 months were significantly higher in the osteochondral cylinder transplantation group.

Bentley et al\(^{31}\) presented a larger trial of 100 patients who were randomised to either ACI (58 patients) or mosaicplasty (42 patients). In the ACI group, either periosteum or porcine collagen membrane was used and in contrast with many rehabilitation protocols, patients were immobilised in a cylinder cast for ten days after surgery in both groups. There was no significant difference between the groups. However, subgroup analysis showed that the Cincinatti score\(^{61}\) was significantly better in medial femoral condyles treated by ACI compared with those treated by mosaicplasty (\(p < 0.032\)). Arthroscopy was performed at one year in some of the patients and the ICRS assessment showed significantly better grades in the ACI group (\(p < 0.01\)).

A randomised trial from Norway compared ACI with microfracture two years after surgery with 40 patients in each group.\(^{21}\) There was little difference between the groups, and the only score which revealed a difference was the SF-36 physical component score which was significantly better for the microfracture group (\(p = 0.004\)). There were no significant differences in either the ICRS arthroscopic evaluation or the histological assessment between the two groups.

Discussion

The role of cartilage repair techniques will continue to be debated. Several techniques give reasonable short- and medium-term results. Randomised clinical trials have, as yet, failed to identify a method of cartilage repair which is superior. Bentley et al\(^{31}\) study was slightly in favour of ACI, the Norwegian study\(^{21}\) favoured microfracture and Horas et al\(^{49}\) concluded that there was no compelling evidence in favour of mosaicplasty or ACI, in correspondence published in response to their paper.\(^{62}\)

Marrow-stimulation techniques have the advantage of being easily performed arthroscopically. They may be most suitable for smaller, well-contained lesions. Larger lesions may be more amenable to treatment with ACI. The place for mosaicplasty is not well defined and, when compared with ACI in randomised trials, there has been one study in favour and one against.\(^{30,31}\) ACI has shown good long-term durability and moderately good histological findings, but it is not known if it will prove cost-effective in the long term.

Is the addition of cultured chondrocytes beneath a periosteal patch of additional benefit to periosteal grafting alone? No clinical trials to compare these techniques has been completed, although periosteal grafting alone has not shown the long-term durability of ACI.\(^{42}\)

Intense research is underway into second generation tissue-engineering solutions for cartilage repair. A number of approaches are being investigated and new techniques will allow arthroscopic implantation of cells, thereby reducing morbidity. Autologous chondrocytes may be delivered on either a matrix\(^{63,64}\) or gel.\(^{65}\) Alternative cell sources such as bone-marrow-derived mesenchymal stem cells\(^{41}\) are also being investigated and may reduce the possibility of donor-site morbidity. Are cultured cells needed at all? Microfracture has shown good results, especially for smaller, well-contained defects. A combination of microfracture and a synthetic matrix may allow larger chondral defects to be treated. The addition of growth factors or gene vectors into a matrix may stimulate the transformation of the bone marrow cells into chondrocytes.

Of the numerous techniques available today, no method has as yet been able to consistently reproduce normal hyaline cartilage, and the best treatment in the long term is still unknown. Further randomised trials are needed to compare the long-term results of existing treatments. In the United Kingdom the Medical Research Council is funding a multicentre, randomised trial of ACI vs alternative non-cell-based cartilage repair techniques, with a planned ten-year follow-up period. This trial may provide answers, although the field of cartilage repair will remain controversial for some time to come.

Supplementary material

A further opinion by Tim Briggs is available with the electronic version of this article on our website at www.jbjs.org.uk

References


