FIXATION OF OSTEOCHONDRAL FRACTURES IN RABBIT KNEES

A COMPARISON OF KIRSCHNER WIRES, FIBRIN SEALANT, AND POLYDIOXANONE PINS

B. R. Plaga, R. M. Royster, A. M. Donigian, G. B. Wright, P. M. Caskey

From Wilford Hall USAF Medical Center, Texas

We compared fibrin sealant, polydioxanone (PDS) pins and Kirschner wires in the fixation of osteochondral fractures in rabbit knees. Standardised osteochondral fractures of the right medial femoral condyle were made in 56 adult New Zealand white rabbits. There were equal groups of control knees, and those which had Kirschner-wire, fibrin-sealant or PDS-pin fixation. No external immobilisation was used. One animal from each group was killed at two, three and four weeks. The remaining rabbits were killed at six weeks.

A fracture which healed with less than 1 mm of displacement was considered a success.

There was successful healing in 29% of the control group, in all of the Kirschner-wire group, in 50% of the fibrin-sealant group, and in 86% of the PDS-pin group. The use of PDS pins appears to be a reliable alternative to the use of metal in the fixation of osteochondral fractures in rabbits.

Osteochondral fractures and osteochondritis dissecans are common orthopaedic conditions, and many are treated by metallic fixation using Kirschner wires, Herbert screws or mini-fragment screws. This can be difficult and time-consuming; a second operation is often needed for the removal of metal.

Alternatives to metal fixation have been investigated. These include: cyanoacrylate adhesives (Harper and Ralston 1983; Harper 1988); polymethylmethacrylate cement (Weber and Chapman 1984; Rutherford, Cardea and Jessee 1987); and fibrin adhesives (Zilch 1980; Meyers and Herron 1984; Weber and Chapman 1984; Keller et al 1985; Schlag and Redl 1988). The ideal bonding agent for bone should allow the anatomical reduction of fracture and joint surfaces, have enough strength to resist displacement, not require removal, and be neither toxic nor carcinogenic.

We have evaluated fibrin-sealant and polydioxanone pins (Orthosorb; Johnson and Johnson, Braintree, Massachusetts) in comparison with Kirschner wires, for the fixation of unstable osteochondral fractures in rabbit knees.

MATERIALS AND METHODS

We divided 56 adult New Zealand white rabbits of either sex, weighing 4 to 5 kg, into four treatment groups of 14 each, designated: control, Kirschner (K) wires, fibrin-sealant and polydioxanone (PDS) pins.

The rabbits were anaesthetised with intramuscular ketamine (35 mg/kg) and xylazine (0.5 mg/kg). The right hind limbs were prepared for sterile surgery. Through a medial parapatellar arthrotomy the patella was dislocated laterally to expose the distal femoral articular surface. A 6 mm osteotome and a mallet were used to create an oblique osteochondral fracture of the medial femoral condyle (Aichroth 1971) (Fig. 1). All soft-tissue attachments were cut, and the fragment was removed, measured, and then replaced in anatomical position.

In the control group of rabbits there was no fixation. In the K-wire group, two 0.71 mm K-wires were inserted in divergent directions to engage the opposite femoral cortex. They were placed at the edge of the articular surface of the fragment and countersunk.

For the fibrin-sealant group, we used a four-
component fibrin-sealant (Tissucol – Two Component Fibrin Sealant; Immuno AG, Vienna, Austria). This contains: 1) freeze-dried protein concentrate of human fibrinogen, factor XIII, fibronectin and plasminogen; 2) freeze-dried bovine thrombin (500 IU/ml); 3) aprotinin solution (fibrinolysis inhibitor); and 4) calcium chloride (40 mmol/l). These were heated to 37°C, mixed according to the instructions included in the kit, and applied to the fragment by a two-stage technique using equal amounts of first the sealer solution and then the thrombin solution. The fragment was then reduced anatomically and held with firm digital pressure for two to three minutes.

For the PDS group we used two 1.3 mm polydioxanone Orthosorb pins to stabilise the fragment. They were inserted through previously drilled 1.3 mm holes in divergent directions, and countersunk by about 1 mm below the articular surface.

The wounds were closed in two layers with absorbable sutures, and anteroposterior and lateral radiographs obtained. The animals were then returned to their cages and allowed to move freely with no immobilisation of the limb. At two, three and four weeks postoperatively, one animal from each of the four groups was killed. The remaining 11 rabbits from each group were killed at six weeks. Anteroposterior and lateral radiographs were obtained (Figs 2a, b) and the distal 4 cm of femur harvested.

Each specimen was inspected for cartilage change, fracture healing, and displacement under 3.5 × loupe magnification. The synovium was examined for evidence of inflammation and biopsies obtained. Specimens were fixed in 10% buffered formalin; after decalcification, sections of the fracture site were made and stained with haematoxylin and eosin. Light microscopy was used to assess both fracture and cartilage healing and inflammatory changes.

### RESULTS

The only postoperative complication was a superficial seroma in one control animal. All the rabbits limped for three to four days after operation and then moved normally.

The osteochondral fractures were similar in shape, but their size varied. The mean fragment size (length × width) was 58.5, 65.4, 66.4 and 72.2 mm² respectively for control, K-wire, fibrin-sealant and PDS-pin groups, giving an overall mean of 67.2 mm². The mean thickness of the fragments was 3.9 mm in all groups (Table I).

A successful result was recorded if there was radiographic and histological bony union, with less than 1 mm of displacement. Loose fragments and those which had displacement greater than 1 mm were recorded as failures. The results from each group were compared by chi-squared analysis with Yates’ correction (Table II).

### Table I. The size of the osteochondral fragment in each group

<table>
<thead>
<tr>
<th>Group</th>
<th>Length × width (mm²) (mean ± SE)</th>
<th>Mean thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>58.5 ± 7.0</td>
<td>3.7</td>
</tr>
<tr>
<td>K-wire</td>
<td>65.4 ± 9.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Fibrin sealant</td>
<td>66.4 ± 4.9</td>
<td>4.1</td>
</tr>
<tr>
<td>PDS pins</td>
<td>72.2 ± 7.6</td>
<td>4.1</td>
</tr>
</tbody>
</table>

VOL. 74-B, No. 2, MARCH 1992
Control group. In the control group of 14, four of the fractures (29%) healed in acceptable position, the other ten fragments being loose within the joint.

K-wires. In the K-wire group, all 14 fractures healed in an anatomical position. This was significantly better than the fibrin-sealant group (p < 0.01), but not better than the PDS-pin group (p = 0.46).

Fibrin-sealant. In the fibrin-sealant group, seven of the fractures (50%) healed anatomically, and seven fragments (50%) were loose in the joint. This was not significantly better than the control group (p = 0.44).

Polydioxanone pins. In this group, 12 fractures (86%) healed in a satisfactory position. This was better than in the fibrin-sealant group (p < 0.05). The two fragments which failed were loose in the joint; the PDS pins had sheared off at fracture level. The fragments (13 × 10 × 7 mm; 13 × 9 × 7 mm) were the largest in the entire study.

Histology. In all four groups, fragments which remained in anatomical position showed bony healing with bridging trabeculae as early as two weeks postoperatively. By six weeks there were mature trabeculae across the osteotomy site (Figs 3a, b). All the fragments which had become loose showed yellow, opaque discoloration of the articular cartilage with fibrocartilage deposited both on the undersurface of the fragment and on the defect in the medial femoral condyle (Fig. 4). The loose fragments also had hypocellularity of the marrow spaces and early evidence of trabecular bone necrosis. Synovial biopsies from all four treatment groups showed a hypercellular, chronic inflammatory-cell reaction.

DISCUSSION

Accurate internal fixation of small articular fragments to restore joint congruity can be difficult. Metallic internal fixation is the recognised method, but subsequent removal is often necessary, and implants must be countersunk to avoid further damage to articular cartilage. There is need for an acceptable alternative.

In Europe, fibrin adhesives have been investigated for various orthopaedic applications including repair of peripheral nerves (Matras, Dinges and Lassman 1972; Moy et al 1988) and of osteochondral lesions (Albrecht, Roessner and Zimmerman 1983), bone grafting (Bösch et al 1980), treatment of chronic osteomyelitis (Lack, Bösch and Arbes 1987), tendon repair, and the fixation of osteochondral fractures (Kaplonyi et al 1988; Schlag and Redl 1988).

In the United States, there have been several experimental investigations of the use of fibrin glue for the repair of the dura (Cain, Dryer and Barton 1988), menisci (Arnoczky, Warren and Spivak 1988), nerves (Narakas 1988), and osteochondral fractures (Meyers and Herron 1984; Weber and Chapman 1984). Commercially available fibrin adhesives have not yet been approved by the Food and Drug Administration for general clinical use.

Absorbable internal fixation devices made of biodegradable synthetic polymers (polydioxanone, polylactide, lactide-glycolide co-polymer and polyglycolide) have been available in Europe for about five years, and have been used successfully as absorbable rods, pins, and

Table II. Osteochondral fracture healing

<table>
<thead>
<tr>
<th>Group</th>
<th>Success (%)</th>
<th>Confidence interval (%)</th>
<th>Failure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>28.6</td>
<td>(10 to 61)</td>
<td>71.4</td>
</tr>
<tr>
<td>K-wire</td>
<td>100</td>
<td>(79 to 100)</td>
<td>0</td>
</tr>
<tr>
<td>Fibrin sealant</td>
<td>50</td>
<td>(21 to 79)</td>
<td>50</td>
</tr>
<tr>
<td>PDS pins</td>
<td>85.7</td>
<td>(61 to 97)</td>
<td>14.3</td>
</tr>
</tbody>
</table>

Fig. 3a
Photograph (a) and section (b) of an osteochondral fragment stabilised with two polydioxanone pins. Histology showed mature bony trabeculae across the osteotomy site (× 2).
screws in both experimental and clinical applications (Böstman et al 1989, 1990).

Greve and Holste (1985) first reported on the use of 1 mm polydioxanone pins to fix osteochondral fractures in rabbit knees: 14 of 18 fractures stabilised with two PDS pins healed anatomically. Claes et al (1986) evaluated the shear strength of osteochondral fractures fixed with PDS pins in sheep. The in vivo shear strength of 1 mm pins was 92 MPa, decreasing to approximately 45 MPa by five weeks. The mean shear strength of the healed fractures was 9.5 MPa at three months, compared with 11.5 MPa for normal bone. Haas (1986) reported on the use of polydioxanone pins in the treatment of hand fractures, and Böstman et al (1989, 1990) had satisfactory results with absorbable rods in treating ankle fractures.

We created unstable osteochondral fractures and compared the results of fixation with fibrin-sealant and absorbable PDS pins with internal fixation with K-wires. Our study could be criticised in that the experimental fractures were not exact replicas: there was a non-statistically significant difference in mean fragment size between groups. The control group had the smallest mean size and the polydioxanone-pin group the largest. The smaller fragments were possibly more stable than the larger, and more resistant to displacement.

This may explain the finding that four of the 14 fragments in the control group healed in an anatomical position; they were all quite small, with an average size of 38.5 mm². In the fibrin-sealant group the seven fragments which healed anatomically had a mean fragment size of 55.7 mm², smaller than the mean (78.8 mm²) for the seven fractures in this group which failed to heal. The only two fractures in the PDS-pin group which failed to heal had produced large fragments (130 mm², 117 mm²), and presumably there were large shear forces acting on the fragment.

The initial bonding strengths in tension of fibrin of PDS pins in animals with no external immobilisation used a smaller mean fragment size (20 mm²) than in our study. Greve and Holste (1985) reported 78% anatomical healing and Claes et al (1986) had 100% healing.

**Conclusions.** Our study has shown that an absorbable pin of polydioxanone appears to be a reliable alternative to metal for the fixation of unstable osteochondral fractures. Stabilisation with fibrin-sealant alone yielded inferior results; it should not be used as a sole means of fixation.

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Defense or other departments of the United States government.

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**


