Proximal entry for intramedullary nailing of the tibia

THE RISK OF UNRECOGNISED ARTICULAR DAMAGE

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The risk of articular penetration during tibial nailing is well known, but the incidence of unrecognised damage to joint cartilage has not been described. We have identified this complication in the treatment of tibial fractures, described the anatomical structures at risk and examined the most appropriate site of entry for tibial nailing in relation to the shape of the bone, the design of the nail and the surgical approach.

We studied the relationship between the intra-articular structures of the knee and the entry point used for nailing in 54 tibiae from cadavers. The results showed that the safe zone in some bones is smaller than the size of standard reamers and the proximal part of some nails. The structures at risk are the anterior horns of the medial and lateral menisci, the anterior part of the medial and lateral plateaux and the ligamentum transversum. This was confirmed by observations made after nailing 12 pairs of cadaver knees. A retrospective radiological analysis of 30 patients who had undergone tibial nailing identified eight at risk according to the entry point and the size of the nail. Unrecognised articular penetration and damage during surgery were confirmed in four.

Although intramedullary nailing has been shown to be a successful method for treating fractures of the tibia, one of the most common problems after bony union is pain in the knee. Unrecognised intra-articular injury of the knee may be one cause of this.

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During intramedullary nailing of the tibia the nail has a tendency to puncture the posterior cortex. To avoid this Küntscher¹ recommended the introduction of a straight nail

into the upper part of the bone. Because this may penetrate the articular surface, Herzog² modified the nail by adding a proximal angle to allow lower insertion in the anterior tibia above the tibial tubercle. However, a nail in this position will irritate the patellar tendon if it is left too long and therefore Lottes, Hill and Key³ and Lottes⁴ changed the approach to allow a more medial position. For high fractures of the tibia, depending on the displacement,⁵ a lateral approach has been recommended. Nails also vary in their degree of stiffness,^{6,7} particularly when interlocking screws are used, and a stiffer nail has to be placed higher in the tibia for insertion without damage to the posterior cortex. In order to choose the most appropriate site of entry for the nail the anatomy of the proximal tibia should be correlated with the design. Although the danger of penetration of the articular surface is well known, the incidence of damage to the meniscus or cartilage of the tibial plateau is uncertain.

To identify the most suitable site of entry for the nail, we studied the shape of the proximal tibia on cadaver specimens to determine whether this position could affect the intra-articular structures. We first reviewed their configuration in cadaver specimens and then evaluated the risks of damage during nailing in such knees. A retrospective review of patients with diaphyseal fractures treated by tibial nailing was undertaken to determine the incidence of unrecognised articular penetration during surgery and the possible clinical relevance of this to pain in the knee.^{8,9}

Material and Methods

The surface for entry is situated above the tibial tubercle on the anterior surface of the proximal tibia. Usually, after incision of the skin, the infrapatellar fat pad is pushed proximally and posteriorly with an elevator. The safe zone for nailing should be anterior to the articular area in the upper part of the knee. The limit of this surface anteriorly was determined at arthroscopy by Johnson et al¹⁰ and found to be the anterior horn of each meniscus. It has been shown that in 69% of knees the ligamentum transversum connects the anterior horns of the medial and lateral menisci^{10,11} (Fig. 1) and therefore the ideal site and safe zone should be anterior to the ligamentum transversum and the anterior horn of each meniscus (Fig. 2).

Figure 3 shows that the safe zone is a three-dimensional

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Fig. 1

Photograph of the articular surface of a right tibia showing the menisci and the ligamentum transversum. All these intra-articular structures are very close to the site of insertion of the nail.

Fig. 2

Photograph of the articular surface of the tibia. The insertion of the medial meniscus is outlined. The quadrilateral BCDE, excluding the insertion of the medial meniscus, is the safe zone for the site of insertion. The dotted line is the midline of the tibia.

Fig. 3

Photograph of the articular surface of a right tibia with a tracing of the safe zone showing the horizontal and vertical areas.

space with a small upper part which is nearly horizontal, and an anterior part, which is almost vertical with a slight posterior slope. It can be considered as a three-dimensional polygon (BCRDEG). When the entry hole is too high above the tibial tubercle, particularly for a nail with a large proximal diameter, the posterior part of the nail may impinge on the upper part of the safe zone and there is a risk of damage to the intra-articular structures. If the safe zone is the three-dimensional structure limited by the points BCDE, the surface available for the entry point of the awl and the flexible guide rod is even smaller. For example, the centre of a 12 mm diameter nail should remain 6 mm from

the limits of the safe zone. For a given tibia, the appropriate surface allowed for the centre of the nail decreases as the diameter of the upper part of the nail increases. We refer to the ideal entry point allowing the greatest diameter of the nail for a given tibia as the 'sweet spot' expressed as millimetres above the tibial tubercle (Fig 4).

Samples and methods of measurement. We used 30 unpaired and 24 paired adult cadaver tibiae to find the ideal site for the insertion of a nail. These 29 male and 25 female tibiae had a mean total length of 36 cm (30 to 40). The tibia was fixed by two supports on a table with scales corresponding to the X, Y and Z co-ordinates. This allowed

Fig. 4

Photograph showing the height of the sweet spot above the tibial tubercle (see Table I and QS in Figure 7).

localisation of the bony landmarks (A, B, C, D and E) in relation to the Cartesian co-ordinates.

The distances between these points were also measured on the bone with a calliper. The method was calibrated by taking four linear measurements (including the distance BC) on a single specimen and repeating each one ten times. The smallest linear measurement was the distance BC. For this length (mean 19 mm) we determined the coefficient of variation as a measure of relative precision by dividing the standard deviation by the arithmetic mean. It was found to be less than 4%.

The posterior border of the safe zone was determined as a line drawn tangentially to and joining the anterior margins of the insertion of the medial meniscus (point D) and of the articular surface of the lateral tibial plateau (point E). The tibial tuberosity was determined as the peak of the patellar tuberosity (point A) (see Fig. 6) in the transverse plane at the midpoint of the insertion of the ligamentum patellae. Points B and C represent the medial and lateral borders of the tibial tubercle and the line BC is the anterior limit of the safe zone. The centre of the knee (O) (Fig. 2) was marked as the midpoint of a line drawn between the medial and lateral intercondylar eminences. The transverse axis of the tibial plateau was a line through the centre of the knee (O), parallel to the posterior margin of the tibia in the transverse plane. The midline of the tibia was the perpendicular to the posterior margin passing through the point O.

To determine the slope of the anterior surface for tibial nailing, metal markers were placed on the points BCRG and mediolateral radiographs were obtained. The slope of the tibia in this region was measured as the angle to the axis of the bone on the lateral radiograph.

Geometrical construction and parameters measured.

We determined the long axis of the tibia on the mediolateral radiograph as a line through the centre of the knee and the

Fig. 5

Diagram showing the influence of various proximal angles of the nail in the upper tibia.

centre of the ankle. This was considered as the medullary canal for the nail which was considered to have an angle of 0° , 10° or 20° proximally (Fig. 5). Figures 6 and 7 represent a sagittal section of the tibia through the three-dimensional structure giving the limits of the safe zone for the nail. For a given tibia the largest permissible diameter for the entry hole or for the upper part of the nail depends on the slope (B) and the height (QP) of the anterior part of the tibia, as well as the angle of the nail to the superior part of the tibia (α). For the same tibia, using a reverse geometrical

Fig. 6

Photograph of the articular surface of the tibia indicating how the points Q, P and N in Figure 7 are obtained.

Fig. 7

Diagram showing that QP represents the height of the anterior surface for nailing on the sagittal cut of the tibia. Q, P and N are respectively the intersection points of the sagittal cut with RG and DE. NT is parallel to the long axis of the tibia. β is the slope of the anterior surface for nailing. α is the angle of the proximal part of the nail with the longitudinal axis of the tibia. MN is the maximum anterior and posterior points which are allowed for the nail on the sagittal cut. QR is the maximum diameter allowed for the nail. U is the middle point of QR. S represents the sweet spot. QS is the height of the sweet spot above the tibial tubercle (see Table I).

$$QR = QN \cos \theta$$

$$\text{with } QN = \sqrt{(MN)^2 + (QP \cos \beta)^2}$$

$$\text{and } \theta = \text{Arctg} \left(\frac{QP \cos \beta}{MN} \right) - \alpha$$

$$QS = \frac{QR}{2 \sin (\alpha + \beta)}$$

construction, we can identify the position of the sweet spot on the anterior proximal part of the tibia when the greatest diameter of the nail is known. The measurements and calculations were done with a computer using a three-dimensional software package for each approach (anterior, medial, lateral) (Mathematica, Champaign, Illinois), when using nails with a different proximal angle to the axis of the tibia (0° , 10° , 20°) to estimate the maximum diameter for the nail without affecting the intra-articular structures and to identify the position of the sweet spot.

Statistical analysis. We used both paired and unpaired tibiae to calculate means and standard deviations for each of the linear and angular parameters. Measurements for each pair of tibiae were averaged and then combined with the measurements for the unpaired knees to calculate the means and standard deviations for the entire group. The procedure was then repeated independently for male and female tibiae separately. Differences between the genders were determined by unpaired two-tailed *t*-tests. Bilateral asymmetry was assessed only in relation to the 24 paired tibia.

Evaluation of the risks for intra-articular structures during nailing

Anatomical risks during tibial nailing of cadaver knees.

To determine the risks to the intra-articular structures of the knee and the ideal site for the nail, we performed nailing with a nail of 10 mm diameter and an angle of 10° on 12 pairs of adult cadaver knees (seven men and five women) using medial, lateral and anterior approaches through the patellar ligament.

After dissection the intra-articular findings were noted and the distances between the entry site and the medial and lateral meniscus and the medial and lateral articular surfaces were recorded. Eight knees were used for each approach.

The nail was inserted by a surgeon who was unaware of the previous anatomical study, but was experienced in tibial nailing. After dissection and recording of the intra-articular findings, the tibiae were used for measurement of anatomical variables.

Position of the implant site in patients with diaphyseal fractures.

We performed a retrospective study on 30 patients with diaphyseal fractures of the tibia without injury to the knee and without other injuries in the same limb. These fractures had been stabilised by an intramedullary nail and had been followed up for at least one year. All had healed at the time of our study.

Only patients whose nail had been advanced at least flush with the tibia during insertion, or whose nail had been buried with the bone, were included. We excluded patients with a prominent nail proximally and those older than 45 years of age in order to avoid a degenerative cause for pain in the knee.

The operation had been performed as soon as possible and no damage to the anatomical structures of any of the knees during nailing had been reported. Thirteen Gross and Kempf nails and 17 Küntscher nails had been used. Pain in the knee was analysed before and when necessary after removal of the nail. It was defined as anterior knee pain related to the entry site but also as any 'articular' pain associated with different activities such as climbing stairs or ladders, or walking more than 500 metres.

The height of the site of entry of the nail above the tibial tubercle (Fig. 8) was determined in millimetres on the mediolateral radiograph. The position of the point of entry was determined on the anteroposterior radiographs in relation to the midpoint between the intercondylar eminences. This position was compared with the limits of the sweet spot determined on the cadaver specimens to determine which nails were at risk of entering the tibial plateau, the meniscus or the ligamentum transversum. For the patients considered to be 'at risk' we determined unrecognised articular penetration during nailing by arthrography before removal of the nail, by careful examination of the knee during removal and sometimes by CT afterwards. After removal of the nail four patients had CT of the upper segment of the tibia which showed the exact site of insertion in the proximal tibia (Fig. 9).

Fig. 8a

Fig. 8b

Radiographs showing the method used to determine the position of the entry point on radiographs.

Fig. 9a

Fig. 9b

CT three-dimensional reconstruction of the upper tibia after removal of the nail. The insertion site is too high.

Results

Data obtained by direct measurement. The position of the tibial tuberosity (point A, Fig. 6) was measured in the horizontal plane as the number of millimetres of lateral deviation of A from the perpendicular passing through the middle of the transverse axis of the tibia. The centre of the tibial tubercle was found to be 16.2 ± 5.9 mm (SD) lateral to the midline of the tibia.

The slope of the anterior surface for nailing is on average $20 \pm 3^\circ$ with respect to the axis of the tibia. There were no significant differences associated with gender or side and no correlation between this angle and the length or width of

the tibia. Since the variation was slight between different tibiae the value of 20° was chosen for computer analysis.

The height of the anterior surface (QP) for nailing (Fig. 6) was on average 21 mm. There were no significant differences associated with gender or side. Correlations were sought between this and the tibial length by regression analysis. As the tibial length increases, the height of the surface for nailing also increases ($R = 0.87$; $p = 0.012$). No correlation was found between the height and the slope of the anterior surface.

A linear correlation was also found between the distance QN (Figs 6 and 7) and the length of the tibia ($R = 0.86$; $p = 0.011$). The equation of the linear correlation as a function of the length of the tibia was used (both for QP

Table I. Maximum diameter of the proximal part of the nail and position of the sweet spot (height above the tibial tubercle) according to the tibial length, to the shape of the nail, and to the surgical approach. The tibial length was measured in millimetres. The results are given in centimetres (± 2 cm)

Anterior approach						
Nail angle (degrees)						
Tibial length (cm)	20		10		0	
	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)
30	16	11	13	13	10	15
32	17	11	14	14	11	16
34	18	12	15	15	12	18
36	19	13	16	16	13	20
38	20	13	17	17	14	21
40	21	14	18	18	15	22
Lateral or medial (10 mm) approach						
Nail angle (degrees)						
Tibial length (cm)	20		10		0	
	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)
30	14	9	11	11	8	12
32	15	10	12	12	9	14
34	16	11	13	13	10	15
36	17	11	14	14	11	17
38	18	12	15	15	12	18
40	19	13	16	16	13	20
Medial or lateral (20 mm) approach						
Nail angle (degrees)						
Tibial length (cm)	20		10		0	
	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)
30	12	8	9	9	6	9
32	13	9	10	10	7	10
34	14	9	11	11	8	12
36	15	10	12	12	9	13
38	16	10	13	13	10	15
40	17	11	14	14	11	16
Medial (30 mm) approach						
Nail angle (degrees)						
Tibial length (cm)	20		10		0	
	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)	Nail diameter (mm)	Sweet spot (mm)
30	10	7	7	7	4	6
32	11	7	8	8	5	7
34	12	8	9	9	6	9
36	13	9	10	10	7	10
38	14	9	11	11	8	12
40	15	10	12	12	9	13

and QN) for the computer analysis to find the position of the sweet spot and the maximum diameter of the nail allowed for tibiae of varying size without risk of articular damage.

Maximum diameter of the entry hole and sweet spot according to tibial length, angle of the nail and approach for nailings. Table I gives the variables chosen and the results obtained. The anterior approach is through

the patellar ligament on a vertical line passing through the tibial tubercle (point A, Fig. 6). We evaluated lateral and medial approaches at 10, 20 and 30 mm on each side of point A. With an anterior approach the maximum diameter allowed for the entry hole of the nail is 18 mm for a tibial length of 34 cm when the angle of the proximal part of the nail is 20° to the axis of the tibia. The sweet spot should be 12 mm above the tibial tubercle and should not be higher in order to avoid articular penetration, or lower to avoid impingement on the tibial tubercle (Table I). For a tibia of 34 cm in length, when using a nail of only 10 mm diameter with a proximal angle of 20° , the entry point may be 4 mm above or below the sweet spot. For the same tibial length and the same anterior approach, the maximum diameter allowed for the entry hole is only 12 mm when the angle between the nail and the axis of the tibia is 0° .

With an approach 20 mm medial to point A the maximum diameter of the nail is 10 mm for a tibial length of 32 cm and an angle of the nail of 10° . The sweet spot is situated 10 mm above the tibial tubercle. This means that if the entry point is situated at 11 mm above the tibial tubercle, the maximum permissible diameter of the nail is only 8 mm.

According to the measurements on the 30 tibiae and the computer analysis, the best position in the transverse plane for the entry of a nail of maximum diameter is 18.7 ± 4.5 mm lateral to the midline or 2.5 ± 1.8 mm lateral to the centre of the tibial tubercle (point A). As indicated in Table I, an approach 10 mm lateral or 10 mm medial to this point decreases the maximum diameter allowed for the nail. The operative approach should be in the direction of this entry point and it is obvious that this is best obtained by the anterior route. With a medial approach, the nail is very close to the insertion of the medial meniscus and to the ligamentum transversum and with a lateral approach it will be close to the lateral articular surface. With an anterior approach through the patellar ligament, the nail is at a distance from the medial articular surface, from the lateral articular surface and from the ligamentum transversum.

Risks to intra-articular structures during nailing

Anatomical structures. The safety of the anterior approach through the patellar tendon was confirmed by the intra-articular findings observed after insertion of a Küntscher nail in 12 pairs of cadaver knees. The structures particularly at risk were the medial meniscus, the lateral articular surface and the ligamentum transversum (Table II). With a medial approach, the 10 mm nail was situated 2.2 ± 2.1 mm from the medial meniscus. Injury to the medial meniscus was observed in one case, with impingement of 2 mm, and injury to the ligamentum transversum in two. Increasing the diameter of the nail with reaming would have led to an injury to the medial meniscus in two cases with a 12 mm nail and in four with a 13 mm nail. With a lateral approach, the 10 mm nail was situated 2.5 ± 2.3 mm from the lateral articular surface. There was one case of injury to this area. Increasing the diameter of the nail to

Table II. Intra-articular findings after nailing 24 cadaver tibiae giving the distance (mm) between the nail (10 mm diameter) and the structure. A negative value indicates injury to the structure

	Medial meniscus			Lateral articular surface			Ligamentum transversum		
	Approach			Approach			Approach		
	Medial	Lateral	Anterior	Medial	Lateral	Anterior	Medial	Lateral	Anterior
	3	9	5	6	4	7	4	2	4
	1	10	4	9	5	8	2	5	2
	2	8	7	10	2	4	NA*	1	4
	4	6	5	11	1	6	-1	NA	0
	2	7	4	9	-1	5	3	4	-1
	-2	10	8	7	0	6	3	3	5
	3	13	7	8	4	7	5	3	3
	5	7	6	9	5	8	-1	1	NA
Mean $\pm$ SD	2.2 $\pm$ 2.1	8.7 $\pm$ 2.2	5.7 $\pm$ 1.5	8.6 $\pm$ 1.6	2.5 $\pm$ 2.3	6.3 $\pm$ 1.4	2.1 $\pm$ 2.3	2.7 $\pm$ 1.5	2.4 $\pm$ 2.2

* not available

Table III. Variables of the tibia and of the nail for the three cadaver knees in which articular penetration was observed. The position of the entry point is indicated by the medial position (distance medial to point A) and by the height in millimetres above the tibial tubercle

Case	Tibial length (cm)	Nail angle (degrees)	Entry point position	
			Medial to point A (mm)	Height (mm)
1	34	10	+20	15
2	30	10	0	18
3	31	10	-12	17

Table IV. Variables of the tibia, the nail and the entry point for the eight knees in which the nail was considered at risk of intra-articular penetration. The tibial length was estimated according to the length of the nail; the entry nail hole was measured on the AP radiograph with respect to the midpoint between the intercondylar eminence (situated on average 6 mm medial to the tibial tubercle). The height was measured on the mediolateral radiograph. The Gross and Kempf (GK) nail is 16 mm in diameter regardless of the diameter of the diaphyseal part of the nail

Case	Nail			Entry point position		
	Type	Diameter (mm)	Angle (degrees)	Tibial length (cm)	Medial to point A (mm)	Height (mm)
1	GK	16	20	36	13	18
2	Küntscher	12	10	34	20	15
3	GK	16	20	33	2	16
4	Küntscher	11	10	30	-12	14
5	GK	16	20	32	10	15
6	GK	16	20	31	1	16
7	GK	16	20	36	28	12
8	GK	16	20	35	19	13

11 mm would have resulted in injury to the lateral articular surface in one more case; with a nail of 12 mm, there would have been injury to the lateral articular surface, with impingement of 1 mm, in three cases. With an anterior approach, the 10 mm nail was situated 5.7 ± 1.5 mm from the medial meniscus and at 6.3 ± 1.4 mm from the lateral articular surface. Table III gives the variables for the tibia and the nail for the three knees in which articular penetration was observed. A comparison with Table I shows that the position of the entry point was too high above the tibial tubercle according to the medial or lateral situation of the entry point. For example, in case 1, the tibial length was 34 cm, the angle of the nail 10° , and the entry point was 20 mm medial to point A and 15 mm above the tibial tubercle instead of the maximum of 13 mm allowed according to Table I.

Position of the implant in the retrospective review. In the 30 patients, the position of the entry point of the nail was

considered to be at risk in eight as indicated in Table IV. Of these eight, the intra-articular position and the possibility of unrecognised damage were highly likely in four because an effusion was present. Direct confirmation of the intra-articular site was obtained in two by arthrography before removal of the nail and in two others during removal. Three small lesions of the medial meniscus, with impingement of the nail on the anterior horn of less than 3 mm, were observed with a medial approach. Impingement of the lateral plateau with an intra-articular bone spur was seen in one patient with a lateral approach. For the other four, there was no direct confirmation of unrecognised articular penetration. Three-dimensional reconstruction with CT after removal of the nail, however, showed that the entry hole was at the site of the ligamentum transversum (Fig. 9). All of these eight patients had pain in the knee before the nail was removed. Of the four patients who had direct confirmation of the intra-articular position of the nail, two reported

Fig. 10

Photograph of the top of a Küntscher and a Gross and Kempf (GK) nail of the same diameter (10 mm) in their diaphyseal sections; the proximal part of the GK nail has a diameter of 16 mm.

an improvement after the nail had been removed but still had slight pain and two had no benefit. In the other four patients pain was relieved in three after removal of the nail but not in the fourth.

Discussion

During nailing of the tibia a wide hole is made from just above the tibia down to the medullary canal. The angle of the awl is usually chosen so that it is pointing parallel to the anterior border of the tibia as soon as the cortex has been perforated. It is especially important in the tibia to enter the medullary canal at the right point which theoretically allows the nail to be introduced in line with the axis of the tibia in both the coronal and sagittal planes. If the point is too low and the angle of the nail is too large, the posterior surface of the proximal tibia is endangered, particularly with a thick inflexible nail. If the point is too high and if the nail is driven in vertically, there is a risk of unrecognised articular penetration. In our study we have determined the best position for the nail in relation to the shape of the tibia and the nail. The size of this zone depends on the length of the tibia and the diameter and proximal angle of the nail.

The risk of unrecognised articular penetration is higher when the tibia is shorter. Since the length of the tibia is related to the size of the patient,^{12,13} the medial and lateral approaches are dangerous in patients of small build. This is particularly so when the diameter of the top of the nail is

larger than that in the diaphysis; the two are not necessarily the same. Unlike the Küntscher nail, many nails in use have the same proximal diameter which is usually greater than the diameter of the distal part (Fig. 10). This could explain the articular penetration found with a Gross and Kempf nail in three small patients in our series. After fractures of the proximal quarter of the tibia the muscles and ligaments exert strong deforming forces on the fracture fragments and the nail will not maintain reduction nor will it stabilise the fracture as in the shaft of the bone. To avoid valgus and a flexion deformity, a lateral incision and entry site with reaming against the dense anterior bone are sometimes used. This approach may compromise the lateral articular surface since the entry point chosen is lateral and posterior. The anterior approach through the patellar ligament is safer but nevertheless there is the risk of intra-articular penetration, particularly when using nails without a proximal angle or when the entry point of the nail is too high and too large.

Regardless of the shape of the nail and the tibia, the stiffness of the nail and the technique of unreamed intramedullary nailing^{6,7,14} may require a shift of the point of insertion. When the stiffness of the nail increases because of the proximal angle, the force required to introduce the nail is greater, causing more strain on the bone and probably also an increase in pressure in the medullary canal. To avoid this it may be necessary to place the entry point higher when using a very rigid interlocking nail, even if the nail has a proximal angle. In such a situation, the maximum diameter allowed for the entry hole decreases markedly.

The intra-articular structures particularly at risk of damage during tibial nailing are the medial meniscus, the lateral tibial plateau and the ligamentum transversum. Depending on the diameter and angles of some nails and some reamers, and the height of the entry point, the risk of unrecognised intra-articular penetration is probably higher than is generally perceived. Secondary extrusion of the nail into the knee may occur later.¹⁵ In our series, eight out of the 30 patients were suspected of having unrecognised articular penetration and confirmation was obtained in four. These patients had pain in the knee and there was a possibility that this was linked to unrecognised articular damage.

It is thought that if the pain was due to injury to the intra-articular surface, removal of the nail could exacerbate it by causing further damage. In five of the eight patients the pain was relieved by removal of the nail. A probable explanation is that the pain was not only caused by the articular penetration but also by the presence of the nail, i.e., by the bending strain exerted by the proximal part of the nail on the bone. Since unrecognised articular penetration occurs with the use of nails of large diameter in small patients, the bending strain at the upper end may also increase in such individuals.

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