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A new and simple intraoperative method for correction of leg-length discrepancy in total hip arthroplasty

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ABSTRACT

Total hip arthroplasty (THA) can eliminate pain caused by hip joint destruction and correct leg-length discrepancies (LLD). We present a short and simple intraoperative method for LLD correction in THA. We performed 55 primary THAs using this technique. The measurement error was 1.86 ± 1.4 mm, which was within 3 mm in 49 of 55 cases (89%) and within 5 mm in 54 of 55 cases (98%). This method is simple and does not require specialized devices, making it versatile to be used anywhere. No new skin incisions or extra costs are required, which will likely make it attractive to surgeons.

1. Introduction

Total hip arthroplasty (THA) can eliminate pain caused by hip joint destruction in various diseases, increase range of motion (ROM), and provide robust support. It can also instantaneously correct leg-length discrepancies (LLD) caused by various diseases. LLD is particularly common in acetabular dysplasia accompanying osteoarthritis of the hip. However, the length that can be corrected instantaneously is limited, and surgeons must be careful to avoid nerve paralysis when correcting LLD.

Given the patients' high expectations of THA, postoperative LLD can lead to patient dissatisfaction and cause gait disorders. In the United States, large postoperative LLDs are reported to be a common cause of post-THA patient lawsuits. Although there is no consensus as to whether structural or functional leg length should be considered postoperatively, it is nevertheless important to be able to accurately envision the anticipated amount of leg-length extension during surgery.

Surgeons need to be mindful of the amount of soft tissue tension after repositioning a dislocation. However, because soft tissues along the approach route must be dissected and there is no muscular tension when patients are under anesthesia, it can be difficult to precisely measure soft tissue tension during surgery. Using a muscle-sparing approach to protect soft tissue as much as possible can make it difficult to position the implant accurately. The abovementioned factors can hinder the ability to correct LLD accurately. Compared to surgeries in the supine position, leg-length correction in the lateral position is particularly difficult because of the higher likelihood of pelvic displacement and the difficulty of making comparisons with the opposite leg.

Previous attempts at intraoperative leg-length correction have used radiography, specialized devices, navigation, and other tools. However, each has problems—radiation exposure, additional invasiveness in the form of extra skin incisions or longer surgeries, and greater cost—that prevent them from becoming widely used. Our method of leg-length correction during THA does not use radiography or specialized devices and does not extend the operation time. The objective of the present study was to evaluate the precision of this method.

2. Materials and methods

This study was a level 3 evidence prospective study. Ethical approval was granted by an institutional review board of the Faculty of Medicine in Oita University and has been performed according to the principles of the Declaration of Helsinki. All study participants provided informed consent.

A total of 105 patients who underwent unilateral primary THA in our department between May 2017 and March 2018 were included in the study. We excluded 50 patients with incomplete operation record. Fifty-five patients had disordered hip joints that were affected by rheumatoid arthritis, idiopathic osteonecrosis of the femoral head, and osteoarthritis and contralateral healthy hip joints with less morphological abnormalities. The study group consisted of nine men and 46 women with an average age of 66.5 (range 48–84) years.

SQRUM (Japan-Kyocera, Shiga, Japan) was used in 43 hips, G7

Abbreviations: BMI, Body mass index; CT, Computed tomography; LLD, Leg-length discrepancies; ROM, Range of motion; THA, Total hip arthroplasty

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(Zimmer Biomet, Warsaw, IN, USA) in nine hips, and R3 (Smith & Nephew, London, IN, UK) in three hips. INITIA (Japan-Kyocera, Shiga, Japan) was used in 24 hips, ANTHOLOGY (Smith & Nephew, London, IN, UK) in 13 hips, SL-PLUS MIA (Smith & Nephew, London, IN, UK) in 11 hips, POLAR STEM (Smith & Nephew, London, IN, UK) in four hips, J-Taper (Japan-Kyocera, Shiga, Japan) in two hips, and Exeter (Stryker Orthopedics, Mahwah, NJ, USA) in one hip.

2.1. Preoperative planning

All patients completed computed tomography (CT) of their hip joint from the iliac crest to the knee joint and through the distal femoral condyles using a 320-row multi-detector helical CT scanner (Aquilion ONE; Toshiba Medical Healthcare, Tochigi, Japan) (detector configuration 80×0.5, beam collimation 40 mm) with reconstructed slice widths of 1 mm and slice intervals of 1 mm. Imaging data were in Digital Imaging and Communications in Medicine format (DICOM; National Electrical Manufacturers Association, Rosslyn, VA, USA) and were transferred into CT-based simulation software (ZedHip LEXI Co., Ltd., Tokyo, Japan). This software included the implant database with computer-aided three-dimensional design models provided by the implant manufacturer. This software allowed preoperative THA planning, and we planned the amount of leg-length extension using this software.

2.2. Intraoperative procedures

Intraoperative leg-length measurements were performed as follows. A posterolateral approach was used in all cases. After incising the joint capsule and developing the acetabulum posteriorly but before dislocation, Luer' forceps or a bone chisel was used to cut a 1-mm-wide, 3-mm-long line in the posterior acetabulum. A guidepost was also made at this location with a sterilized skin pen to make it even clearer (Fig. 1). The affected leg was placed with the hip in the neutral position between extension and flexion, and between internal and external rotation; then, this shape was marked on sterilized sheets using a skin pen, so this leg position can be reproduced as closely as possible after repositioning. A ruler was placed against the guidepost on the posterior acetabulum, so it was perpendicular to the operating table, and the site where the ruler touched the greater trochanter of the femur was marked with a skin pen (Fig. 1). Then, osteotomy of the neck was performed, the acetabulum was opened, the acetabular cup was positioned using only navigation, and the trial liner was placed. Thereafter, rasping of the femur was performed, the trial stem was inserted, and a repositioning test was performed with the neck and ball head attached. ROM was tested, the absence of impingement was confirmed, and the leg was positioned to match the sterilized sheet marked in the leg shape prior to dislocation. The ruler was then placed against the mark on the posterior acetabulum so that it was perpendicular to the operating table, and the distance between the location where the ruler contacted the greater trochanter and the site where the posterior acetabulum was marked before dislocation was measured with a ruler, which represented the amount of intraoperative leg-length extension (Fig. 2). If there were osteophytes on the posterior acetabulum that needed to be removed, some of the osteophytes on the marked area were retained, which were then removed after the final check on the leg-length correction.

2.3. Postoperative procedures

All patients completed CT by the same method as preoperation. Imaging data were in DICOM format (National Electrical Manufacturers Association, Rosslyn, VA, USA) and were transferred into CT-based simulation software (ZedHip LEXI Co., Ltd., Tokyo, Japan). We measured the amount of postoperative leg-length extension using this software. The difference between the intraoperative and postoperative amounts of leg-length extension was defined as the measurement error. For this measurement procedure, we also evaluated the correlation between the measurement error and body mass index (BMI) and the amount of postoperative leg-length extension. We used the chi-square test with official approval of person.

3. Results

The mean amount of intraoperative leg-length extension was 11.5 ± 6.0 mm, and the mean leg-length extension measured by postoperative CT was 11.3 ± 6.2 mm, with a measurement error of 1.86 ± 1.4 mm (intraoperative leg-length extension – leg-length extension measured by postoperative CT) (Table 1). The measurement error was within 3 mm in 49 of 55 cases (89%) and within 5 mm in 54 of 55 cases (98%). The correlation coefficients of the absolute error with BMI and amount of postoperative leg-length extension were $p = 0.064$, $r = 0.252$, and $p = 0.877$, $r = 0.021$, respectively, which were not significant.

4. Discussion

The intraoperative-postoperative error in the present study was 1.86 ± 1.4 mm, which is not inferior to the results of previous studies that used devices or navigation. This method required approximately 3 min, which does not take much time, for the whole procedure. This method is quite less invasive for patients, as it does not require any new skin incisions. This method is also simple for surgeons, as it does not require specialized devices, making it versatile enough to be used anywhere. It does not require any extra costs, which will likely make it attractive to hospitals.

Post-THA LLD can lead to low-back pain, limping, and laxity and may increase risk of dislocation.[1,2] Moreover, LLD is the main cause of patient dissatisfaction and lawsuits after THA.[3] Edeen et al. and Ranawat et al. have reported that LLD must be ≤ 10 mm to ensure a high

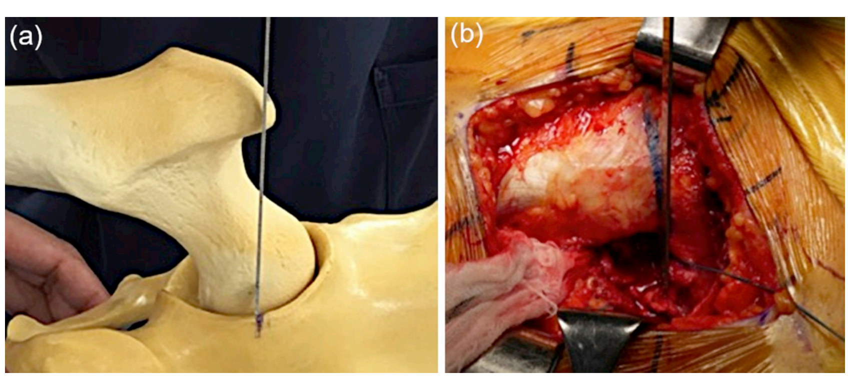

Fig. 1. Marking at the acetabular rear wall and marking at the greater trochanter in a model (a). Marking in the acetabular rear wall and marking at the greater trochanter during surgery (b).

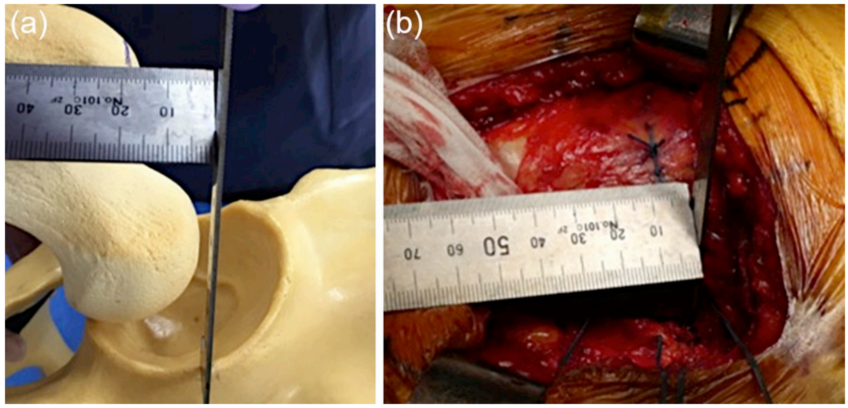

Fig. 2. A model of leg-length discrepancy (a). Leg-length discrepancy during surgery (b).

Table 1
Comparison of intraoperative and postoperative amount of leg length extension.

Intraoperative amount of leg length extension	11.5 ± 6.0 mm
Postoperative amount of leg length extension	11.3 ± 6.2 mm
Measurement error	1.86 ± 1.4 mm

level of life satisfaction.[4,5] Nevertheless, previous studies have indicated that approximately 10–16 mm of LLD can occur unexpectedly.[4,6] Possible causes include unanticipated cup-stem positioning due to excessive intraoperative reaming or other factors, preoperative hip flexion contracture, imprecise preoperative planning due to discrepancies in radiographic magnification, and lack of experience of the surgeon.

There is no standard definition of LLD, which can be understood as structural LLD, which is measured by radiography, or subjective LLD, which is assessed with the patient in the standing position. Subjective LLD is reported to have a bigger effect on satisfaction levels than structural LLD.[7,8] Moreover, reducing structural LLD can reduce subjective LLD, thereby improving quality of life.[9] However, consensus has not been reached as to the target amount of leg-length extension. In any case, accurate measurement of the amount of leg-length extension during surgery is important.

Objective methods of measuring leg-length extension intraoperatively include an incredibly simple method reported by McGee et al. that uses a bent Kirschner wire.[10] Later, Shiramizu et al. reported an intraoperative-postoperative error of 1.7 ± 1.6 mm using an improved L-shaped caliper.[11] Ogawa et al. obtained positive outcomes using a PCA limb-lengthening gauge, reporting an intraoperative-postoperative error of 2.1 ± 1.6 mm.[12] However, these methods involve increased invasiveness from additional skin incisions or inserting pins into the ilium. They also require specialized devices or a learning curve before surgeons are accustomed to the techniques and manipulations, which harm the versatility of these methods.

Methods that use navigation have also been reported recently. Ogawa et al. used navigation to obtain positive results in 30 cases, reporting an intraoperative-postoperative error of 2.4 ± 1.7 mm.[12] Other positive reports on navigation include a study by Kitada et al., who reported an error of 1.3 ± 4.1 mm in 16 cases, and a study by Ecker et al., who reported an error of 0.5 ± 1.7 mm in 344 cases.[13,14] However, the high cost of navigation systems makes these methods less versatile. Other disadvantages that have been pointed out include loss of calibration and laxity of femoral pins.

The intraoperative-postoperative error in the present study was 1.86 ± 1.4 mm, which is not inferior to the results of previous studies that used devices or navigation. The error exceeded 5 mm in one case in the present study. This was an obese patient with an intraoperative measurement of 10 mm and a postoperative measurement of 1.52 mm. The amount of error can be increased by insufficient pelvic fixation, which may place distal traction on the pelvis during the repositioning test that rotates it on the coronal plane, which could cause the intraoperative measurement to be shorter than the actual amount of extension. Alternatively, because the greater trochanter is marked on the gluteus medius, intraoperative measurements that are greater than the actual amount of extension may occur due to soft tissue tension that accompanies leg extension and increased offsetting of the pelvis and femur. In addition, if the marks on the posterior acetabulum or greater trochanter were unclear, different measurement sites could be used before dislocation and after implant insertion. We take care to ensure that the mark is as clear as possible, but if a harmless ink that did not disappear during surgery were available, there would be no need to cut the posterior acetabulum, which is an area to improve in the future. Further, the ruler was placed perpendicular to the operating table using the naked eye. Using a bar with a level gauge could further improve precision.

Limitations of this study include the lack of a control group in which this method was not used, and the lack of head-to-head comparisons with other methods. In addition, we did not measure exactly the amount of time this method requires, although it appears that this method adds about 3 min to the operation. Finally, we did not sufficiently investigate correlations with factors such as preoperative flexion contracture or the amount of pelvic-femoral offset.

5. Conclusion

If the marks inside the patient's body are made carefully and the affected limb is positioned precisely, our method can be used to correct LLD to an extent that is not inferior to other methods. This method is simple and does not require specialized devices, making it versatile enough to be used anywhere. In addition, it does not require any new skin incisions or extra costs, which will likely make it attractive to patients, surgeons, and hospital.

Author contributions

H Tagomori, N Kaku, T Tabata, and H Tsumura contributed equally to this work; H Tagomori collected and analyzed the data, and drafted the manuscript; N Kaku devised the new leg-length correction method and provided insights and valuable comments to data analysis; T Tabata revised the manuscript for important intellectual content and, offered technical and material support; H Tsumura conceived, designed and supervised the study; all authors have read and approved the final version to be published.

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Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jor.2019.04.007.

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