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Fixation of osteochondral fractures

Fibrin sealant tested in dogs

Standardized osteochondral fractures in the left femoral condyle in 19 adult mongrel dogs were fixed with either fibrin sealant or Kirschner wire. Adaptation and mechanical strength after 4, 7 or 8, and 14 days were compared with an *in vitro* study of the initial strength of the fibrin sealant in osteochondral fractures. After 4 days, the maximum tensile strength was increased in the fibrin sealed group, whereas no difference in energy absorption at failure was found. Although the initial strength of the fibrin bond was low, the tendency to displacement was less in this group. Our results suggest that fibrin sealant can be used for fixation of small osteochondral fragments, provided that immobilisation is sufficient.

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In recent years fibrin sealant has received a great amount of attention in various areas of surgery (Schimpf 1980, Cotta & Braun 1982). In orthopaedics fibrin sealant has been suggested for the fixation of osteochondral fractures and in cancellous bone transplants (Zilch 1980, Bösch 1981, Braun et al. 1982, Meyers & Herron 1984).

We have compared fibrin sealant and Kirschner wire for fixation of an osteochondral fracture.

Material and methods

In 19 adult mongrel dogs, standardized osteochondral fractures were made in the medial and lateral condyles of the left femur through a lateral arthrotomy. The patella was dislocated medially, the tendon to the extensor digitorum longus muscle divided, and the infrapatellar corpus adiposum resected. The knee was then flexed maximally. An osteochondral cylinder with a diameter of 7 mm and a depth of 3 to 4 mm was made in the distal articulating surface of the femoral condyles with a specially designed circumferential saw mounted on a standard orthopaedic drill (Figure 1). A small slice of cartilage was resected anterior to the cylinder. Then the cylinder was resected just under the bone/cartilage interface with a 6 mm osteotome at a depth of 1.5 mm and at an angle of 30°. The smallest and largest height was recorded.

Fixation of these cylinder fragments was performed with 1.0 mm Kirschner wires or fibrin sealant after random allocation. The fragment was fitted into the condylar defect and two Kirschner wires were drilled through the fragment, crossing centrally and emerging on the medial and lateral aspects of the condyles. The wires were inserted so deeply that they did not protrude above the surface of the cartilage, and the other ends were bent and buried into the periosteum.

Approximately 0.2 ml mixed fibrin sealant (Immuno AG, Vienna, Austria) containing dog fibrinogen and Factor XIII (45 mg/ml), thrombin (125 I.U./ml), aprotinin (1500 I.U./ml) and CaCl (10 mM) was applied to the defect in the femoral condyle. The fragment was placed in the defect and gentle pressure was applied for 5 min. The patella was reduced and the wound closed in layers. One gram of ampicil-

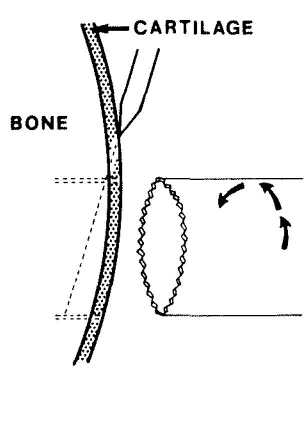

Figure 1. Standardized osteochondral fracture in the knee.

lin was given during induction of anaesthesia (intravenously), immediately postoperatively (intramuscularly), and daily during the following 5 days (subcutaneously). The left leg was immobilized with the knee in full extension taped to a brace which permitted ambulation. The dogs were observed daily and the brace adjusted if necessary.

Seven dogs were killed after 4 days, eight after 7 or 8 days, and four after 14 days. The distal 6 cm of the femur was sawn off and the semilunar cartilages were inspected. Displacement of the standardized fragment would necessarily result in an elevation of the edge. This was evaluated and rated on a semi-quantitative 1–4 scale: (1) elevation more than 0.5 mm in > 180° of the fragment circumference; (2) > 90° and < 180°; (3) > 0° and < 90°; (4) no elevation at all.

The distal femur was mounted in a specially designed cage which was adjustable so that the force of traction was perpendicular to the fragment (Figure 2) and a 5 mm plastic cylinder was glued to the fragment with cyanoacrylate.

The set-up was mounted in a materials testing machine (Alvetron 250, Lorentsen and Wettres) and traction applied with a constant speed of 10 mm/min, while load and deformation were recorded with transducers coupled to measuring bridges. The signals from the bridges were fed into an X–Y recorder in order to obtain a continuous load versus deformation curve for each specimen. The curves were read into a calculator by a digitizer, and maximum load values converted to maximum tensile strength values by dividing load values by the total area of bone contact between fragment and condyle. The area between the load-deformation curve and the deformation-axis to the point where failure became evident represented the energy absorption of the fracture. This area was calculated and divided by the total area of bone contact between fragment and condyle, giving the failure energy.

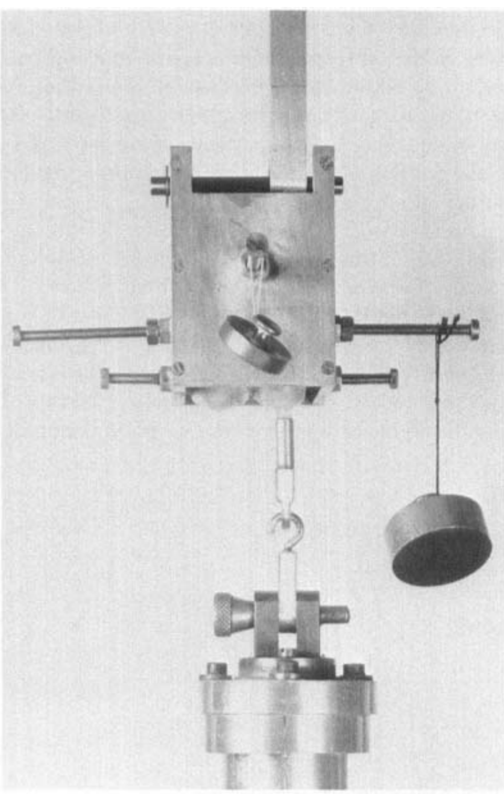

Figure 2. The distal femur is mounted in a special cage for mechanical testing. The osteochondral fragment is glued to the underlying cylinder with cyanoacrylate.

Table 1. Initial biomechanical properties of dog or human fibrin sealant-fixed osteochondral knee fractures. Values are mean ±SEM

	No.	Maximum tensile strength (N/cm^2)	Failure energy (N/cm)
Dog fibrin sealant	6	0.73±0.11	0.037±0.005
Human fibrin sealant	6	0.96±0.17	0.047±0.009

The initial mechanical strength of dog fibrin sealant was compared with human fibrin sealant (same concentration as described above) in standardized knee fractures in the right leg of the sacrificed dogs. The measurements were performed half an hour after application of the sealant, using the same procedure as described above.

The mechanical results were analyzed by t-test after assuring homogeneity of variances and normal distribution. The semi-quantitative data were analysed by Fisher's exact test.

Results

No difference in maximum tensile strength or failure energy was found between human and dog fibrin sealant (Table 1). After 4 days the maximum tensile strength of the fibrin sealed fragment had increased approximately sevenfold (Table 2). The maximum tensile strength of the fragments fixed with fibrin sealant was increased compared with those fixed with Kirschner wires, but no change in failure energy was found (Table 2). The total bone contact area of the fragments was almost identical

Table 2. Biomechanical properties in osteochondral fractures fixed with either Kirschner wire or fibrin sealant after 4 days of healing. Values are mean ± SEM

	No.	Maximum tensile strength (N/cm^2)	Failure energy (N/cm)
Fibrin sealant	7	5.1±0.8[a]	0.25±0.04
Kirschner wire	7	2.6±0.5	0.20±0.03

[a] $2P < 0.05$ compared to Kirschner wire.

(fibrin sealant 0.63 cm^2 ± 0.02 and Kirschner wires 0.64 cm^2 ± 0.02).

After 7 or 8 days, eight knees were tested. Six of eight fragments fixed with fibrin sealant and four of eight fixed with Kirschner wires could not be separated in the fracture line before breakage of the cyanoacrylate bond occurred in the range of 12–60 newton/cm^2. Two fragments fixed with fibrin sealant and four with Kirschner wire separated through the fracture line at load values of 5.8 and 10 and 3.1, 3.9, 4.7 and 15 newton/cm^2, respectively.

After 14 days, no fragments in the two groups could be separated through the fracture line. Breakage of the cyanoacrylate bond occurred in the range of 35–63 newton/cm^2.

In the semi-quantitative rating, 18 out of 19 fractures fixed with fibrin sealant and 12 of 19 fixed with Kirschner wires scored maximum points. This difference was significant. Damage to the underlying semilunar cartilage was registrated in one case of Kirschner wire fixation.

Discussion

In our model it was possible to create fragments of homogeneous quality and size, thus enabling comparison of different fixation techniques.

The initial maximum tensile strength of dog and human fibrin sealant, was considerably less than 7.1 newton/cm^2 reported by Claes et al. (1982). However, the circumstances differed as the two surfaces in their model were plane, whereas in our study they were less congruent.

Bösch (1981) measured the mechanical strength of fibrin sealant clots and found values of about 12 newton/cm^2. Initial strength between collagen wound dress and spleen tissue and between cellulose sponges fixed with fibrin sealant was 0.95 newton/cm^2 (Spilker et al. 1981) and 2.5 newton/cm^2 respectively (Andreassen & Jørgensen 1985). The sealant was broken between the fibrin clot and the attached surfaces rather than through the clot itself, corresponding to our observations.

The low initial mechanical strength in the fractures fixed with fibrin sealant demands a reliable immobilization to prevent displacement. This is in agreement with Braun et al. (1982) who reported displacement of 15 of 24 fractures in non-immobilized and 1 of 16 in immobilized knees in rabbits.

After 4 days, we found the fragments fixed with fibrin sealant had enhanced maximum tensile strength compared to those fixed with Kirschner wire, but there was no difference in failure energy; in addition, less displacement was found in the fibrin sealant fractures. Whether these findings were caused by a more satisfactory adaptation or rapid healing cannot be concluded from our study.

Zilch (1980) and Bösch (1981) have reported increased vascularisation and bone healing after application of fibrin sealant, but these findings were not confirmed in newer quantitative studies (Albrektsson et al. 1982, Lucht et al. 1985). Similarly, Andreassen & Jørgensen (1985) found no difference in formation of collagen and development of mechanical strength in granulation tissue formed in sponges treated with or without fibrin sealant.

We suggest that fibrin sealant can be used as an alternative method for the fixation of small, well-adapted, osteochondral fragments, provided reliable immobilization is obtained.

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