



## An analysis of different types of surgical fixation for avulsion fractures of the anterior tibial spine

Ajay SHARMA, Palaniappan LAKSHMANAN, Jeetender PEEHAL, Huw DAVID

*From the University Hospitals of Wales, Cardiff, United Kingdom*

This is a retrospective study of 25 patients, looking at the outcome of open reduction and fixation of displaced anterior tibial spine avulsion fractures with absorbable and non-absorbable materials. The mean period of follow-up was 44 months (range, 21 to 88 months). The results of surgery were assessed clinically and radiologically. Outcome was evaluated by using the Lysholm knee scoring system. Anterior cruciate ligament laxity was assessed by using a KT-1000 arthrometer and range of movements with a goniometer. Overall, children did better than adults, but age *per se* did not appear to affect the final outcome. There was no significant difference between children fixed with absorbable or non-absorbable materials. Adults fixed with non-absorbable material had significantly better results than those fixed with absorbable material. Herbert screws had a tendency to migrate into the bone substance, and are best avoided. Protected early mobilisation in a knee brace was found to be safe and helped to regain early range of movements in the knee joint.

**Keywords** : anterior tibial spine fracture ; anterior cruciate ligament laxity ; range of movements ; knee score.

### INTRODUCTION

Fracture of the anterior tibial spine is an uncommon injury occurring more in children than in adults. Skak *et al* reported an incidence of 3 per 100,000 children each year (13). In children the usual mechanism of injury is a fall from a bicycle

or a wall, and in adults a sports or road traffic accident injury. There has been a limited number of studies on this injury looking at the management with conservative and surgical methods. It has become apparent that surgery (open or arthroscopic) offers the best chance of full recovery following a completely displaced anterior tibial spine fracture. We retrospectively studied 25 patients with a displaced anterior tibial spine fracture treated by open reduction and internal fixation. The study looked at the outcome of treatment in relation to the age of patients at the time of injury, mode of injury, type of fracture, associated injuries ; we also compared the results of absorbable and non-absorbable materials used for fixation of displaced

---

■ Ajay Sharma, MS (Orth), MCh (Orth), Consultant Orthopaedic Surgeon.

*University Hospital of Wales, Cardiff, United Kingdom.*

■ Palaniappan Lakshmanan, MS (Orth), AFRCs, Specialist Registrar – Trauma & Orthopaedics.

*Freeman Hospital, Newcastle-Upon-Tyne, United Kingdom.*

■ Jeetender Pal Peehal, MS (Orth), MRCS, Trust Registrar. *New Cross Hospital, Wolverhampton, United Kingdom.*

■ Huw David, FRCS, FRCS (Orth), Consultant Orthopaedic Surgeon.

*Derriford Hospital, Plymouth, United Kingdom.*

Correspondence : Palaniappan Lakshmanan, 36, Greenhills, Killingworth, Newcastle-Upon-Tyne NE12 5BB, United Kingdom. E-mail : lakunns@gmail.com

© 2008, Acta Orthopædica Belgica.

---

anterior tibial spine fractures. The results of surgery were assessed clinically and radiologically. The functional outcome was evaluated by using the Lysholm knee scoring system. Anterior Cruciate Ligament (ACL) laxity was assessed by using a KT-1000 arthrometer and range of movements (ROM) by goniometer.

### MATERIAL AND METHODS

This study reviewed 32 patients with displaced fracture of the anterior tibial spine treated by open reduction and internal fixation. Patients with associated major proximal tibial fracture were excluded from the study and 25 patients returned for review. Two declined to be part of the study and five were not traceable. The average period of follow-up was 44 months (range 21 to 108 months). Indication for surgery in these cases was Type III and Type IV in Meyers and McKeever's classification (8).

Patients were called back for review and detailed history and clinical examination were performed. A goniometer was used to record the range of motion of the knee joint, and a KT 1000 Arthrometer (MEDmetric Corporation, San Diego, CA, USA) was used to quantify anterior laxity in the knee joint. Persisting anterior laxity was checked by Lachman's test and anterior drawer test, and by measuring the increase in anterior excursion of the tibia over the femur in millimetres, when compared to the opposite normal knee, with the help of the KT-1000 arthrometer. Difference between the two sides was noted and due care was taken to apply a force of 20 lbs (98N/9Kg) with the knee flexed at  $20^\circ \pm 5^\circ$  (5). Knee function was assessed by using the Lysholm Knee Scoring Scale and results were graded as excellent (100-95), good (84-94), fair (65-83), and poor (less than 64).

Radiological evaluation was done utilising three views (antero-posterior, lateral and tunnel views), and the radiographs were assessed for union of fracture, bony overgrowth of the tibial eminence, implant position and for any evidence of osteoarthritis. The statistical analysis was performed using the software SPSS for Windows Version 11.5.

### RESULTS AND ANALYSIS

Fourteen children and 11 adults were reviewed. The average age of children at the time of injury was 13 years (range 8-16 years) and the average age of adults was 28 years (range, 18-49 years).



*Fig. 1.* — Meyers-McKeever Classification Type I & II Fractures.



*Fig. 2.* — Meyers-McKeever Classification Type III & IV Fractures.

Among children, 10 were boys and 4 were girls and in adults, four were men and seven were women. All patients attended the emergency department on the day of injury, except one who attended 4 days after injury. Nineteen cases were Type III and six were Type IV following Meyers and McKeever's classification (8) (fig 1 & 2).

The most common mode of injury was sports injury. Three adults and one child sustained injury after a relatively low-velocity fall from a motorbike or bicycle. Three adults who sustained road traffic accidents were pedestrians hit by a car. The diagnosis was missed in four cases in our study. In three patients (Cases 6, 9, 23) it was missed by the emergency department, but later picked up in the fracture clinic within a week's time. One patient had

Table I. — Materials used for fixation

| Material Used        | Number of Children | Number of Adults |
|----------------------|--------------------|------------------|
| AO Screw             | 5                  | 3                |
| Herbert Screw        | 2                  | 3                |
| Stainless Steel Loop | 2                  | 2                |
| Absorbable Suture    | 5                  | 3                |

suffered polytrauma, with ipsilateral fracture of the shaft of the femur and a supracondylar fracture of the humerus. The anterior tibial spine fracture was diagnosed only after his femur was fixed. All these four cases were operated late (Day 4, 7, 6, 25) but interestingly there was no effect on the final outcome.

The materials used in the present study to fix the anterior tibial spine fracture are shown in table I, fig 3 and fig 4. The anterior knee joint laxity assessed with the KT-1000 Arthrometer was analysed separately for children and adults and median increase in knee joint laxity with regards to absorbable or non-absorbable material was noted (table II). The median knee scores obtained in children and adults with regards to absorbable or non-absorbable materials used were also noted in table III.

Both children and adults had a 2 mm median increase in laxity. Among children 8 out of 14 (57%) and in adults 6 out of 11 (57%) had a laxity of 2 mm or more. Thus, there was no significant difference in increase of laxity with respect to age.

Children fixed with an absorbable stitch had a median increase in laxity of 2 mm compared to 1 mm in children fixed with non-absorbable materials (screw or stainless steel wire loop). The difference between these two groups was not statistically significant ( $p = 0.36$ ) on applying Mann Whitney U test. In adults, those fixed with absorbable stitch had a median increased laxity of 3mm compared to 0.5 mm in those fixed with non-absorbable materials. This was statistically significant ( $p = 0.04$ ) on applying Mann Whitney U test.

Children fixed with absorbable material achieved a median Lysholm knee score of 100 (range 85-100) and those fixed with non-absorbable had a score of 89 (range 69-100). The difference between

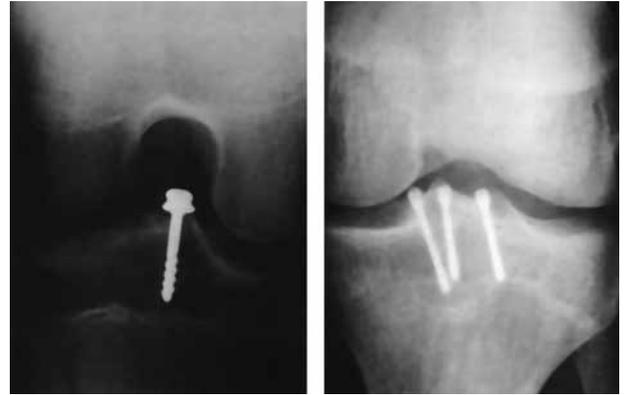


Fig. 3. — 4 mm cancellous screw and Herbert screw



Fig. 4. — Stainless steel wire loop

the two groups in children was not significant (Mann Whitney U test  $p = 0.21$  ; Fischer exact test  $p = 0.30$ ). In adults, patients fixed with absorbable material achieved a median Lysholm knee score of 80 (range 22-81) while patients fixed with non-absorbable materials achieved a median Lysholm score of 94.5 (range 49-95). The difference between the two groups in adults was also not significant (Mann Whitney U test  $p = 0.21$  ; Fischer exact test  $p = 0.18$ )

Table II. — Median increase in anterior laxity in children and adults in relation to the material used for fixation

| Methods of fixation |         | Median increase in laxity (mm) | p value |
|---------------------|---------|--------------------------------|---------|
| Children            | Group A | 2                              | 0.36    |
|                     | Group B | 1                              |         |
| Adults              | Group A | 3                              | 0.04    |
|                     | Group B | 0.5                            |         |

Group A – Absorbable stitch fixation

Group B – Non-absorbable material Fixation (Screw or stainless steel wire loop) fixation.

Table III. — Median knee scores in children and adults in relation to the material used for fixation

| Methods of fixation |         | Median knee score | p value |
|---------------------|---------|-------------------|---------|
| Children            | Group A | 100 (85-100)      | 0.21    |
|                     | Group B | 89 (69-100)       |         |
| Adults              | Group A | 80 (22-81)        | 0.21    |
|                     | Group B | 94.5 (49-95)      |         |

Group A – Absorbable stitch fixation

Group B – Non-absorbable material fixation (screw or stainless steel wire loop) fixation.

Table IV. — Lysholm Knee Score in all patients

| All patients      | Median knee score | p value |
|-------------------|-------------------|---------|
| Children (n = 14) | 92.5 (69-100)     | 0.064   |
| Adult (n = 11)    | 81.0 (22-95)      |         |

Overall in the study, including both the children and the adults, 16 patients (64%) had good to excellent results. The median of knee scores in all patients (table IV) and in patients without articular injuries (table V) revealed that in patients without articular injuries, scores of children and adults were very similar ( $p = 0.569$ , Mann Whitney U test). However, if all the patients were included for analysis, even though statistically there was no difference between adults and children, there appeared to be a trend favouring better outcome in children with 11 out of 14 (78.5%) having good to excellent results compared to 5 out of 11 (45.5%) in adults ( $p = 0.064$ , Mann Whitney U test). Six children achieved a Lysholm score of 100 which

Table V. — Lysholm Knee Score in patients without intra-articular damage

| Patients without articular damage | Median knee score | p value |
|-----------------------------------|-------------------|---------|
| Children (n = 14)                 | 92.5 (69-100)     | 0.569   |
| Adult (n = 7)                     | 95(80-95)         |         |

Table VI. — Median Lysholm Knee Score in patients with associated knee injuries

| Associated injury             | Median Knee Score | p value |
|-------------------------------|-------------------|---------|
| Articular damage (n = 4)      | 57.5 (22- 78)     | 0.01    |
| Ligament injury (n = 3)       | 90.0 (81-95)      |         |
| No associated injury (n = 18) | 95.0 (69-100)     |         |

none of the adult could achieve. The poor outcome in three adults occurred in patients with car bumper injury. Table VI and table VII show details of associated injuries to the knee along with the knee scores achieved. Associated injuries to the knee were more common in adults, with 6 out of 11 (54.5%) compared to 1 out of 14 (7.1%) in children.

Normal range of movement in the knee was achieved in 68% of children as compared to only 18% of adults. Loss of only terminal extension was a common finding in both children (28.5%) and in adults (45.5%). All patients were put in a cylinder cast for 6 weeks after surgery, but in 2 patients (Case 9 and 18) the cast was removed at 3 weeks, replaced by a brace for another 3 weeks, and movements were allowed up to 90° of flexion.

The main symptoms noted were pain, giving way and locking sensation. Half of the children were pain free and the remaining half had minimal pain, whereas all adult patients had some amount of pain and it was worst in 3 patients who had a car bumper injury. Though the incidence of giving way was similar in both children (42.8%) and in adults (45.5%), the severity was more in adults. Locking sensation was reported by 3 children and 2 adults and occasional locking occurred in one child and one adult. Swelling of the knee joint was not noted in children, but 3 adults developed swelling on severe exertion and 2 on normal daily activities.

Table VII. — Details of associated injuries to the knee

| Case No. | Associated Injury | Mode of Injury   | McKeevr's Type | Treatment                        | Knee Score |
|----------|-------------------|------------------|----------------|----------------------------------|------------|
| 9        | LCL Tear          | Ice Hockey       | III            | Conservative                     | 90         |
| 17       | LCL Tear          | Skiing           | III            | Conservative                     | 95         |
| 19       | Crack LTC & PTS # | Cycle            | III            | PTS Herbert Screw & LTC AO Screw | 78         |
| 20       | MLC               | Car Bumper       | IV             | Conservative                     | 49         |
| 21       | LCL               | Fall from height | III            | Conservative                     | 81         |
| 23       | Fibula #          | Car bumper       | IV             | Conservative                     | 66         |
| 24       | MCL               | Car bumper       | IV             | Conservative                     | 22         |

# - Fracture

LCL – Lateral Collateral Ligament

PTS – Posterior Tibial Spine

LTC - Lateral Collateral Ligament.



Fig. 5. — Migration of Herbert Screw

One patient developed superficial skin infection which subsided with a course of antibiotics. Ten patients (40%) felt numbness around the operative scar and 2 patients (8%) had a hypersensitive scar causing discomfort on kneeling. Two adults had migration of a Herbert screw, which was fortunately into the substance of tibia and did not affect union or displacement of the fracture (fig 5). One child developed non-union (fig 6) which required re-fixing with an absorbable stitch.

## DISCUSSION

Fracture of the anterior tibial spine is an uncommon injury. Skak *et al* reported an incidence of 3/100,000 children per year (13). The avulsion fracture of the tibial attachment of the ACL is also commonly known as fracture of the anterior tibial spine of the intercondylar eminence. Both these



Fig. 6. — Non-union

terms are a misnomer as this avulsion fracture usually involves only the intercondylar depression anterior to the spine where the ACL attaches (5). Less frequently, a large fractured piece may involve the tibial spine and may also extend medially and laterally to lift up wings of articular cartilage. Such fragments have high chance of falling back in position on mere extension of the knee as the large piece is squeezed back into place by the femoral condyles (10,14).

Injuries with similar forces are responsible for causing avulsion of bone in children and rupture of the ACL in adults. Noyes *et al* tried to explain this based on their work in primates and suggested that

this could be a function of the rate of application of load, as bone and ligament behave in a viscoelastic manner (9). At low strain rates, the area of insertion of the ACL into the tibia becomes the weakest link and fails by tibial avulsion. However at higher strain rates, the bone-ligament complex adapts more than the mid-substance of the ligaments by exhibiting more strength and stiffness because of the strain rate-dependent property of the bone-ligament complex and the relative strain rate-insensitive property of the mid-substance of the ligament. This results in mid-substance tears of the ACL when high strain rates are applied. Another reason for this different response between children and adults could be related to the ossification of the proximal tibia, the bony insertion being a weak point before ossification. Fall from a cycle is a well recognised injury in children (8,10). In our series only 21% of children sustained injury by fall from a cycle and the commonest cause was a sports related injury (57%). In adults, sports and road traffic accidents were the two most common modes of injury.

These injuries can easily be missed by untrained eyes if not suspected. In our series three patients were missed in the emergency department and the fourth patient had polytrauma with ipsilateral fracture of the shaft of the femur and humerus. This injury is difficult to be seen in anteroposterior view but more likely to be picked up in lateral view. The possibility of a fractured tibial spine should therefore be entertained in all acutely swollen knees after trauma.

Various methods of treatment have been recommended for displaced anterior tibial spine fractures in the literature, starting with conservative management, manipulation and open or arthroscopic reduction (1,3,8,10,15). In our series all displaced fractures (Type III and Type IV) were treated with open reduction and internal fixation and Type I and Type II conservatively.

Myers and Mckeever in their classical article suggested that fixing the fragment with absorbable suture was adequate in children (8). Since then others have used this technique both in children and adults. In our series, 5 children (35%) and 3 adults (27%) were treated with absorbable suture.

There was no significant difference in anterior laxity between the groups of children treated with absorbable or non absorbable materials. But, in adults treated so, there was a significant difference between the two groups. This suggests that absorbable suture should not be used for adults.

Migration of a Herbert screw was observed in two of the five patients treated with it. This was into the substance of the bone instead of backing out and fortunately the fracture united without any ill effects on stability or ROM or functional outcome of the surgery. Due to this finding, we do not recommend use of Herbert screw for fixing anterior tibial spine fractures. Moreover, the ordinary AO type screw works adequately and the screw head is easily accommodated within the femoral notch without causing any impingement.

Previously it was thought that ligament injuries do not occur in children and failure occurs by an avulsion fracture, but this was later proved wrong (6). In our series, we had one child and two adults with collateral ligament injury associated with anterior tibial spine fracture. In addition, two patients with articular damage also had collateral ligament injury. It is quite likely that this study, like other retrospective studies, underestimated the frequency of collateral ligament damage, especially injury to the deep part, which commonly accompanies these fractures. If not specifically looked for, medial collateral ligament (MCL) injury may be missed and after remaining in cast for 6 weeks this would heal, leaving little if any clinical evidence of collateral ligament injury.

In the present study, children as a whole did better than adults (median knee score in children = 92.5 and adults = 81.0 ;  $p = 0.06$ ). But interestingly, if all the patients with articular damage in the adult group are removed, then the median knee score was 92.5 for the remaining adults, which is as good as in children (changed  $p = 21$ ). Thus associated articular damage seems to be an important factor affecting the final outcome. Fracture of the anterior tibial spine in adults is caused by a more violent trauma than in children, leading to more associated injuries, which in turn leads to poor results in adults. Age *per se* does not seem to affect the final outcome directly.

In this study restricted ROM was seen in 36% of children and 82% of adults. The most common problem was loss of terminal extension (28.5% of children, 45% of adults). All four patients who had more than 20° of loss of motion were adults and 3 out of 4 were pedestrians hit by car.

All the patients with fixed flexion deformity had fair to poor results. Inability to freely extend the knee stops the knee from getting locked and leads to a feeling of instability and giving way, which contributes to poor outcome. Hence, we think that fixed flexion deformity is a major contributing factor for poor results.

The majority of our patients were immobilised in a cylinder plaster cast at 0-10° of flexion for 6 weeks. Three patients were immobilised in 25-50° of flexion in an effort to relax the ACL but this led to delay (12 to 18 months) in regaining normal ROM and it seems advisable to immobilise the knee in 0-10° of flexion. Three patients, who were given a brace for three weeks after an initial cylinder cast for 3 weeks, achieved early full ROM without any ill effects or non union. It seems safer to immobilise operated patients at 3 three weeks in a brace which could be maintained for a further 3 weeks.

None of the adult patients were pain free. Seven had slight and inconstant pain on severe exertion, whereas the other four had more severe pain. Among children, half were totally pain free and the remaining half had only slight and inconstant pain on severe exertion.

Giving way of the knee can be due to many reasons like ligament laxity, catching or locking of the knee, loss of full extension with inability to lock the knee, or it can occur due to patello-femoral joint problems. In our series it could not be related to ligament laxity. Children were affected as frequently as adults, with 3 children and 2 adults giving way rarely during sports or on severe exertion. Three more children and one adult frequently gave way during sports or severe exertion, but children achieved a fair result whereas the adult achieved a poor result. Two more adults, whose knee often gave way during daily activities achieved poor results and all the adults who achieved poor results had associated ligament and articular injuries to the knee.

Only 50% of the children had excellent results, 28.5% had good results, while 21.5% of the children had only a fair outcome ; 28.5% of the children had Tegner's activity score lowered by two levels compared to their previous activity level. These results are similar to those observed by Gronkvist *et al* (7).

In conclusion anatomical reduction and internal fixation is important for displaced anterior tibial spine fractures of McKeever's Type III and IV. In children both absorbable and non absorbable materials yield good results, but in adults non-absorbable materials yield better results than absorbable materials. Herbert screw is best avoided as it has an inherent problem of migrating deep into the tibial plateau.

## REFERENCES

1. Ahn JH, Yoo JC. Clinical outcome of arthroscopic reduction and suture for displaced acute and chronic tibial spine fractures. *Knee Surg Sports Traumatol Arthrosc* 2005 ; 13 : 116-121.
2. Baxter MP, Wiley JJ. Fractures of the tibial spine in children ; An evaluation of knee instability. *J Bone Joint Surg* 1988 ; 70-B : 228-230.
3. Bong MR, Romero A, Kubiak E *et al*. Suture versus screw fixation of displaced tibial eminence fractures : a biomechanical comparison. *Arthroscopy* 2005 ; 21 : 1172-1176.
4. Clanton TO, Delee JC, Sanders B, Neidere A. Knee ligament injuries in children. *J Bone Joint Surg* 1979 ; 61-A : 1195-1201.
5. Fyfe IS, Jackson JP. Tibial intercondylar fractures in children. A review of the classification and treatment of malunion. *Injury* 1981 ; 13 : 165-169.
6. Garcia A, Neer CS II. Isolated fractures of the intercondylar eminence of the tibia. *Am J Surg* 1958 ; 95 : 593-598.
7. Gronkvist H, Hirsch G, Johansson L. Fracture of the anterior tibial spine in children. *J Pediatr Orthop* 1987 ; 4 : 465-468.
8. Meyers MH, McKeever FM. Fractures of intercondylar eminence of the tibia. *J Bone Joint Surg* 1959 ; 41-A : 209-222.
9. Noyes FR, Elucus JL, Torvik P. Biomechanics of ACL failure : An analysis of strain-rate sensitivity and mechanisms of failure in primate. *J Bone Joint Surg* 1974 ; 56-A : 236-253.
10. Rang M. *Children's Fractures*. J.B. Lippincott, Philadelphia, 1983 : pp 282-284.

11. **Reynders P, Reynders K, Broos P.** Pediatric and adolescent tibial eminence fractures : arthroscopic cannulated screw fixation. *J Trauma* 2002 ; 53 : 49-54.
12. **Rockwood CA, Wilkins KE, King RE.** *Fractures in Children.* J B Lippincott, Philadelphia, 1983, pp 1237-1242.
13. **Skak SV, Jenson TT, Paulsen TD, Sturup J.** Epidemiology of knee injuries in children. *Acta Orthop Scand* 1987 ; 58 : 78-81.
14. **Smillie IS.** *Injuries of the Knee Joint.* Churchill Livingstone, New York, 1970, pp 154-158.
15. **Willis RB, Blokker C, Stoll TM, Paterson DC, Galpin RD.** Long term follow up of anterior tibial eminence fracture. *J Ped Orthop* 1993 ; 13 : 361-364.
16. **Zaricznyj B.** Avulsion fractures of the tibial eminence : treatment by open reduction and pinning. *J Bone Joint Surgery* 1977 ; 59-A : 1111-1114.