L-shaped caliper for limb length measurement during total hip arthroplasty

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The existing methods of assessing limb lengthening during total hip arthroplasty (THA) are prone to error because the measurements are not parallel to the limb lengthening axis. In order to address this, we designed a caliper to estimate limb lengthening during THA and evaluated its accuracy compared with our previous device, the straight caliper. Limb lengths were measured in 100 patients. The L-shaped caliper was used in 50 cases and the straight caliper in 50. The correlation between intra-operative and post-operative radiographic measurements was significantly improved using the L-shaped device (p < 0.0001, r = 0.934). This method was extremely accurate in predicting changes in limb length due to surgery.

Different methods of measuring limb length during total hip arthroplasty (THA) have been described, including one from our department. They measure the distance between two reference points on the pelvis and femur. Measurements thereby obtained are affected by the position of the hip or the reference point on the pelvis, because the line between them is not usually parallel to the limb lengthening axis. Therefore, a discrepancy between intra-operative limb length and post-operative radiographic measurement is possible. In order to reduce this error, the L-shaped caliper was designed and in our practice it replaced our previously used straight caliper in August 2002 (Fig. 1).

Patients and Methods

We studied 100 consecutive patients undergoing THA between 2001 and 2002. All operations and measurements of limb length were done by the same surgeon (MN). The L-shaped caliper was used in 50 cases (group I) and the straight caliper in 50 cases (group II). The groups were similar in terms of age and pre-operative diagnosis. The mean age at the time of operation was 62 years (44 to 77) in group I and 59 years (24 to 84) in group II. The pre-operative diagnoses were primary or secondary osteoarthritis (45 patients in group I and 46 patients in group II), rheumatoid arthritis (one and one, respectively), and osteonecrosis (four and three).

When using the L-shaped caliper and before dislocation of the hip, a reference point was established below the iliac crest close to the anterior superior iliac spine. This was achieved by inserting a threaded Steinmann pin percutaneously through both cortices of the ilium. A second reference point was marked over the great trochanter using electrocautery. The L-shaped caliper with sliding pointer and length indicator was attached to the iliac Steinmann pin with its longer arm parallel to the limb lengthening axis (Fig. 1c). The sliding pointer was placed on the femoral reference point and the indicator locked beside the pointer for later reference.

In order to determine limb length, the reference position of the hip was made as neutral as possible. The caliper was detached from the Steinmann pin and the hip dislocated. After stable reduction with the trial components in place, the caliper assembly was attached to the Steinmann pin. The sliding pointer was moved to the femoral reference point with the hip in the same position as before dislocation. Limb lengthening was measured as the distance between the pointer and the indicator (Fig. 2).

The straight caliper used in the patients in group II measured the distance between two reference points on the pelvis and the femur (Fig. 3).

In 31 cases from group I and 33 cases from group II who had unilateral involvement, we attempted to equalise limb lengths as much as possible. In 19 cases from group I and 17 cases from group II who had bilateral involvement, the correction of leg length aimed to restore the
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Limb lengthening was evaluated from a standard anteroposterior radiograph of the pelvis with the hip joint in the neutral position. Horizontal lines through the inferior aspect of the teardrop were drawn. The vertical distance between the most prominent point of the lesser trochanter and the trans-teardrop line was measured using templates magnified by 10%. These measurements were made on pre-operative radiographs and on post-operative radiographs obtained at a mean of seven days after surgery.

The L-shaped caliper assembly, Figure 1a – The assembly comprises the L-shaped caliper with sliding pointer and indicator and threaded Steinmann pin. The longer arm of the L-shaped caliper should be parallel to the limb lengthening axis. The indicator is placed proximally to the sliding pointer for lengthening and distally for shortening. When attaching this assembly to the threaded Steinmann pin on the pelvis, the hip joint should be in neutral. Figure 1b – Diagram of the L-shaped caliper assembly. Figure 1c – Intra-operative position, the pointer can rotate in the direction shown by the curved arrow.

Fig. 1a

Intra-operative photograph of limb length measurement using L-shaped caliper after reduction with the trial prosthesis. The distance between the length indicator and the sliding pointer was measured (arrows).

Fig. 2

Photograph of the straight caliper, the limb measuring axis is not parallel to the limb lengthening axis.

Fig. 3

anatomical centre of the hip according to pre-operative planning.

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In order to reduce the cancelling effect of the plus and minus dispersions of the data, the error between the intra-operative measurement and the radiographic measurement was assessed in each group in terms of absolute value. In cases with unilateral involvement, post-operative limb length inequality was also investigated and compared between the two groups. These results were analysed using the Student’s $t$-test. In order to determine the correlation between intra-operative and post-operative measurements, Pearson’s correlation coefficient was used.

**Results**

The error between the intra-operative measurement and the radiographic measurement in absolute value was reduced significantly in group I ($p < 0.0001$); the means were $1.7 \pm 1.6$ mm in group I and $6.2 \pm 4.1$ mm in group II (Fig. 4). Among the 31 cases from group I and 33 cases from group II with unilateral involvement, the post-operative limb length inequality was also reduced significantly in group I ($p < 0.0001$); the means were $2.1 \pm 1.5$ mm in group I and $8.2 \pm 3.8$ mm in group II (Fig. 5). A significant correlation
between intra-operative and post-operative measurements was also observed in group I (group I, p < 0.0001, r = 0.934; group II, p = 0.013, r = 0.345) (Fig. 6).

**Discussion**

Conventional methods of intra-operative limb length measurement are based on the distance between two reference points marked on the pelvis and the femur. The location of the reference point on the pelvis varies in each case and the line between the two reference points is generally not parallel to the limb lengthening axis. Therefore the limb lengthening determined by these methods does not match the true limb lengthening (Fig. 7). The L-shaped caliper allows measurement parallel to this axis. This improvement over the straight caliper enables accurate measurement, regardless of the location of the Steinmann pin.

When attaching the L-shaped caliper to the Steinmann pin it is important to place the femur in the same position relative to the pelvis at the time of measurement and to estimate the limb lengthening axis accurately. Occasionally, the surgeons could not observe the hip joint position or limb lengthening axis accurately because they were too close to the patient. In this study, staff around the operating table helped determine the position of the L-shaped caliper because they could observe the entire patient.

The Steinmann pin sometimes loosens due to osteoporosis. Woolson and Harris\(^3\) reported that a measuring device with three-point fixation on the pelvis prevented loosening. We have found that incorporating a 2-cm thread to the Steinmann pin significantly reduces intra-operative loosening.

The length indicator of the L-shaped caliper was normally placed proximal to the sliding pointer. This is because patients undergoing THA usually need limb lengthening. If the patient needs shortening, the indicator should be placed distal to the sliding pointer.

During total hip arthroplasty, it is sometimes not possible to achieve an accurate insertion angle of the Steinmann pin. In order to accommodate pelvic tilt and insertion angle of the Steinmann pin, the sliding pointer can rotate freely. Furthermore, by calibrating the Steinmann pin and allowing controlled movement of the caliper on the pin, the system can also evaluate offset.

The accurate assessment of limb lengthening during surgery is helpful, especially in those patients with marked inequality pre-operatively. We believe that measurement parallel to the limb lengthening axis reduces error between the intra-operative and the post-operative measurement of limb length.

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**References**


