THE TECHNIQUE AND COMPLICATIONS OF UPPER TibIAL OSTEOTOMY

A Review of 226 Operations

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Osteotomy through the upper end of the tibia was originally used to correct valgus and varus deformities of the knee caused by rickets or poliomyelitis. In 1958 one of us reported the results of this operation in patients with osteoarthritis of the knee (Jackson 1958), and further papers were published in 1961 and 1969 (Jackson and Waugh 1961, 1969; Jackson, Waugh and Green 1969). In a series of 105 osteotomies, fifty-four patients had little or no pain and thirty were much improved; there was some improvement in sixteen patients and in only five was there no improvement. The operation has, therefore, been of considerable benefit to 85 per cent of our patients. Many other surgeons have also recommended tibial osteotomy for osteoarthritis (Bouillet and Van Gaver 1961; Venemans 1962; Wardle 1962; Coventry 1965; Torgersen 1965; Bauer, Insall and Koshino 1969; Devas 1969; Gariépy 1969; Harris and Kostuiik 1970; Coventry 1973).

At the Eleventh Congress of the Société Internationale de Chirurgie Orthopédique et de Traumatologie (1969), one of the subjects was “La chirurgie de l’arthrose du genou”, and nine papers were given which discussed upper tibial osteotomy. Although there was general agreement that the results were satisfactory, several different ways of doing the operation were described. Variations in technique may not matter if the same result is achieved, but it is clearly important to discover which operation is most easily carried out and has the least risk of complications.

This paper reports our experience of 226 upper tibial osteotomies done by six different techniques during the past twenty years (Fig. 1). The complications and difficulties of each method are reviewed in an attempt to decide which is the safest procedure.

DEVELOPMENT OF THE OPERATION

The operation has in most instances been performed for osteoarthritis of the knee with greater loss of articular cartilage in either the medial or the lateral tibio-femoral compartment and consequent varus or valgus deformity. The object has been to correct the malalignment and so to redistribute weight-bearing pressures to the more normal side of the joint. Pain has been the principal indication, and in only one patient was the operation done to improve appearance and with the hope of preventing osteoarthritis.

Curved osteotomy below the tibial tuberosity—This was the method we first used. The fibula was divided through a lateral incision over its middle third, one centimetre of bone being removed when a varus deformity was corrected. Osteotomy of the tibia was done just below the tuberosity, the site having first been outlined in a curve with its convexity upwards by a series of drill holes. The bone was almost completely divided with a gouge and then broken. The aim was to make the leg look straight. A plaster from groin to toes was worn for about eight weeks.

The use of external compression—In 1961 a fat woman with valgus deformity was to be operated upon and we thought that better control and immobilisation of the fragments would be obtained if external compression with two Steinmann pins and a Charnley clamp were used. The result was satisfactory and several similar operations were carried out. We then devised a method
in which two Steinmann pins were inserted above and two below the osteotomy: these were held together in a special clamp by which compression could be applied after correction of the deformity. Rigid fixation was achieved so that knee movements could be started the day after operation. The apparatus was removed four to eight weeks later and in a few patients a short period of plaster immobilisation followed.

**Diagram showing the different techniques of osteotomy described in this review.**

**Wedge osteotomy above the tuberosity**—This was first done in 1964 and we have nearly always used an anterior rather than a lateral approach to the upper end of the tibia. A wedge of bone was excised above the tuberosity (based either medially or laterally) with a small handsaw or sometimes a mechanical reciprocating saw. If necessary, part of the head of the fibula was removed to allow closure of the wedge when correcting a varus deformity. One or more staples were inserted for fixation. After operation the knee was immobilised in a plaster cylinder for four to six weeks: the patient was allowed to bear weight on the affected leg after two weeks.

**Curved osteotomy above the tuberosity**—A number of curved osteotomies above the tuberosity have also been carried out. The line of the tibial osteotomy was marked with drill holes, the bone being almost completely divided with a gouge and then broken by gentle pressure.

**Wedge osteotomy with transposition of the tibial tuberosity**—In 1970 the results of 105 operations were reviewed. There were three groups: thirty-five curved osteotomies below the tuberosity with plaster immobilisation; thirty-five curved osteotomies with external compression and
thirty-five wedge osteotomies above the tuberosity. Although there were fewer complications in the last group the results were not so good as in the seventy patients who had had osteotomies at a lower level. In particular, those with a varus deformity were less satisfactory than those in which a valgus deformity was corrected. It seemed possible that the upward and outward displacement of the insertion of the patellar ligament might aggravate the retropatellar osteoarthritis which was often present. We thought that this might be avoided if the tibial tuberosity were transposed downwards and medially. After division of the fibula, one Steinmann pin was inserted above and one below the site of the osteotomy; the tuberosity was then detached by a horizontal saw cut and a wedge excised through its bed. Compression was applied and staples inserted. The clamp and nails were removed and the fragment of tuberosity fixed in its new position with a screw. The knee was immobilised in a plaster cylinder for six weeks.

Wedge osteotomy through the lower part of the tuberosity—In this operation a wedge osteotomy has been done through the tuberosity after detachment of the distal half of the patellar tendon, which is resutured to the soft tissues over the upper end of the tibia. The cut edges of the bone are firmly apposed by external compression and staples inserted. The nails and clamp are removed and a plaster cylinder applied. This is retained for six weeks.

THE PATIENTS AND THE OPERATIONS

Two hundred and twenty-six osteotomies through the upper end of the tibia have been done in 206 patients. In eighteen the operation was carried out on both knees and two patients had a second operation on the same leg because satisfactory correction had not been obtained. The figures given throughout the paper refer to the number of operations and not to the number of patients. All the operations were done by the authors or their assistants. Records and radiographs before and after operation were available.

Age, sex and deformity—Ninety-four of the operations were on men and 132 on women. The average age was 59.9 years (men 54.8 years; women 63.4 years). One hundred and fifty-four knees had a varus deformity and seventy-two a valgus deformity. The relation between sex and deformity was: men—valgus ten, varus eighty-four; women—valgus sixty-two, varus seventy.

Diagnosis—The operation was done for the following conditions: osteoarthritis 214, rheumatoid arthritis seven, healed tuberculous arthritis one, pain, deformity and instability two, deformity two.

Type of osteotomy—The technique used in the 226 osteotomies was: below the tuberosity ninety-two; through the tuberosity fifty-one; above the tuberosity eighty-three (Table I).

There were three operations in which one or other of us departed from the methods described. Internal fixation of a low wedge osteotomy with an angled nail-plate was used twice. In one patient an osteotomy above the tuberosity was wedged open with a piece of Kiel bone.

Other operations—In eleven patients the knee joint was opened at the time of the osteotomy. In two, loose bodies were removed, and in two the medial meniscus was removed. One patient had both a loose body and the medial meniscus removed. Once the anterior cruciate ligament was divided in an attempt to correct a flexion contracture. In the remaining six knees the joint was opened to determine the condition of the articular cartilage or for synovial biopsy. We have never removed the patella at the time of tibial osteotomy.

A number of patients have had further operations. In two the osteotomy had to be revised: in one of these correction was not at first achieved and in the other there was at first over-correction. In one patient the patella was removed for retropatellar osteoarthritis three years after the first operation. One patient had the lateral meniscus removed three years after operation for a valgus deformity; another had a loose body removed six years after
osteotomy; and one patient underwent arthrodesis because of persistent pain associated with under-correction of the deformity.

**COMPLICATIONS**

**Deaths**—Three patients died within six months of the operation, one from coronary thrombosis a month after operation, one from hepatic failure due to halothane anaesthesia ten days after the second tibial osteotomy, and one from pulmonary embolism three weeks after the operation. **Deep vein thrombosis**—Seven patients were diagnosed as having deep vein thrombosis and three others had pulmonary embolism, one of which was fatal.

| Table 1 |

**Site and Type of Osteotomy in 226 Cases, with Incidence of Certain Complications**

<table>
<thead>
<tr>
<th>Site of operation and type</th>
<th>Number of operations</th>
<th>Bone grafting for delayed union</th>
<th>Immobilised more than 12 weeks</th>
<th>Weakness of dorsiflexion of foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below the tuberosity</td>
<td>92</td>
<td>3</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Curved and plaster</td>
<td>47</td>
<td>2</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Curved and compression</td>
<td>45</td>
<td>1</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Through the tuberosity</td>
<td>51</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Wedge and plaster</td>
<td>21</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wedge, transposition and plaster</td>
<td>30</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Above the tuberosity</td>
<td>83</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Wedge and plaster</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Curved and plaster</td>
<td>16</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Wound infection**—Any wound which did not heal by first intention or in which there was any discharge was considered to be infected. There was superficial infection after twenty-five operations but in most of these the discharge was sterile and the skin was healed by the time the plaster was removed. Deep infection was a serious complication in six patients (3 per cent); in two of these, somewhat unorthodox operations had been carried out. One of the two patients in whom a nail-plate had been used for fixation developed signs of infection three years after operation. The nail-plate was removed and healing occurred. Deep infection also complicated the only operation in which Kiel bone was used. Healing followed removal of the graft two months later. One of the other deep infections was in a patient who had had a low curved osteotomy of both tibiae. On one side the wound was slightly red and tender when the plaster was removed eight weeks after the operation. The skin remained healed but subsequent radiographs showed a cavity containing sequestra. Nevertheless the fragments united and there have been no symptoms for thirteen years. The remaining three patients had staphylococcal infections which healed after the removal of staples.

**Pin-track infection**—Some discharge from the lower pin-track was present in nineteen out of forty-five operations in which external compression was used. Infection of the upper-pin track did not occur. In this group of patients there were only two superficial infections and there was no case of deep infection of the main wound. The sinuses healed when the pins were removed except in two cases: in one patient staphylococcal infection of the lowest pin-track was followed by the formation of a ring sequestrum which had to be removed, and in the other the tibia had to be saucered.

**Delayed union**—Bone grafting for delayed union was necessary in five patients. The types of osteotomy concerned are shown in Table I. The average age of these patients was sixty-five
years. In spite of prolonged immobilisation the final range of movement in each was 110 degrees, 105 degrees, 110 degrees, 110 degrees and 80 degrees.

In thirteen patients the knee was immobilised for more than twelve weeks before union was achieved. There is no doubt that union occurred most quickly in wedge osteotomies done above the tuberosity (Table 1). Delay is most likely with a curved osteotomy below the tuberosity which is immobilised in plaster.

Fibrous union of the tibial tuberosity—In thirty operations the tibial tuberosity was detached, transposed downwards and medially, and fixed into its new position with a screw. Fibrous union with displacement of the bony fragment was present after nine osteotomies, but all the patients regained full active extension of the knee.

Failure to obtain correction—It is important to obtain slight over-correction of the initial deformity, but this was not achieved in thirty-seven osteotomies. Under-correction occurred in twelve out of forty-seven curved osteotomies below the tuberosity and in thirteen out of sixty-seven wedge osteotomies above the tuberosity. The remaining twelve were in the following groups: external compression, four; curved above the tuberosity, three; and transposition of tuberosity, five. All twenty-one wedge osteotomies through the lower part of the tuberosity gave full correction.

A minor degree of flexion or extension may occur at the osteotomy, and significant angulation was found after four operations, two with extension and two with flexion, all below the tuberosity.

The distal fragment may shift medially or laterally, particularly if there has been rotation at the osteotomy, but severe displacement was seen in only three patients: in two external compression had been used. In one patient the shaft of the tibia displaced medially (Fig. 2) and in the other, laterally. In the third patient, who had osteotomy with transposition of the tuberosity but without compression, the shaft of the tibia displaced medially. Sideways shift has not resulted in delayed union or affected the result of the operation.

Fracture into the knee joint—This happens only when osteotomy is carried out high above the tuberosity. Fractures, often seen only as a hairline crack in radiographs taken immediately after operation, occurred in nine out of sixty-seven wedge osteotomies and three out of sixteen curved osteotomies (an incidence of 15 per cent). Bauer et al. (1969) reported six fractures in sixty-three osteotomies and regarded them as of no consequence. An apparently trivial fracture may, however, produce irregularity of the articular surface (Figs. 3 and 4) and there was considerable displacement after one operation (Fig. 5).

If the proximal cut of the wedge is close to the articular surface the upper limb of a staple used for fixation may enter the joint. This occurred in six patients and the staples were removed.

Stiffness of knee—The range of movement six months or more after the operation was known in 198 knees: of these, 177 regained more than 90 degrees of flexion. Twenty-one knees had less than 90 degrees of flexion: of these, nine had osteotomies below or through the tuberosity.
and twelve had osteotomies above the tuberosity (the latter includes two patients with deep infections and one patient who had only 40 degrees of movement before operation). Manipulation of the knee was done eight times: in five knees with osteotomies below or through the tuberosity and in three with osteotomies above the tuberosity. The level of osteotomy does not seem to influence recovery of movement.

**Weakness of dorsiflexion of the foot**—In our experience this is the most common and least well understood complication that can follow tibial osteotomy. The extensor hallucis longus muscle alone may be affected or there may be paralysis of all the muscles supplied by the common peroneal nerve and sensory loss on the dorsum of the foot. These patients may complain of severe pain over the front of the ankle and foot after operation. Recovery is usually complete but sometimes there is slight residual weakness.

![Figure 3](image1.png)  
**Figure 3**—Radiograph showing a fracture extending into the joint after a very high wedge osteotomy.  
**Figure 4**—The fracture has produced irregularity of the articular surface of the lateral tibial condyle.

In a previous paper (Jackson, Waugh and Green 1969) we reported that eight out of seventy patients with curved osteotomies below the tuberosity had weakness of one or more muscles supplied by the common peroneal nerve but in none of these did it cause any disability. Coventry (1965) noted one “peroneal palsy” in thirty wedge osteotomies above the tuberosity which he attributed to a tight plaster. Devas (1969) reported two cases due to a “tight bandage” out of twenty-seven high osteotomies, and Harris and Kostuik (1970) found two in forty-four high osteotomies. Judet (1969) had eight “nerve complications” in 176 osteotomies but he did not give any details.

In the present review of 226 operations we found that twenty-seven patients had this complication. Only in one case, which is discussed below, were the consequences serious: in most cases recovery was complete, and when it was not, the residual weakness was so slight that it did not produce any disability. No patient had to wear a drop-foot appliance.
The incidence in the various types of operation is important (Table I). Weakness of dorsiflexion was not seen after any of the eighty-three osteotomies which were done above the tuberosity. It did, however, occur after four out of the fifty-one osteotomies through the tuberosity or its bed (Table I). In one case the consequences were disastrous.

CASE REPORT

A man aged forty-eight underwent tibial osteotomy in 1971: the tuberosity was detached and a wedge excised through its bed. The fibula was divided through a separate incision. Circulation returned normally but after the operation he complained of pain in the ankle and foot (which were included in the plaster cast). When the plaster was removed he was found to have slight weakness of dorsiflexion of the foot and diminution of sensibility on the dorsum of the foot. After six months he developed progressive ischaemia of his foot. Arteriography showed a block in the popliteal artery. A by-pass operation was carried out by Mr H. H. G. Eastcott ten months after the osteotomy. The patient had a coronary thrombosis three days later. The vein graft then failed and the leg had to be amputated. He died from a second coronary thrombosis.

Examination of the amputated specimen confirmed that there was no injury to the popliteal or posterior tibial arteries, but there was an atheromatous plaque at the bifurcation with retrograde thrombosis. The anterior tibial artery was seen in a coronal section of the bones and was patent. It seems possible that the ischaemia was precipitated by an injury to the anterior tibial artery during the operation—presumably by compression rather than division—in a patient with widespread arterial disease involving the posterior tibial artery.

DISCUSSION

We have written previously that upper tibial osteotomy is a safe procedure (Jackson, Waugh and Green 1969) and our present review of 226 operations does not make us change this opinion. Complications have occurred but they have seldom affected the final result, and when they have, the connection between failure and complication has often been indirect.

Weakness of dorsiflexion of the foot after the operation has concerned us, and its occurrence in nineteen out of forty-five curved osteotomies below the tuberosity when compression was used made us abandon this method. The cause is by no means certain, although tight bandaging is sometimes blamed (Devas 1969). The lateral popliteal nerve might be stretched when a valgus deformity is corrected, but weakness was found after seventeen osteotomies for varus deformity and only in ten for valgus deformity. Rise in tension in the anterior tibial compartment, associated either with the osteotomy or the insertion of pins into the shaft of the tibia, might be another relevant factor: of the eighteen patients with weakness after a curved osteotomy with compression, ten had pin-track infections. In one case contracture of the extensor hallucis longus muscle suggested that muscle ischaemia had been followed by fibrosis. Injury to the anterior tibial artery might have been responsible for weakness of dorsiflexion in some patients. The artery passes forward just below the lower part of the inferior tibio-fibular joint (Fig. 6) and above the upper edge of the interosseous membrane. This narrow opening is usually at the level of the lower border of the tibial tuberosity and

FIG. 5
Radiograph through plaster after the operation showing displacement of the lateral tibial condyle following a fracture produced during a wedge osteotomy above the tuberosity which was closed before the medial cortex had been sufficiently divided.
the artery is in danger when the osteotomy is done below the tuberosity. It might be divided or compressed by instruments; or it might be stretched or compressed when the osteotomy is angulated.

The possibility of damaging the anterior tibial artery was recognised by Wardle (1962), and to avoid it he carried the osteotomy five centimetres distal to the tuberosity. Steel, Sandrow and Sullivan (1971) carried out osteotomies in children at or below the insertion of the patellar tendon to avoid damage to the proximal tibial epiphysis: they suggested that the anterior tibial artery might be compressed as it passes through the interosseous membrane during osteotomy to correct a varus deformity, or stretched when a valgus deformity is corrected. They thought that this would produce “ischaemic neuritis” with pain, weakness and sensory loss which improved when the angular correction was reduced. This is a potentially serious complication which should not arise if the osteotomy is carried out above the tuberosity, for the bone is then divided proximal to the anterior tibial artery. The popliteal artery is protected by the soleus muscle, and it moves backwards when the knee is flexed (Benjamin 1969).

Osteotomy carried out above the tuberosity is, therefore, the safest procedure and union takes place quickly, whereas it may be delayed if the osteotomy is at a lower level. A curved osteotomy has no special advantage and we prefer to excise a wedge of bone. We no longer believe that it is necessary to transpose the tuberosity: the technique has rather more complications than a high osteotomy and this outweighs the theoretical benefits which led us to try it.

It is important to avoid a fracture into the joint, and the proximal cut of the osteotomy must be at least two centimetres below the level of the joint (Coventry 1973), but this may
be difficult to achieve. The size of wedge needed to produce slight over-correction of the deformity should be measured on an antero-posterior radiograph taken with the patient standing. The tibial tuberosity can be seen in the lateral radiograph and its height from the lowest point of the articular surface estimated. If the wedge can be excised within these limits, leaving two centimetres of bone proximally, then the osteotomy can be done above the tuberosity. A radiograph should be taken during the operation with a guide-wire in position in order to confirm that the line of the proximal cut is parallel to the upper surface of the tibia, as it is not always easy to be certain of this, particularly in a fat patient. It is essential
to recognise that in some osteoarthritic knees there may be a depression in one or other tibial condyle (Fig. 7), so that the proximal cut will be nearer to the articular surface than might be otherwise expected. A fracture may also be produced if the bone is forcibly broken before being completely divided.
There will be occasions when the osteotomy should be carried out through the lower part of the tuberosity. This will be indicated when, for example, there is collapse of a tibial condyle (Fig. 7), which often occurs when there is a severe angular deformity or when there are large subarticular cysts (Fig. 8). Care must be taken to avoid damage to the anterior tibial artery: stripping of muscle from the lateral surface of the tibia is restricted and bone levers are not used.
We have emphasised the complications and difficulties in this paper but these have only rarely affected the result of the operation and upper tibial osteotomy has an established place in the treatment of patients with osteoarthritis of the knee. It is, however, important to recognise the potential dangers and so avoid them.
THE TECHNIQUE AND COMPLICATIONS OF UPPER Tibial Osteotomy

SUMMARY

1. A series of 226 upper tibial osteotomies is reviewed with special reference to the complications occurring in each of the six different operative techniques that have been used.
2. Wedge osteotomy above the tuberosity is the safest operation, but care must be taken to avoid a fracture into the joint.
3. Wedge osteotomy through the lowest part of the tuberosity may be indicated in the presence of large subarticular cysts or collapse of a tibial condyle.
4. The significance of weakness of dorsiflexion of the foot and the dangers of injury to the anterior tibial artery in osteotomies below the tuberosity are discussed.

REFERENCES


