Minimal internal fixation and calcium-phosphate cement in the treatment of fractures of the tibial plateau

A PILOT STUDY

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We used calcium-phosphate cement combined with minimal internal fixation to treat 49 fractures of the lateral tibial plateau. There were 25 split depression fractures, 22 pure depression fractures and two bicondylar fractures. Anatomical reduction was obtained in 38 fractures, satisfactory reduction in nine and imperfect reduction in two. Of 44 patients reviewed at one year, 33 were rated as having an excellent reduction. Functional outcome as measured by the Rasmussen score was good or excellent at six months in 92% (44/48) of patients and in 95% (42/44) at one year. Eight (16%) showed some loss of reduction of the plateau. In seven of these the loss of reduction was slight (<3 mm) and no action was taken. One patient with a deep infection had gross loss of reduction and a poor functional outcome. Calcium-phosphate cement is a useful alternative to bone grafting for the treatment of fractures of the tibial plateau.

J Bone Joint Surg [Br] 2003;85-B:68-73.

Received 27 June 2001; Accepted after revision 13 March 2002

The treatment of choice for displaced fractures of the lateral tibial plateau is considered to be internal fixation.¹⁻⁶ The most common patterns encountered are split depression and localised depression fractures, both of which often require bone grafting in order to augment the internal fixation. Autologous bone graft is usually taken from the iliac crest, which is a painful procedure for the patient and carries a well-documented morbidity.^{7,8}

Recently, biomaterials have been developed which avoid the need for bone grafting.⁹⁻¹⁶ Calcium-phosphate cements are now available for use in metaphyseal fractures in which

autologous bone graft would normally have been required. The Norian Skeletal Repair System (SRS)^{12,17} is an injectable calcium-phosphate cement which hardens in vivo to form a carbonated apatite (dahllite). Its crystallinity and chemical composition are similar to those of the mineral phase of human bone. It also has a high compressive strength.¹⁷ The material can be used to fill contained defects in cancellous bone. Experimental and clinical data suggest that it may be useful in fractures of the distal radius and calcaneus,¹⁸⁻²¹ but, as yet, there are no clinical data on its use in fractures of the tibial plateau.

Our study is a prospective evaluation of calcium-phosphate cement for the treatment of fractures of the tibial plateau. Our aim was to determine whether a combination of calcium-phosphate cement and minimal internal fixation would be successful.

Patients and Methods

Between January 1997 and June 1999 we treated surgically 80 consecutive patients with fractures of the lateral tibial plateau. Of these, 49 patients (60%) had calcium-phosphate cement (Norian SRS, Cupertino, California) and minimal internal fixation. There were 26 men and 23 women with a mean age of 60 years (21 to 89). The mechanism of injury was a road-traffic accident in 17 (14 pedestrians, two car drivers and one cyclist), falls in 23, and sporting injuries in nine. In all, fracture of the tibial plateau was the only injury.

Using the classification of Schatzker et al,² there were 25 split depression fractures, 22 depression fractures and two

Table I. AO classification of fracture types for the 49 patients treated by minimal internal fixation and calcium-phosphate cement for fractures of the tibial plateau

AO group	Number of patients	Percentage
B2.1	2	4.1
B2.2	14	28.6
B2.3	6	12.2
B3.1	23	46.9
B3.2	1	2.0
B3.3	1	2.0
C3.1	2	4.1
Total	49	100.0

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doi:10.1302/0301-620X.85B1.12575 \$2.00

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Radiographs showing a) a depression fracture of the lateral tibial plateau, b) reduction and fixation with an AO screw with the nozzle of the cement gun in the subchondral defect, c) after insertion of calcium-phosphate cement intra-operatively and d) follow-up at two years.

bicondylar fractures. The fractures were also classified using the AO comprehensive classification²² (Table I). All patients were treated by minimal internal fixation using cancellous AO screws augmented with calcium-phosphate cement. The two patients with bicondylar fractures had additional external fixation. The median time from injury to surgery was four days (1 to 19). The senior author (JFK) carried out all the operative procedures.

Norian SRS consists of a dry powder of monocalcium-phosphate, tricalcium-phosphate and calcium carbonate and a sodium phosphate solution which are combined by an automatic mixer. The material is presented as an injectable paste in a plastic sleeve which is loaded into a delivery gun and injected into the cancellous bone defect (Fig. 1). It hardens in a non-exothermic reaction, begins to set within four

minutes and is almost completely set in 15 minutes. Thereafter, it hardens to 90% of its eventual compressive strength within four hours and reaches full strength within 24 hours.

Operative technique. The patient was placed supine with a tourniquet on the affected side and both knees flexed to 90°. The plateau was exposed through a lateral parapatellar, longitudinal incision. The lateral meniscus was elevated and conserved in all patients. A limited exposure of the proximal tibia was required, since buttress plating was not used. The fracture was reduced and the reduction maintained with AO cancellous screws, occasionally augmented by temporary Kirschner wires. The subchondral defect was cleaned of debris and irrigated with saline lavage. The calcium-phosphate cement was then used to fill this defect. The mean volume of calcium-phosphate used was 6 ml (3 to 10).

Table II. The range of knee movement after surgery for fractures of the lateral tibial plateau

Follow-up (weeks)	Mean loss of extension (degrees)	Mean range of flexion (degrees)
Discharge	9	74
3	7	82
6	5	101
12	1	118
26	0	125
52	0	129

After surgery, patients were mobilised in a hinged knee brace which allowed 90° of knee movement. They were advised to remain non-weight-bearing for two weeks and to have touch weight-bearing for a further two weeks. They were then allowed to progress to full weight-bearing by six weeks. Thromboprophylaxis with subcutaneous heparin was given in all patients during their stay in hospital.

Follow-up. The mean duration of follow-up was 18 months (12 to 24). Four patients had changed address or defaulted from follow-up after six months. One was followed up for six months and then died. To date, 44 patients have been followed up for one year or longer and of these 14 have been followed up for two years. They were seen at a specialist knee clinic and clinical examination was carried out by the senior author. Functional outcome scores and visual analogue pain scales were recorded by a research nurse.

The length of surgery, the implants used and the duration of the hospital stay were recorded for each patient. Complications requiring further surgery were recorded. The range of movement of the knee was measured with a goniometer. Valgus and varus instability was measured at 20° of knee flexion and compared with that on the normal side. The Lachman and anterior and posterior drawer tests were used to define any associated injury to the cruciate ligaments. Pain was assessed using a visual analogue scale and subsequently scored from one to ten, with ten being the most severe pain. The Rasmussen score²³ was used to evaluate function and the SF-36 questionnaire was used as a measure of general health outcome. These scores were assessed at six months and one year after operation.

Radiographs were used to assess the degree of maximal joint depression, before and after operation and at six, 12, 26 and 52 weeks. The reduction was graded as excellent if the residual depression was 2 mm or less, satisfactory if it was between 2 and 5 mm, and poor if it was greater than 5 mm. The radiographs were rated by the senior author and by a research assistant who was independent of the surgical treatment. Interobserver agreement was tested using Cohen's kappa statistic. The values for interobserver agreement for the initial degree of depression, the quality of reduction, and the loss of reduction were 0.67, 0.62 and 0.68, respectively. These indicated a good level of agreement and the methods of measurement were therefore considered to be reproducible. The incidence of new osteoarthritic changes was noted on radiographs.

Statistical analysis. Statistical comparison was made using the Mann-Whitney U test and Student's *t*-test. Significance was set at $p < 0.05$.

Results

The mean duration of surgery was 55 minutes (40 to 110). The median number of cancellous screws used was two. The median duration of hospital stay was nine days. For patients under the age of 60 years the median hospital stay was six days compared with ten days in patients aged over 60 years (Mann-Whitney U test, $p < 0.001$).

Functional outcome. The mean range of flexion and extension at the time of each review is shown in Table II. Two patients (4%) developed significant postoperative stiffness of the knee. Both had a manipulation under anaesthesia. In one patient the knee movement subsequently returned to normal. The other patient had persistent stiffness with a 10° flexion contracture and 105° of knee flexion two years after operation.

Associated injuries to ligaments were found in four patients. Two had grade-II sprains of the medial collateral ligament. These were treated non-operatively and there was no symptomatic residual instability. One patient had a mid-substance tear of the anterior cruciate ligament (ACL) which was associated with a peripheral depression fracture of the tibial plateau. The ACL tear was reconstructed using a quadruple hamstring graft. One patient had grade-III laxity of the medial collateral ligament and ACL insufficiency at one year with symptomatic instability. The bony reduction of the lateral plateau was satisfactory. The patient subsequently underwent reconstructions of the ACL and medial collateral ligament 18 months after injury with satisfactory restoration of stability.

Relief of pain was acceptable as measured by the visual analogue score. The median score at six weeks was two and at one year was one. The median Rasmussen score was 25 at six months (10 to 30) and 27 (18 to 30) at one year. This rating system allocates a maximum score of 30 to a normal knee. Based on the score, the result can be graded as excellent, good, fair or poor. The results were good or excellent in 92% (44 of 48) of patients at six months and 95% (42 of 44) at one year.

The SF-36 scores at six months, one year and two years are shown in Figure 2. The role function and physical function components of the score were low at six months, but returned to more normal levels by two years. The components of the score which evaluated emotional and mental function did not vary greatly over the period of the study.

Complications. There was one case of deep-venous thrombosis and two of pulmonary embolism. Infective complications occurred in three patients (6%). There were two superficial wound infections, which responded to antibiotic treatment and local dressings, and one deep infection. This occurred in a 78-year-old man who presented with an extensive split depression fracture in osteoporotic bone. A satis-

Fig. 2

SF-36 outcome after minimal internal fixation and calcium-phosphate cement in the treatment of 49 fractures of the tibial plateau (GH, general health; PF, physical functioning; RP, role physical; RE, role emotional; SF, social functioning; BP, bodily pain; VT, vitality; MH, mental health; RHT, reported health transition).

factory reduction was achieved initially, but a gradual loss of reduction occurred with resorption of bone around the cement. A sinus developed from the wound seven months postoperatively. The discharge cultured *Staphylococcus aureus*. The patient was readmitted and underwent an excision of the implants and the calcium-phosphate cement. He was severely cachectic because of an eating disorder and a knee replacement was not considered feasible. He declined an arthrodesis. The infection has now been eradicated, but he only walks short distances with the aid of a frame.

Radiological evaluation. The mean maximal preoperative joint depression was 9 mm (2 to 25). Thirty-eight patients had an excellent reduction with 2 mm or less of residual incongruity. In a further nine patients the reduction was satisfactory (2 to 5 mm incongruity) and in two it was poor, with a residual displacement of greater than 5 mm. Eight patients (16%) showed some loss of reduction. The initial reduction in four of these was excellent, satisfactory in three and poor in one. In seven the loss of reduction was slight (<3 mm) and no action was taken. Loss of reduction was associated with a split depression configuration in five patients and pure depression in three. This difference was not statistically significant. Loss of reduction was commoner in older patients. The mean age of patients with a loss of reduction was 68 years compared with 48 years in patients who maintained reduction ($p < 0.004$). The patient with a deep infection had gross loss of reduction and a poor outcome.

Of the 44 patients reviewed at one year, the anatomical result was excellent in 33 patients (Fig. 1d), satisfactory in seven and poor in four. The mean maximal joint depression at one year was 0.7 mm. At the time of the follow-up, nine patients (20%) had some radiological evidence of post-traumatic osteoarthritis. In all patients the changes were mini-

mal. Complete resorption of the cement had occurred in eight patients at one year. In the remaining patients, the cement was still visible with little evidence of resorption.

Discussion

Our findings suggest that calcium-phosphate cement, augmented with minimal internal fixation, is a useful alternative to buttress plating and bone grafting for fractures of the lateral tibial plateau. The operating time is short, the plateau can be reached with a reduced surgical exposure, and the pain and morbidity associated with using graft from the iliac crest are avoided. Despite the use of minimal internal fixation, satisfactory reduction was achieved and maintained in most patients. The functional and radiological outcomes have been good, although the follow-up has been short. Loss of reduction was the main complication and is more likely in older patients, which probably reflects the increased incidence of osteoporosis in these patients.

There is some experimental evidence concerning the effectiveness of calcium-phosphate cement, but published clinical data have been limited.^{12,14,17,24,25} Biomechanical cadaver studies of fractures of the distal radius, calcaneus and tibial plateau have shown that calcium-phosphate cement is more effective than bone grafting in maintaining articular reduction in response to axial loads.²⁴⁻²⁶ Our study is the first clinical evaluation of the material in the treatment of fractures of the tibial plateau. In previous studies of such fractures, satisfactory results have been reported with interporous hydroxyapatite as an alternative to bone graft.^{10,27}

Calcium-phosphate cements are a more recent alternative to bone grafting and have a number of advantages over other bone graft substitutes for these fractures. The material has a compressive strength comparable to cancellous bone and

sets in a non-exothermic reaction, which minimises cellular damage in adjacent bone. The cement-bone interface is satisfactory and the material is gradually incorporated into the surrounding lamellar bone structure.¹⁷ The crystalline structure closely resembles the mineral phase of normal bone which accounts for its biocompatibility. Careful surgical technique is required with this material. The handling characteristics are very different from those for acrylic cement. The material cannot easily be inserted by hand into a bony cavity. Meticulous preparation of the cavity is required to clear loose debris and the injection of the cement must be planned so that the deepest recesses are filled first. The cannula is then withdrawn and the more superficial areas are filled in a retrograde fashion.

Other clinical studies have reported the successful use of this material in other locations. Kopylov et al¹⁹ compared the use of a calcium-phosphate cement (Norian SRS) with external fixation for fractures of the distal radius. Early functional outcome in terms of grip strength was superior in the calcium-phosphate cement group, but there was no difference between the two groups at subsequent follow-up. Some loss of reduction was noted in both groups. In a prospective, randomised trial,²⁰ 110 patients with fractures of the distal radius were treated either with calcium-phosphate cement (Norian SRS) and a cast for two weeks or by routine closed reduction and a cast for six weeks. The functional outcome was better in the calcium-phosphate cement group at one year (82% satisfactory compared with 56% in the closed reduction group) and there was also a reduced rate of malunion (18% v 42% in the closed reduction group). In a clinical study carried out by Schildauer et al²¹ on 36 calcaneal fractures it was concluded that early weight-bearing was possible after the use of calcium-phosphate cement.

Although bone grafting may not always be necessary in the treatment of fractures of the tibial plateau there is evidence to suggest that its use gives superior results.⁶ In our previously published experience, bone grafting was required in 50% of patients.²⁸ Despite the use of bone graft and buttress plating in that series, there was a significant rate of loss of reduction and an incidence of degenerative change of 68% at follow-up. Other studies have confirmed a high rate of degenerative change in the knee after fractures of the plateau with an incidence of between 30% and 80%.^{1,29-32}

It is generally accepted that the key to minimising the risk of post-traumatic osteoarthritis is to maintain an accurate reduction of the articular surface while the fracture heals.^{3,32} We consider that calcium-phosphate cement is a useful alternative to autogenous bone graft for fractures of the tibial plateau and may be a superior way of maintaining articular reduction in response to an axial load. Although this study shows the feasibility of this material for fractures of the tibial plateau, the main weakness is the lack of a control group. A randomised study is now required to validate these promising results.

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.

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