Factors influencing the improvement in external contracture following anterolateral total hip arthroplasty: A prospective study

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Title

Factors influencing the improvement in external contracture following anterolateral total hip arthroplasty: A prospective study

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Author Contribuitons

TO, TK, and HT were responsible for the conception and design of the study. TO, TK, YK, DI, YY(Yuki), AT, TK, SK, YY(Yu) and TY were involved in data acquisition. TO, YS and TK were responsible for data analysis. TO, TK, YK(Yuki), DI, YY, AT, TK, SK, YY(Yu), TY and HT were involved in data interpretation. TO developed the first draft of the manuscript. All authors contributed to the interpretation of the results and critical revision of the manuscript for important intellectual content. All authors have read and approved the final manuscript.

Abstract

Background

External contracture of the hip joint occurs with the progression of hip osteoarthritis. It can be easily imagined that improvement of the external contracture can be expected with the posterior approach as it dissociates the short external rotator muscle group and the posterior tissue. However, improvement of external contracture with the anterior approach, which does not dissociate the posterior tissue, is unclear. In this study, we examined the degree of external contracture improvement after anterolateral approach THA, its influencing factors, and the effect on lower limb function.

Methods

We prospectively examined 73 patients who underwent THA using an anterolateral approach for hip osteoarthritis of Crowe type 1 and 2. Lower limb rotation, leg lengthening, and various offsets in the natural position were measured using three-dimensional templating software based on computed tomography before and two weeks after surgery; factors related to lower limb rotation were investigated by multiple regression analysis. A functional evaluation, which are gait speed, knee extensor strength, functional reach test, and the Japanese Orthopaedic Association hip score, was performed one year after surgery.

Results

All functional outcomes significantly improved after THA. As for the setting of implants, the acetabular offset became shorter with the medialization of the cup as planned; the stem side could be compensated accordingly, and the global offset could be almost reproduced. The stem was inserted almost along the original anteversion. There were no postoperative dislocation cases. External contracture was improved by 4.7° ± 8.3° after anterolateral THA. Age and preoperative femoral external contracture were significant factors for the amount of improvement in femoral external contracture (adjusted R2: 0.492) and for the postoperative remaining external contracture (adjusted R2: 0.577), but they were not significantly correlated with lower limb function and the Japanese Orthopaedic Association hip score 1 year after surgery

($p > 0.05$).

Conclusion

Even anterolateral approach THA, which does not dissociate the posterior tissue, improved postoperative external contracture of the hip joint by about five degrees, and the stronger the preoperative external contracture, the greater the improvement. However, there was no significant correlation with lower limb function one year after surgery.

Keywords: total hip arthroplasty, external contracture, anterolateral approach, hip osteoarthritis

Introduction

Progression of osteoarthritis of the hip joint contributes to pain in the hip joint, shortening of the leg length, and progression of external contracture(1–4). Total hip arthroplasty (THA) is the most common treatment for hip osteoarthritis, and it is a well-known fact that improvement of hip joint function can be expected after the procedure. There are many reports demonstrating good outcomes in terms of pain relief and leg length correction following THA(5). On the other hand, there are few reports evaluating the degree of external contracture improvement after THA. Remaining external contracture leads to gait problems and decreased range of motion and may therefore lead to postoperative dissatisfaction(3,6). The degree of external contracture improvement may differ depending on the approach used to perform THA (anterior or posterior) because the posterior approach dissociates posterior tissues (including the short external rotator muscle group), while the anterior approach does not. There are some reports describing the femur rotating inward about 10 degrees(7,8). On the other hand, few reports have examined the rotational position of the femur after anterior approach THA.

Until now, changes in the lower limb alignment before and after THA were mainly measured by Xp. However, because of several position of the femur, an accurate evaluation of the amount of leg lengthening and offset changes is not possible unless the relationship between the femur and the pelvis is kept constant. Furthermore, there have been no studies on the effects of changes in lower limb rotation on postoperative lower limb function. Therefore, in this study, we examined the degree of external contracture improvement following anterolateral approach THA, and further examined the factors affecting it. In addition, effect on lower limb function 1 year after surgery was also investigated.

Methods

Study design and statement of ethics

The protocol for this prospective study was approved by our institutional research ethics board, and all patients provided informed consent.

Patient selection

Prospective patients were those who underwent primary THA at our hospital by the anterolateral approach between December 2015 and November 2018, for the treatment of hip osteoarthritis. Patients with severe hip deformity (Crowe types 3 and 4), those who underwent bilateral THA, as well as those with osteonecrosis, prior history of hip surgery, flexion contracture of the knee (10°≤), knee pain from knee osteoarthritis, lumbar spondylolisthesis of grade 2 or higher according to the Meyerding classification, or lumbar compression fracture were excluded.

After screening, 73 hips were included in this study. (Figure 1)

Three-dimensional templating software

We obtained computed tomography (CT) images (LightSpeed VCT Series/Discovery CT750; GE Healthcare, Tokyo, Japan) of all patients in a relaxed limb position before and two weeks after surgery.

3D models of the pelvis and femur were constructed by a CT-based three-dimensional (3D) templating system (Zed Hip TM Lexi Co., Tokyo, Japan). Zed hip can be performed by virtual THA, and allows the position of both femurs (varus/valgus, flexion/extension, internal rotation/external rotation) to be matched to the pelvis. This software can be used to accurately measure leg length and several offset parameters(9–12).

Preoperative planning and Operation

Preoperative planning was performed using Zed hip.

In principle, the cup height was set so that the center of the contralateral femoral head center was reproduced, and the cup was medialized to contact the outer plate of the tear drop. Then, the femoral offset was increased by the amount of medialization of the cup, and the global offset was adjusted to the contralateral side. The leg length was planned to be matched that of the contralateral side. All operations were performed using the anterolateral approach. Only the anterior joint capsule was dissected; the posterior joint capsule and posterior muscle tendon were preserved. CT-based navigation was used, and the cups and stem were set to reproduce the preoperative planning.

Three-dimensional coordinate plane

We defined the pelvic coordinate system relative to the functional pelvic plane (FPP)(13). Each axis is shown in Figure 2a.

The femoral coordinate system was defined relative to the posterior condylar plane of the femur(14). Each axis is shown in Figure 2b.

Neutral position

Based on the above reference coordinate system, the Y-axis of the pelvic coordinate system and the Y-axis of the femur were made parallel. The rotation was such that the X-axis of the pelvic coordinate system and the X-axis of the femoral coordinate system were made parallel. This position was defined as the neutral position. (Figure 2c)

Three-dimensional evaluation

Leg length

The length projected distance from the anterior superior iliac spine (ASIS) to the knee center at the neutral position was defined as the leg length. (Figure 3a) The amount of leg lengthening of the operated side was calculated from the difference in leg length before and after surgery.

Offset

At the neutral position, the acetabular offset was defined as the length of the projected line on the XY plane of the FPP. The projected line was obtained based on the line between the pubic symphysis and the cup center. The femoral offset was defined as the length of the projected line on the XY plane of the FPP. The projected line was obtained based on the line between the cup center and the femoral bone axis. Global offset was defined as the sum of acetabular offset and femoral offset. (Figure 3b)

The angles shown below were measured. The direction of external rotation was set to a positive value.

Femoral anteversion

Preoperative femoral anteversion was measured according to the report by Sugano et al(15). Postoperative femoral anteversion was measured as the angle between the posterior condyle line (PCL) and the line including the head center and the neck center. (Figure 3c)

Rotational position of femur

The inclination of the femur with respect to the pelvis in the natural supine position was defined as the degree of external contracture. According to the method of Uemura et al., the angle between the line connecting both ASIS and the line connecting the PCL on the XZ plane of the FPP coordinate system was defined as the femoral rotational angle (FRA), and the change in FRA before and after surgery was the degree of improvement in external contracture(16). (Figure 3c） The direction in which the femur is externally rotated with respect to the pelvis is defined as positive value.

Clinical Outcome measurements

The gait speed (comfortable and maximum), knee extensor strength (operated side), functional reach test (FRT), and the Japanese Orthopaedic Association (JOA) hip score were measured before and one year after THA. The JOA hip score, which has a maximum score of 100 points, is an observer-descriptive disease-specific health outcome and consists of four parts: pain, range of motion, gait ability, and activities of daily life.

Physical function tests

The 10-m gait time was the time that a participant needed to walk 10 m with a maximum and comfortable speed after walking 2 m, and then, the gait speed (m/s) was calculated.

Knee extensor strength was measured for the operated side leg using a hand-held dynamometer (μTas F-1; ANIMA Corp., Tokyo, Japan).

The FRT was measured by moving the upper limb as far forward as possible in a natural standing position(17).

Statistical analysis

EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) was used in this study(18). Continuous variables for normality are expressed as the mean and standard deviation, and continuous variables for non-normality are expressed as the median value with interquartile range (IQR). The comparison of two pairs of groups was performed by paired t-test and Wilcoxon signed rank sum test. Univariate regression analyses were performed to find a good correlation. After choosing a factor $P < 0.20$ in univariate analysis, multiple linear regression analysis by a forced entry method was used to search for meaningful factors.

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Results

Table 1 shows the results of various 3-dimensional parameters and functional outcomes before and after surgery. All functional outcomes significantly improved after THA. As for the setting of implants, the acetabular offset became shorter with the medialization of the cup as planned; the stem side could be compensated accordingly, and the global offset could be almost reproduced. The stem was inserted almost along the original anteversion, but it was about 3° smaller before and after surgery. There were no postoperative dislocation cases during the study period.

FRA was significantly reduced from − -1.1° ± 10.7° to − -5.8° ± 9.2°. Univariate analysis of the factors affecting the change in FRA found that age, leg lengthening, leg lateralization, and preoperative FRA were significant factors. While multiple regression analysis showed age and preoperative FRA to be significant factors. (adjusted R^2: 0.492; p <0.001) (Table 2a) Univariate analysis of the factors affecting the postoperative FRA revealed age, BMI, and preoperative FRA to be significant factors. As a result of multiple regression analysis, age and preoperative FRA were significant factors. (adjusted R^2: 0.577; p <0.001) (Table 2b)

Table 3 shows the correlation between changes in FRA, postoperative FRA, and various functional outcomes one year after surgery. There was no significant correlation with any functional outcome.

Discussion

The most important findings in this study are that the external contracture of the hip joint improved even with anterolateral approach THA, which does not dissociate the posterior tissue, and the degree of improvement was greater when the preoperative external contracture degree was larger. On the other hand, there was no significant correlation between the degree of improvement of external contracture and lower limb function.

There are only three reports of hip rotational position after THA. As for the rotational position of the femur in the early postoperative period (one to three weeks after the operation), Akiyama et al. reported 11° internal rotation (5° internal rotation in the anterior approach, 13° internal rotation in the posterior approach), while Uemura et al. reported 13.1° internal rotation, and Tezuka et al. reported 4.6°internal rotation(7,8,19). However, in the study by Uemura et al., a mix of posterior and anterior approaches were employed, and in the study by Tezuka et al., lateral and anterolateral approaches were mixed. Previous reports have verified that the femur tends to rotate internally after THA. It can be easily imagined that improvement of the external contracture can be expected with the posterior approach as it dissociates the short external rotator muscle group and the posterior tissue. However, improvement of external contracture with the anterior approach, which does not dissociate the posterior tissue, is unclear. In this study, even with the anterior approach, the rotational limb position of the femur was internally rotated after THA, and an improvement in external rotation contracture was observed.

It is well known that as hip OA progresses, osteophytes are formed medially and posteriorly to the femur(20,21). Uemura et al. stated that this osteophyte formation is one of the causes of external rotational contracture of the femur(22). In other words, the external rotational contracture of the lower limbs was improved by removing the osteophytes around the femoral head without releasing the posterior soft tissue, and the degree of improvement was approximately 5° on average. Other causes of external rotational contracture include shortening of the joint capsule and surrounding muscles(23). Previous reports have shown that the posterior approach improved external rotational contracture by 10° or more, suggesting an increase in the amount of internal rotation of the femur due to the dissection of the posterior joint capsule and short external rotation muscles. It is thought that the duration of OA affects the shortening of soft tissues, but further studies are needed.

Although Akiyama et al. reported that sex, preoperative internal rotation (ROM), surgical approach, underlying disease (OA), leg lengthening, and femoral anteversion are risk factors for femoral rotation, Uemura et al. reported that leg lateralization was the only indicator(7,8,24). Thus, the factors of each past reports were different. In addition, leg lengthening and leg lateralization did not correct the positional relationship of the femur, so there was a possibility that the evaluation was not accurate. As a result of correcting the positional relationship between the femur and the pelvis and measuring the postoperative alignment three-dimensionally, the amount of rotation of the femur has no significant relationship with leg lateralization, leg lengthening, or change in femoral anteversion. Age and preoperative FRA were the only significant factors. A large preoperative FRA indicates that the preoperative external contracture is strong. The stronger preoperative external contracture led to internal rotation of the femur after the operation. Similary, Tezuka et al. stated that preoperative FRA is an important factor for postoperative FRA(19).

Uemura et al. also showed a strong correlation (r = 0.59) between postoperative FRA and preoperative FRA(22). In this study, the postoperative FRA is affected by age and preoperative FRA. Remaining contracture has been shown to be an important factor for gait, but there have been no reports of changes in femoral rotation after THA and the relationship between contracture and lower limb function, including gait(25). We prospectively investigated the changes one year after the operation, but found no significant correlation between gait speed, balance function, and knee extension muscle strength.

There are four limitations to this study. First, we only considered the anterolateral approach. It is necessary to compare with the posterior approach. Second, we were not able to evaluate changes in FRA over time. Regarding the long-term course of femoral rotation, Uemura et al. rotated 3.4° externally (13.1° internal rotation immediately after surgery) two years after surgery, and Akiyama et al. reported 1.5° -2.5°externally (12.5° internal rotation immediately after surgery) two years after surgery(8,24). In other words, the amount of change in the internal rotation of the femur after surgery is decreased by approximately 20% two years after surgery. Third, the long-term (greater than one year) effect of FRA on lower limb function was not evaluated. However, there was no effect on gait or muscle strength at one year after the operation, but changes in functional limb position may lead to changes in muscle balance. Long-term studies are also required, including changes in muscle mass. Fourth, we were unable to examine changes in contracture during standing or gait. When standing, the gluteus medius muscle acts to apply force in the internal rotation direction of the femur(26,27). As a result, it is said that the FRA becomes even smaller when standing up(16).

Despite the above limitations, this report is the first report which indicate the degree of improvement in external contracture of the femur with anterolateral THA alone, its influencing factors, and the relationship with postoperative functional prognosis.

Conclusion

External contracture improved by approximately five degrees after THA via the anterolateral approach. The stronger the preoperative external rotation contracture, the greater the improvement expected after the operation. On the other hand, there was no effect on gait speed, lower limb muscle strength, and balance function one year after surgery.

Declarations

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

TO, TK, and HT were responsible for the conception and design of the study. TO, TK, YK, DI, YY, AT, TK, SK and TY were involved in data acquisition. TO, YS and TK were responsible for data analysis. TO, TK, YK, DI, YY, AT, TK, SK, TY and HT were involved in data interpretation. TO developed the first draft of the manuscript. All authors contributed to the interpretation of the results and critical revision of the manuscript for important intellectual content. All authors have read and approved the final manuscript.

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Availability of data and materials

All the data used and/or analyzed during this study are available upon reasonable request from the corresponding author.

Ethics approval and consent to participate

This study was approved by the Kanazawa University Medical Ethics Review Committee (approval No. 1947-2, 1751) and conducted in accordance with the Declaration of Helsinki. Informed consent was obtained in writing from all the individual participants included in the study.

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Reference

1. Solomon L. Patterns of osteoarthritis of the hip. J Bone Joint Surg Br. 1976 May;58(2):176–83.
2. Birrell F, Croft P, Cooper C, Hosie G, Macfarlane G, Silman A. Predicting radiographic hip osteoarthritis from range of movement. Rheumatology (Oxford). 2001 May;40(5):506–12.
3. Arokoski MH, Haara M, Helminen HJ, Arokoski JP. Physical function in men with and without hip osteoarthritis. Arch Phys Med Rehabil. 2004 Apr;85(4):574–81.
4. Farmer SE, James M. Contractures in orthopaedic and neurological conditions: a review of causes and treatment. Disabil Rehabil. 2001 Sep;23(13):549–58.
5. Pivec R, Johnson AJ, Mears SC, Mont MA. Hip arthroplasty. Lancet (London, England). 2012 Nov;380(9855):1768–77.
6. Hoang PD, Gandevia SC, Herbert RD. Prevalence of joint contractures and muscle weakness in people with multiple sclerosis. Disabil Rehabil. 2014;36(19):1588–93.
7. Akiyama K, Nakata K, Kitada M, Yamamura M, Ohori T, Owaki H, et al. Changes in axial alignment of the ipsilateral hip and knee after total hip arthroplasty. Bone Joint J. 2016 Mar;98-B(3):349–58.
8. Uemura K, Takao M, Hamada H, Sakai T, Sugano N. Change in Axial Rotation of the Femur in the Resting Supine Position Following Total Hip Arthroplasty. Artif Organs. 2018 Mar;42(3):290–6.
9. Suzuki H, Inaba Y, Kobayashi N, Ishida T, Ike H, Saito T. Postural and Chronological Change in Pelvic Tilt Five Years After Total Hip Arthroplasty in Patients With Developmental Dysplasia of the Hip: A Three-Dimensional Analysis. J Arthroplasty. 2016 Jan;31(1):317–22.
10. Shoji T, Yamasaki T, Izumi S, Murakami H, Mifuji K, Sawa M, et al. Factors affecting the potential for posterior bony impingement after total hip arthroplasty. Bone Joint J. 2017 Sep;99-B(9):1140–6.
11. Ohmori T, Kabata T, Kajino Y, Taga T, Hasegawa K, Inoue D, et al. Differences in range of

motion with the same combined anteversion after total hip arthroplasty. Int Orthop. 2018 May;42(5):1021–8.

12. Ohmori T, Kabata T, Kajino Y, Inoue D, Taga T, Yamamoto T, et al. The optimal combined anteversion pattern to achieve a favorable impingement-free angle in total hip arthroplasty. J Orthop Sci. 2019 May;24(3):474–81.

13. Nishihara S, Sugano N, Nishii T, Ohzono K, Yoshikawa H. Measurements of pelvic flexion angle using three-dimensional computed tomography. Clin Orthop Relat Res. 2003 Jun;(411):140–51.

14. KINGSLEY PC, OLMSTED KL. A study to determine the angle of anteversion of the neck of the femur. J Bone Joint Surg Am. 1948 Jul;30A(3):745–51.

15. Sugano N, Noble PC, Kamaric E, Salama JK, Ochi T, Tullos HS. The morphology of the femur in developmental dysplasia of the hip. J Bone Joint Surg Br. 1998 Jul;80(4):711–9.

16. Uemura K, Takao M, Otake Y, Koyama K, Yokota F, Hamada H, et al. Can Anatomic Measurements of Stem Anteversion Angle Be Considered as the Functional Anteversion Angle? J Arthroplasty. 2018 Feb;33(2):595–600.

17. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. J Gerontol. 1990 Nov;45(6):M192-7.

18. Kanda Y. Investigation of the freely available easy-to-use software “EZR” for medical statistics. Bone Marrow Transplant. 2013 Mar;48(3):452–8.

19. Tezuka T, Inaba Y, Kobayashi N, Choe H, Higashihira S, Saito T. The influence of patient factors on femoral rotation after total hip arthroplasty. BMC Musculoskelet Disord. 2018 Jun;19(1):189.

20. Jeffery AK. Osteophytes and the osteoarthritic femoral head. J Bone Joint Surg Br. 1975 Aug;57(3):314–24.

21. Neuman P, Hulth A, Lindén B, Johnell O, Dahlberg L. The role of osteophytic growth in hip osteoarthritis. Int Orthop. 2003;27(5):262–6.

22. Uemura K, Takao M, Sakai T, Nishii T, Sugano N. The Validity of Using the Posterior Condylar Line as a Rotational Reference for the Femur. J Arthroplasty. 2016 Jan;31(1):302–6.

23. Fox P, Richardson J, McInnes B, Tait D, Bedard M. Effectiveness of a bed positioning program for treating older adults with knee contractures who are institutionalized. Phys Ther. 2000 Apr;80(4):363–72.

24. Akiyama K, Nakata K, Kitada M, Yamamura M, Owaki H, Fuji T. Chronological Changes in Axial Alignment of the Ipsilateral Hip and Knee After Total Hip Arthroplasty. J Arthroplasty. 2018 Feb;33(2):415–22.

25. Attias M, Chevalley O, Bonnefoy-Mazure A, De Coulon G, Cheze L, Armand S. Effects of contracture on gait kinematics: A systematic review. Clin Biomech (Bristol, Avon). 2016 Mar;33:103–10.

26. Preininger B, Schmorl K, von Roth P, Winkler T, Schlattmann P, Matziolis G, et al. A formula to predict patients' gluteus medius muscle volume from hip joint geometry. Man Ther. 2011 Oct;16(5):447–51.

27. Kumagai M, Shiba N, Higuchi F, Nishimura H, Inoue A. Functional evaluation of hip abductor muscles with use of magnetic resonance imaging. J Orthop Res. 1997 Nov;15(6):888–93.

Figure legends

Figure 1

Flow chart of patient selection and characteristic of patients

Figure 2

a: Definition of FPP and each axis

b: Definition of posterior condylar plane and each axis

c: Neutral position of the femur

Figure 3

a: Definition of leg length

  A: leg length

b: Definition of several offset

  B: acetabular offset

  C: femoral offset

  B + C: global offset

c: Definition of femoral anteversion and femoral rotational angle

  D: femoral anteversion

  E: femoral rotational angle

Figures

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