LOWER LIMB

The effect on mechanical axis deviation of femoral lengthening with an intramedullary telescopic nail


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Internal lengthening devices in the femur lengthen along the anatomical axis, potentially creating lateral shift of the mechanical axis. We aimed to determine whether femoral lengthening along the anatomical axis has an inadvertent effect on lower limb alignment. Isolated femoral lengthening using the Intramedullary Skeletal Kinetic Distractor was performed in 27 femora in 24 patients (mean age 32 years (16 to 57)). Patients who underwent simultaneous realignment procedures or concurrent tibial lengthening, or who developed mal- or non-union, were excluded. Pre-operative and six-month post-operative radiographs were used to measure lower limb alignment. The mean lengthening achieved was 4.4 cm (1.5 to 8.0). In 26 of 27 limbs, the mechanical axis shifted laterally by a mean of 1.0 mm/cm of lengthening (0 to 3.5). In one femur that was initially in varus, a 3 mm medial shift occurred during a lengthening of 2.2 cm.

In a normally aligned limb, intramedullary lengthening along the anatomical axis of the femur results in a lateral shift of the mechanical axis by approximately 1 mm for each 1 cm of lengthening.
geometric relationship (approximately 7° of valgus) of the normal anatomical femoral axis to the normal mechanical femoral axis (Fig. 1), we hypothesised that the ISKD would consistently cause lateralisation of the overall mechanical axis of the limb.

Patients and Methods
We reviewed 88 ISKDs that had been implanted in patients undergoing femoral lengthening between April 2002 and February 2006. All 88 ISKDs reviewed for the current study were part of the group of 242 ISKDs that were reviewed in our previous ISKD mechanical failure study.12 We excluded patients who underwent realignment procedures of the tibia and/or femur, who had a previous or simultaneous tibial lengthening, or who developed malunion or nonunion after lengthening. Patients whose limbs were improperly positioned when radiographs were obtained (i.e., the patella was not facing forward) were also excluded.

A total of 24 patients (20 men and four women) with a mean age of 32 years (16 to 57) were included in the study. This group of 24 patients included two patients who experienced mechanical failures of the ISKD in our previous study.12 The malfunctioning rods were replaced in both cases, and the limbs lengthened uneventfully. Three patients received bilateral treatment, hence 27 femora were included. The diagnosis was congenital shortening in 11 cases, post-traumatic limb-length discrepancy in nine, and constitutional short stature in seven. The mean pre-operative limb length discrepancy was 2.8 cm (0 to 7.0). Of the femoral ISKDs, 21 had been inserted in a standard fashion through the piriformis fossa; six tibial ISKDs had been inserted into the femora through the greater trochanter because of the narrow diameter of the intramedullary canal. The mean level of the osteotomy was 5.5 cm distal to the lesser trochanter (3.3 to 8.9). The operative technique has previously been described.7

Standing long-leg radiographs were used to measure the alignment of the lower limb. These were made pre-operatively and again following consolidation, approximately six months (3 to 9) after the start of lengthening. In addition, the mechanical lateral distal femoral angle13 was measured on immediate post-operative anteroposterior (AP) radiographs to confirm that the osteotomy itself did not alter the mechanical axis. The mechanical lateral distal femoral

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Diagrams showing the methods of limb-lengthening using external femoral fixators and the Intramedullary Skeletal Kinetic Distactor (ISKD). External fixation is typically aligned along the mechanical axis, preserving alignment, while use of the ISKD along the anatomical axis can result in lateral mechanical axis deviation (MAD): the greater the lengthening, the greater the deviation (printed with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore).
angle is the lateral angle formed between the mechanical axis line of the femur and the knee joint line of the femur in the frontal plane. The post-consolidation long-leg radiograph was compared with the pre-operative film to determine whether any change to the mechanical axis deviation had occurred. Mechanical axis deviation, alignment, and joint orientation angles were obtained by one of the authors (RDB) and confirmed by one of the two senior authors (JEH, DP) using published methods. To avoid bias, the author who obtained the measurements was not one of the clinicians who performed the lengthenings.

The study was approved by our institutional review board.

Results

The desired amount of lengthening was achieved in all patients, and no hardware complications were reported. The mean length obtained was 4.4 cm (1.5 to 8.0). None of the 27 limbs had a change in the lateral distal femoral angle on the immediate post-operative AP radiographs, confirming that the osteotomy itself did not alter the mechanical axis.

The mechanical axis deviation was measured both pre-operatively and following consolidation in each case, and the mean change was 4.3 mm (0 to 14). In one leg, it moved 3 mm medially during a lengthening of 2.2 cm (Fig. 2). In the remaining 26 limbs, it moved laterally by a mean of 1.0 mm (0 to 3.5) for each 1 cm of lengthening (Figs 2 and 3).

Because of the potential for errors in measurement or radiological magnification, the data were analysed by considering a total shift in mechanical axis deviation of ≤2 mm to be inconsequential. With this assumption, further analysis of these 26 limbs showed that 15 limbs had an insignificant total lateral change in mechanical axis deviation of ≤2 mm. The remaining 11 limbs underwent a mean lateral shift in mechanical axis deviation of 2.0 mm/cm of lengthening (1.0 to 3.5).

Discussion

Our hypothesis was that femoral lengthening along the anatomical axis with a telescopic intramedullary nail induces lateralisation of the mechanical axis of the limb, based on the fact that there is a difference of approximately 7° between the two axes.

A previous study did not show a consistent pattern of change in the displacement of the mechanical axis when lengthening with an external fixator over an intramedullary nail. That study concluded that the theoretical lateral shift of the mechanical axis did not occur or was clinically unimportant in all but one of a subgroup of 25 limbs. It was postulated that the nail allowed some proximal varus angulation.
through the subtrochanteric osteotomy, thereby compensating for the lateralisation that would otherwise have been observed after lengthening along the anatomical axis.

In a study of 12 patients undergoing lengthening with a fully implantable motorised intramedullary nail, Baumgart et al.\(^5\) recommended shifting the distal fragment laterally before reaming in order to achieve normal mechanical alignment. In that study, no more than 2 mm of mechanical axis deviation occurred in any limb. Cole et al.\(^6\) reported the initial results of ISKD lengthening in 18 patients but made no mention of changes in axis deviation.

Garcia-Cimbrelo et al.\(^{14}\) studied the Albizzia nail in 23 patients and found only one in whom lengthening caused a genu valgum deformity requiring corrective tibial osteotomy. In another study,\(^9\) nine patients underwent detailed radiological evaluation during lengthening with the Albizzia nail, and all had a lateral shift of the mechanical axis. However, the mean increase in genu valgum was only 1.04° (SD 1.3), and the absolute value of the mechanical axis deviation did not correlate with the gain in length. The authors concluded that the Albizzia nail did not modify the alignment of the mechanical axis when used to lengthen limbs that are straight, or ‘normally aligned’.

In reporting their experience with the Fitbone nail in ten patients, Singh et al.\(^{16}\) found no angular deformities and no alteration in the mechanical axis despite a mean lengthening of 40 mm (27 to 60). However, it was not clear whether a corrective manoeuvre had been performed, as previously described by Baumgart et al.\(^5\).

In contrast to the above reports, we found that 26 of 27 limbs had a lateral shift of the mechanical axis, thereby supporting our hypothesis. However, many of these shifts
appeared to be minor and inconsequential. There are difficulties in measuring such small deviations on radiographs. However, inaccuracies due to rotational differences can be minimised by careful positioning of the limb with the patella facing forward, and the reproducibility of the measurement of the mechanical axis deviation can be improved by the use of large 129.5 cm-long radiographs.3

We conclude that our initial hypothesis is generally applicable. This study enabled us to estimate how much mechanical axis deviation will result from any given planned lengthening. As a useful rule of thumb, the mechanical axis will shift about 1 mm laterally for every 1 cm of lengthening.

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References