Acetabular augmentation at six- to 30-year follow-up

A BIOCHEMICAL AND HISTOLOGICAL ANALYSIS

M. Diab, J. M. Clark, M. A. Weis, D. R. Eyre

From the University of California San Francisco, San Francisco and the University of Washington, Seattle, USA

In developmental dysplasia of the hip, a deficient acetabulum may be augmented by placing local autogenous iliac osseous graft, or the ilium itself, over the head of the femur with the expectation that the added bone will function as a bearing surface. We analysed this bone obtained en bloc during subsequent surgery which was performed for degenerative osteoarthritis in three patients at 6, 25 and 30 years after the initial augmentation procedure. In each patient, the augmentation comprised of red cancellous bone covered on its articulating surface by a distinct layer of white tissue. Microscopy of this tissue showed parallel rows of spindle-shaped cells lying between linearly arranged collagen bundles typical of joint capsule. Biochemical analysis showed type I collagen, the principal collagen of joint capsule and bone, with no significant quantity of type II collagen, the principal collagen of cartilage. While the added bone produced by acetabular augmentation was durable, histological and biochemical analyses suggested that it had not undergone cartilage metaplasia. The augmented acetabulum articulates with the head of the femur by means of an interposed hip joint capsule.

In developmental dysplasia of the hip, salvage procedures increase the capacity of the acetabulum and provide cover when the head of the femur cannot be contained by osteotomy and re-orientation of the normal hyaline cartilage surface of the acetabulum. In acetabular augmentation, a deficient acetabulum is enlarged by construction of a shelf from local autogenous iliac osseous graft.1 Medial displacement osteotomy of the pelvis brings the head of the femur beneath a cut surface of ilium.2 These procedures increase the weight-bearing surface and oppose further lateral and cephalad migration of the head of the femur. In response to weight-bearing, the new articulating surface is said to undergo metaplasia to fibrocartilage.3-5

We analysed the articulating surfaces of two slotted acetabular augmentations which were harvested during total hip arthroplasty, and of a medial displacement osteotomy of the pelvis harvested at hip arthrodesis. The secondary procedures were performed for disabling osteoarthritis at 6, 25, and 30 years following the augmentation procedures, respectively. The specimens were assessed to determine whether true metaplasia to fibrocartilage had occurred at the surface of contact between the augmentation and the head of the femur.

Patients and Methods

Three female patients underwent secondary procedures for disabling hip pain some time after acetabular augmentation for developmental dysplasia of the hip.

In the first patient, a shelf acetabular augmentation of the left hip which had been performed at six years of age was converted to total hip arthroplasty when she was 36 years of age. Radiographs showed that there was near-total loss of joint width in the central weight-bearing portion of the native acetabulum with partial preservation of a radiolucent space between the head of the femur and the shelf.

In the second patient, a shelf acetabular augmentation of the left hip which had been performed at 11 years of age. A total hip replacement was undertaken at 36 years of age. Radiographs and computerised axial tomograms demonstrated a normal joint width in the region of the native acetabulum and anterolaterally beneath the area of augmentation. Diagnostic arthroscopy of the hip showed that, while the augmentation was entirely covered by white soft tissue, this was malacic and fibrillated. A dense fibrous band, identified as a remnant of the acetabular labrum, was interposed between the original acetabulum and the area of augmentation.
In the third patient, developmental dysplasia of the hip was recognised at three months of age as a radiographic dislocation. After unsuccessful attempts at closed and open reduction of the hip, as well as an osteotomy of the femur, the patient underwent a medialisation osteotomy of the pelvis at the age of 11 years. Because of intractable pain, this was converted to an arthrodesis of the hip at the age of 17. Radiographs showed no significant osteonecrosis of the head of the femur and a preserved joint width between the native acetabulum and augmented ilium and the head of the femur.

In each patient, an intact block of tissue was harvested from an area of the augmentation which had articulated with the femoral head (Fig. 1). The specimen consisted of red cancellous bone covered on its weight-bearing side by a well-demarcated layer of white soft tissue approximately 2 mm thick (Fig. 2). Tissue from the two shelf procedures was prepared for histology and all three specimens were analysed biochemically for their collagen type.

For histological analysis, the articular aspect of the specimen was fixed in glutaraldehyde, decalcified in ethylenediaminetetracetic acid (EDTA) and embedded in epoxy resin. Sections of 1 µm were taken perpendicular to the articular surface and stained with toluidine blue.

For biochemical analysis, the articulating surface was dissected from the osseous augmentation and washed in normal saline solution with inhibitors (2 mM EDTA), 5 mM benzamidine, 10 mM phenanthroline, 2 mM phenylmethylene sulfonylfluoride). The tissue was digested with cyanogen bromide in 70% formic acid at room temperature for 24 hours. The specimen was dried and brought up in sodium buffer (2mg/ml) to run on 12.5% sodium dodecyl-sulphate-polyacrylamide gel electrophoresis. Protein bands were stained with coomassie blue. A Western blot test was performed and probed with the 1C10 antibody (0.5 µg/ml), which recognises a specific sequence (corresponding with residues 934-942 of the triple helix) in the cyanogen bromide digestion fragment CB9,7 of collagen type II.

Results

Histological analysis. In both shelf specimens, the articulating layer of soft tissue rested on a plate of mature bone with supporting trabeculae and normal bone-marrow spaces. The majority of the tissue consisted of collagen fibres orientated principally in a direction which was parallel to the articular aspect of the specimen (Fig. 2a). The collagen fibres displayed a regular crimp and no metachromasia was observed in the surrounding extracellular matrix. Cells in the tissue were primarily spindle-shaped fibroblasts. Rounded cells, clustered in longitudinal strings and surrounded by lacunae, were observed only at the bone interface and metachromasia was limited to the lacunar spaces around these cells. There was no distinct layer of fibrocartilage at this interface.

The articulating surface of the specimens was smooth, and the uppermost 50 µm layer was virtually acellular (Fig. 2b). Some horizontal fissuring between the collagen fibres was apparent. The fibrous tissue appeared fixed to the underlying bone (Fig. 2c). Fibres from the deep aspect of the fibrous layer curved into the bone and interdigitated with mature lamellar bone.

Biochemical analysis. Sodium dodecylsulphate-polyacrylamide gel electrophoresis of the cyanogen bromide-digested sample of articular surface tissue showed a pattern of protein fragments characteristic of type I collagen (Fig. 3a). No bands of type II collagen were evident in significant quantity. Because fibrocartilage has been shown to contain a mixture of types I and II collagen, a more sensitive Western blot analysis was applied to a duplicate sodium dodecyl-sulphate-polyacrylamide gel using a monoclonal antibody that detects an epitope in the triple-helical domain of type II collagen. Results of this analysis (Fig. 3b) confirmed the absence of type II collagen from the articulating surface tissue.

Discussion

There is a widely held belief that the articular surface of the shelf of bone produced by salvage procedures for acetabular dysplasia, including shelf augmentation and medial displacement osteotomy of the pelvis, undergoes metaplasia to acquire some characteristics of hyaline cartilage. Chiari suggested that, under the influence of force transmitted...
through the femoral head, the cancellous bone of the ilium would remodel to become congruent with the native acetabulum, and the interposed capsule of the hip joint would transform into a fibrocartilaginous articular surface. In 1987, Pozo et al. proposed that similar remodelling might transform the interposed capsule in the Colonna-Hey Groves arthroplasty into hyaline tissue. This speculation was supported by histological studies in animals and of tissue removed from patients. In a rabbit model of a medial displacement pelvic osteotomy, Hiranuma et al. observed increased density of collagen fibres and ovoid cells in the interposed joint capsule with the same physical consistency as the native acetabular hyaline surface at six months after surgery, and they cited this as evidence of cartilage metaplasia. Smith et al. found fibrocartilage beneath a shelf performed at 13 years of age when the joint was converted to a total hip arthroplasty 24 years later. Staheli and Chew made reference to the articular fibrocartilaginous surface of a segment of a slotted augmentation removed in order to relieve impingement to abduction of the hip, and concluded that the capsule under the shelf undergoes metaplasia to fibrocartilage. Litt and Coutelier provided histological evidence of partial transformation of joint capsule to fibrocartilage 25 years after a Colonna capsular interposition arthroplasty.

We have analysed biochemically the articulating surface of three bony augmentations for their collagen type, in addition to undertaking histological studies. Our findings do not support the concept that the added bone and interposed capsule undergo metaplasia to hyaline cartilage or fibrocartilage. Biochemical analysis yielded only type I collagen, the principal collagen of bone, ligament, tendon and capsule. Even the small amount of type II collagen (about 2% of total collagen) found in the surface zone of a meniscus, a typical articulating fibrocartilaginous structure, would be readily evident by Western blot analysis, yet this technique did not reveal any type II collagen in the augmentation specimens. The tissue therefore appears to lack any evidence of hyaline or fibrocartilage by its collagen phenotype. Given its dimensions, structure and composition, we conclude that the articulating tissue lining these augmentations is an enduring remnant of the joint capsule that has fused to the subjacent bone.

The shelf of bone produced by acetabular augmentation in our patients was effective in containing the head of the femur. By radiographic, histological and biochemical criteria, these were successful interposition arthroplasties, with incorporation of the capsule of the hip as the articular surface of the augmentation. The eventual development of disabling hip pain suggests that the augmentations did not reproduce the functions of hyaline cartilage, including the ability to withstand compressive force and reduce friction.

The importance of recognising that the interposed capsule of the hip serves as a weight-bearing surface without undergoing cartilage metaplasia is twofold. Firstly, it should aid in counselling patients that such salvage procedures do not restore normal function of the hip; osteoarthritis is not prevented but delayed. Secondly, it questions the relevance of augmentation or other salvage procedure for dysplasia of the hip, or containment of the head of the
femur (e.g., in Perthes’ disease), when re-orientation procedures are available. The concept of cartilage metaplasia lends weight to the argument that acetabular augmentation is a less aggressive way to construct a functional articulation in young patients. In view of our finding that the capsule does not transform into cartilage or fibrocartilage, rotational acetabular osteotomy may offer better long-term outcomes by bringing hyaline cartilage over the head of the femur.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References