STANDING RADIOGRAPHS CANNOT DETERMINE THE CORRECTION IN HIGH TIBIAL OSTEOTOMY

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The use of standing radiographs to determine correction angles for high tibial osteotomy is not appropriate because the relative angle of the articular surfaces (condylar-plateau angle) in the weight-bearing knee changes after the osteotomy. This may give unpredictable results postoperatively.

We found that the condylar-plateau angle in postoperative standing films is very similar to that seen in non-weight-bearing supine views, and suggest that these latter radiographs be used for pre-operative planning. We describe our early results, using a special osteotomy jig, in 140 knees.

The importance of correct alignment after high tibial osteotomy (HTO) has been recognised by many orthopaedic investigators (Fujisawa, Masuhara and Shiomi 1979; Vainionpää et al 1981; Coventry 1985; Hernigou et al 1987). Weight-bearing anteroposterior radiographs are generally used to evaluate the pre-operative deformity of the knee and to determine the correction angles at osteotomy (Bauer, Insall and Koshino 1969; Coventry 1973, 1985; Harris and Kostuk 1970; Maquet 1976). Standing radiographs are valuable in demonstrating loss of cartilage space or ligament laxity of the osteoarthritic knee, but we have found that osteotomy with a correction angle calculated from the standing radiographs does not always produce the optimal degree of correction (Ogata et al 1984b).

A knee with advanced osteoarthritis and severe varus deformity in the standing position often shows relative laxity of the lateral collateral structures and attrition of the medial articular surfaces, producing an increase in the lateral joint space. If the osteotomy succeeds in transferring the load from the medial to the lateral compartment, the lateral joint space decreases, the medial joint space widens, and there is less stretching of the lateral collateral structures. The standing axial alignment after operation is decided not only by the angle of the osteotomy (osseous component), but also by the change in the angle between the articular surfaces (condylar-plateau angle). The senior author (KO) noted in 1981 that when the osteotomy had been correctly performed the condylar-plateau angle in the postoperative standing film looked very similar to that in the pre-operative supine radiograph (see Fig. 1). We have therefore used supine radiographs rather than standing films for planning high tibial osteotomies, though this has never been previously recommended.

The purpose of our study was to investigate changes in the condylar-plateau angle after osteotomy and to verify that measurement from supine non-weight-bearing radiographs offers more predictable postoperative axial alignment than that from standing radiographs.

PATIENTS AND METHODS

We studied 119 patients who had 161 valgus high tibial osteotomies, performed between 1981 and 1988 for medial compartment osteoarthritis of the knee. There were 128 female knees and 33 male knees, and the mean age of the patients at the time of osteotomy was 63 years (20 to 83). The minimum follow-up was two years with an average of 3.8 years.

All patients had standardised radiography of their lower limbs: orthoradiography of the involved leg used three successive exposures centred over the hip, knee and ankle, with a tube-to-film distance of 2 m. Care was taken to place the leg in neutral rotation so that the patella faced anteriorly. Films were taken in both the supine position and in the standing position.

For pre-operative planning, we used the supine orthoradiograph to determine the amount of correction. Our aim was to produce a mechanical axis from the
The condylar-plateau angle (CPA) is measured between lines tangential to the femoral condyles and the tibial plateau. The CPA in the pre-operative standing film (left) is much larger than either that of the pre-operative supine position (middle) or the very similar postoperative standing view (right).

centre of the femoral head to the centre of the ankle which passed through a point on the tibial articular surface at approximately 70% of its width from the medial margin, at about 40% of the width of the lateral plateau (Fig. 2). This amount of correction usually produces an anatomical femorotibial angle of 165° to 169°, with 6° to 10° of valgus deviation from normal axial alignment.

We used an interlocking wedge osteotomy (Ogata 1984a), a modified closing wedge, with the planned angle precisely made using specially designed instrumentation. This is shown in Figure 3 and its use is fully detailed in Figure 4.

The osteotomy was internally fixed, and range of motion exercises began two weeks postoperatively. Progressive weight-bearing was allowed from six weeks and the patients were discharged from the hospital approximately two months postoperatively.

Orthoradiographs were taken at four to six months, at one to two years, and at five years postoperatively. On these films we measured the femorotibial angle (Bauer et al 1969), the condylar-plateau angle, and recorded the point on the tibial articular surface through which the mechanical axis passed, expressing it as a percentage of its width from the medial margin (Fig. 5).

The significance of differences were assessed using Student’s t-test for paired samples.

RESULTS

Of the 161 osteotomies, six were excluded from the present study because of under-correction, due to miscalculation of the correction angle in two cases and early postoperative displacement of the osteotomy in four. A further 15 osteotomies were excluded because their

Method of determining the angle of osteotomy correction from the supine orthoradiograph (Ogata 1984). The required mechanical axis (M) is drawn from the centre of the femoral head to pass through a point approximately 70% of the width of the tibial articular surface from its medial margin (40% of the width of the lateral part of the plateau). The line AO represents the upper osteotomy, usually 5 mm proximal to the patellar tendon insertion and parallel to the tibial articular surface. A line is then drawn from point O to the centre of the ankle (B), and the corrected position of the ankle (B') is marked on the line M so that the length of OB' equals that of OB. The angle formed by OB and OB' is the correction angle which determines the lower osteotomy site OA'.

Fig. 1

Fig. 2
The proximal end (A) of the alignment bar (a) is usually placed 5 mm proximal to the tibial tubercle, and the other end (B) at the centre of the ankle. The fixed pin-guide (b) is attached to the bar with the angle (θ) between the guide and the bar equal to the plateau-shaft angle. This enables the control pin for the upper osteotomy to be placed parallel to the articular surface and 5 mm proximal to the tibial tubercle. The movable pin-guide (c) is set at the desired angle of correction (α) to mark the lower osteotomy site. After the wedge has been excised and the angle closed between the upper and lower pins, the alignment bar is reattached to the movable pin-guide at the angle (θ) and again placed parallel to the tibial shaft. The angle shown on the protractor (β) is the actual correction which has been obtained. If the osteotomy has been precisely performed, β should be equal to α.

The specially designed osteotomy jig. There is a protractor, or angle gauge, and three detachable parts: an alignment bar (a), a fixed pin-guide (b) for the upper osteotomy site, and a movable pin-guide (c) which can be set at the correct angle to mark the lower osteotomy site.

Characteristics measured on the whole-leg orthoradiograph: FTA (anatomical femorotibial angle); CPA (condylar-plateau angle); %M, the position of the intersection of the mechanical axis M and the tibial articular surface, expressed as 100Y/X.

The relationship between the CPA and the FTA on the pre-operative standing radiographs.

radiographs were incomplete, leaving 140 osteotomies for analysis of all the measured characteristics.

The mean pre-operative standing femorotibial angle (FTA) was 184° ± 4° (SD) and the mean mechanical axis was at 20% ± 18% from the medial edge of the plateau. One to two years after osteotomy, the mean standing FTA was 168° ± 4° and the mechanical axis passed at 67% ± 14%. Of all the 140 osteotomies, 74% had
satisfactory correction with the mechanical axis passing between 60% and 80%.

All knees showed a medial convergence of the articular surfaces, with lateral opening of the condylar-plateau angle (CPA), both before and after osteotomy. The CPA tended to be greater in the knees with a larger varus deformity on the pre-operative standing radiographs (Fig. 6). This tendency was less obvious on the postoperative standing radiographs.

In 85 knees, followed for more than five years after osteotomy, the mean CPA of the pre-operative standing radiographs was significantly greater (p < 0.01) than the pre-operative supine radiographs and the postoperative standing views at four to six months, one to two years, and five years (Fig. 7). However, the mean postoperative standing values at all follow-up periods were similar to the mean pre-operative supine value. The standing CPA and FTA showed no significant changes with time over five postoperative years.

Figure 8 shows the changes in the mean CPA after osteotomy for three groups of knees: 43 with a small CPA (0° to 4°); 85 with moderate angles (5° to 9°); and 12 with over 10°. The knees with larger pre-operative standing CPA showed a greater decrease postoperatively; this ranged from 6.5°, at one to two years, in the group with a large pre-operative angle to only 1.4° in the group with a small angle.

**DISCUSSION**

Miniaci et al (1989) reported disappointing results for postoperative correction angles: only 50% of their osteotomies fell into a satisfactory range (± 10%) of correction. They felt that simple pre-operative planning was not enough, but failed to discuss possible causes for the inconsistencies between expected and actual alignments. They had used similar methods to ours, based on orthoradiographs, but had measured weight-bearing films rather than non-weight-bearing views. Our results using the supine radiographs appear to be more predictable: 74% of our osteotomies gave a mechanical axis within ± 10% of the expected position on the tibial articulation.

Standing radiographs are important to demonstrate loss of cartilage space and ligament laxity, but they are not appropriate for determining the correction angles of high tibial osteotomy. Especially in knees with large standing condylar-plateau angles, a large correction in addition to the bony correction will be produced by the postoperative decrease in the condylar-plateau angle. Although Hernigou et al (1987) used standing radiographs to determine the size of the wedges in most cases, they recommended the use of supine non-weight-bearing radiographs in the presence of lateral ligamentous laxity of more than 7° of condylar-plateau angle on the standing radiograph, in order to prevent excessive correction and the development of a reverse deformity. Our finding that the condylar-plateau angle of the postoperative standing position is equivalent to that of the pre-operative supine position suggests that the use of supine radiographs for pre-operative planning can give more predictable results.

Some may fear that calculation from non-weight-bearing radiographs will result in inadequate correction, and that forces will continue to pass through the painful compartment (Harris and Kostuik 1970). However, we aim to over-correct to about 6° to 10° valgus alignment from normal by placing the mechanical axis at a point approximately 70% of the width of the tibial articular surface from its medial margin. Our six cases of under-correction, with a femorotibial angle of more than 175°, all resulted from technical failures. It should be noted that in these knees the standing condylar-plateau angle did not decrease postoperatively.

The precise evaluation of varus or valgus deformity of the knee and accurate calculation of the correction angle require that whole-leg orthoradiographs be taken with correct positioning. The anatomical femorotibial angle is affected by small changes in limb rotation, therefore, a true anteroposterior view of the knee should be taken with the hip in neutral rotation. This position can be confirmed by ensuring that the patella faces...
straight anteriorly, or more accurately by observing that the centre of the ankle moves in the sagittal plane on flexion and extension of the knee. When the femoral shaft is deformed, precise measurement of the femorotibial angle is difficult and the use of the mechanical axis is the best basis for calculation of the correction angle.

The size of the necessary wedge is influenced by the level and width of the osteotomy site. If this is neglected, as in most methods described previously, the postoperative change in position of the tibial axis may result in a smaller correction than expected (Fig. 9). The method of pre-operative planning shown in Figure 2 can determine the precise wedge size for an osteotomy at any level and has been proved to provide predictable results.

![Diagram](image)

The postoperative change in position of the tibial axis. Note that the new femorotibial angle is smaller (less valgus) when measured from the new axis than from the pre-operative axis of the shaft of the tibia.

It is not always technically easy to obtain the planned correction angle during the osteotomy; this is one of the causes of inconsistency in the postoperative alignment. We feel that surgical instruments like those used for total knee arthroplasty are necessary. The specially designed osteotomy jig (see Figs 3 and 4) is unique in that the actual angle of correction and the final axial alignment of the tibia can be assessed during the procedure. In addition, the osteotomy site is determined precisely without radiographic control (Ogata 1988). It is also important that the osteotomy is firmly fixed to prevent recurrence of deformity during the early postoperative period.

The most desirable axial alignment remains debatable, but many investigators recommend an over-correction of 5° to 10°, so that the final standing valgus deviation is 10° to 15°. Fujisawa et al (1979) report an arthroscopic study after high tibial osteotomy; they demonstrated cartilage regeneration in those knees in which the mechanical axis passed between 30° to 40° lateral to the mid-point of the tibial articular surface. In our series, satisfactory clinical results were noted in the knees where the mechanical axis passed within the lateral compartment, with an over-correction of 6° to 10° valgus. Excessive over-correction beyond this range was often associated with some difficulty in walking due to knocking of the knee against the other leg; under-correction was associated with inadequate relief of pain.

Recently, attempts have been made to measure dynamic loading in the knee, rather than static measurements. Gait studies have shown that the distribution of loads within the knee during walking did not correlate with predictions from standing radiographs (Johnson, Leitl and Waugh 1980; Prodromos, Andricachi and Galante 1985). It may be that pre-operative assessments of dynamic loading may be required in the future to determine more accurately the correction angle of high tibial osteotomy.

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REFERENCES


