Original Article

Changes in Intra-pelvic Obliquity Angle 0–2 Years After Total Hip Arthroplasty and Its Effects on Leg Length Discrepancy: A Retrospective Study

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Abstract

Background: Total hip arthroplasty (THA) is one of the most effective treatments for phase III and IV hip arthrosis. Lower limb length balancing is one of the determining factors of a successful surgery, particularly in patients with developmental dysplasia of the hip (DDH). The purpose of this study was to evaluate the postoperative change in intra-pelvic obliquity (intra-PO) angle in the coronal plane and its effects on leg length discrepancy (LLD) within 2 years.

Methods: A total of 78 patients (70 females, 8 males) were enrolled in this study. All patients were suffering from DDH with varying degrees of LLD. Pelvic plain radiographs were collected before and after the operation. The intra-PO angles were measured 0, 0.5, 1 and 2 years after THA. At the same time, postoperative LLD was measured with blocking test.

Results: PO changed significantly in the first year after THA surgery (0 year vs. 0.5 year, $P < 0.01$; 0.5 year vs. 1 year, $P < 0.01$), and the changing value of intra-PO angle (ΔPO) slowed down substantially during the first 2 years after THA (0.5 year vs. 0.5–1 year, $P < 0.01$; 0.5–1 year vs. 1–2 years, $P < 0.01$). With the change in intra-PO angle, LLD also got narrow within the 1st year (0 year vs. 0.5 year, $P < 0.01$; 0.5 year vs. 1 year, $P < 0.01$). Elderly patients had a smaller intra-PO angle reduction (Group A vs. Group B, $P = 0.01$; Group B vs. Group C, $P < 0.01$).

Conclusions: Intra-PO angle and LLD gap narrowed with time after THA surgery. In particular, elderly patients had smaller change in intra-PO angle.

Key words: Age Related; Leg Length Discrepancy; Pelvic Obliquity; Prosthesis Orientation; Total Hip Arthroplasty

Introduction

Considerable improvements have been made in the diagnosis and treatment of developmental dysplasia of the hip (DDH). Claudication has been solved by plaster or osteotomy treatment in childhood;[1-3] however, there are still many DDH patients who have been missed or ignored. These patients do not visit their physicians until decades of claudication result in unbearable pain. Until then, they have got stage IV arthritis, while total hip arthroplasty (THA) is the only effective treatment for them. Through THA surgery, we can not only give patients a painless, stable joint but also resolve the limping caused by imbalanced leg lengths.

There are many causes of leg length discrepancy (LLD). We have classified the causes into the following three types: Suprapelvic obliquity, intra-pelvic obliquity (intra-PO) and infrapelvic reasons.[4,5] Suprapelvic obliquity is usually originated from spinal disease, and only intra-PO can be corrected by THA surgery; therefore, our research focused primarily on intra-PO, which can lead to apparent LLD, as noted by some Japanese researchers.[6-8] Through surgery, intra-PO had been corrected. Aside from suprapelvic obliquity, intra-PO is the most important cause of LLD. Because of the flexibility and plasticity of the pelvic bone, intra-PO angle changes over time. This conclusion has been introduced in healthy subjects.[8] Thus, it is not difficult to speculate that LLD would also change after THA surgery. However, its range and effects on the patient have not been well studied.

During surgery, surgeons often identify the acetabular component by tactile manipulation and experience. Intra-PO may result in an inaccurate assessment of acetabular anatomy.[9,10] In addition, the change in intra-PO angle would influence the relative position of the cup. Malposition of the cup might affect the longevity of the prosthesis and even

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lead to early failure after surgery.[4] The purpose of this study was to investigate the causes and influences of intra-PO angle change and put forward our concerns regarding reconstruction of lower limb length. We also evaluated the change in intra-PO within 2 years after THA surgery and its influence on the acetabular component orientation.

Methods

This retrospective study was approved by the Institutional Review Board of Shanghai Jiao Tong University Affiliated Sixth People's Hospital. Two hundred and six patients underwent THA due to DDH between October 2000 and December 2011. Lower limb deformities, except deformities of the hip joint, were excluded by physical examination. All primary THAs were performed by four experienced surgeons using an uncemented prosthesis (©DePuy Companies, USA; Zimmer® USA; and Stryker®, USA). One patient died of pharyngolaryngeal cancer. Thirty-one patients were excluded because of contralateral THA within 2 years. Seventy-six patients had their X-ray photographs taken in other hospitals during follow-up; therefore, we could not retrieve the original digital files, and including these patients in our research may result in measuring deviation. Twenty patients did not return for follow-up during the 2-year study period. As a result, a total of 78 patients were enrolled in our study, including 8 males and 70 females. The mean age at surgery was 55.82 ± 4.87 years with a range of 46–65 years. The mean body mass index was 28.06 ± 4.03 with a range of 18.2–37.4. The patients were divided into three groups as follows: Group A ≤50 years old; Group B between 50 and 60 years old; and Group C ≥60 years old.

Standard anteroposterior pelvic plain radiographs were taken 0, 0.5, 1 and 2 years after surgery. To eliminate the influence of muscle tension, patients were asked to lie down and relax during the examination. The intra-PO angle was marked and calculated from these radiographs by the method proposed by Lee *et al*.[5] Briefly, PO was determined by measuring the iliolumbar angle, which is the angle between the line connecting the apices of both iliac crests and another line along the bottom of the fourth lumbar vertebra. We also performed minor adjustments. To reduce the deviation caused by unilateral pelvic tilt, we measured another angle between the line along the bottom of the fourth lumbar vertebra and the line connecting the bottom of the two ischial rami. We then took the average as the intra-PO angle [Figure 1]. Postsurgery LLD was measured using a blocking test.[7] All measurements were performed at least 3 times by different researchers, and the results were averaged.

Statistical analysis

Statistical analysis was performed using SSPS 19.0 (SPSS, Inc., Chicago, IL, USA) and GraphPad Prism5 (Graphpad Software Inc., CA, USA). All values were shown as mean ± standard deviation (SD). The mean values of all the subgroups were compared by the method of paired *t*-test. A value of $P < 0.05$ was considered as statistically significant.

Results

Change of the intra-pelvic obliquity angle

The mean intra-PO angle before THA surgery was 3.91 ± 1.59° on the pain pelvic radiograph. The mean intra-PO angle at 0.5, 1 and 2 years after THA surgery were 2.63 ± 1.16°, 2.06 ± 0.94°, 1.76 ± 0.82°, respectively. As time passed, the intra-PO angle decreased. The differences at each adjacent time points in the 1st year were both statistically significant (0 year vs. 0.5 year, $P < 0.01$; 0.5 year vs. 1 year, $P < 0.01$; 1 year vs. 2 years, $P = 0.1$) [Figure 2].

Changing value of the intra-pelvic obliquity (ΔPO)

The change in the intra-PO angle was calculated by the difference in the angle at two adjacent times. The mean ΔPO angles were 1.28 ± 0.64°, 0.58 ± 0.31°, 0.30 ± 0.17° in the first 0.5 year, 0.5–1 year and 1–2 years, respectively. The result showed a significant decrease in the mean changing value of intra-PO angle (0.5 year vs. 0.5–1 year, $P < 0.01$; 0.5–1 year vs. 1–2 years, $P < 0.01$) [Figure 3].

Change of the leg length discrepancy

With the change in the intra-PO angle, the difference between lengths of two legs also changed. Mean LLD at 0, 0.5, 1 and 2 years after THA surgery were 2.99 ± 1.06 cm, 2.06 ± 0.75 cm, 1.72 ± 0.63 cm and 1.61 ± 0.59 cm, respectively. The result showed that after THA surgery, the LLD narrowed over time, which showed that the LLD changed significantly in the 1st year after surgery (0 year vs. 0.5 year, $P < 0.01$; 0.5 year vs. 1 year, $P < 0.01$; 1 year vs. 2 years, $P = 0.41$) [Figure 4].

Relationship between postoperative intra-pelvic obliquity angle change and aging

We calculated the ratio of the ΔPO angle (2 years) to the original intra-PO angle, to measure the range. The ratios of Group A, Group B and Group C were 0.63 ± 0.05, 0.57 ± 0.08 and 0.46 ± 0.06. The results showed that after THA surgery, elderly patients had a smaller intra-PO angle change (Group A vs. Group B, $P = 0.01$; Group B vs. Group C, $P < 0.01$) [Figure 5].

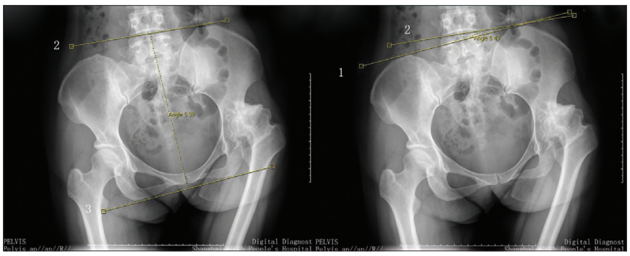

Figure 1: Line 1 was the line connecting the apices of both iliac crests. Line 2 was the line along the bottom of the fourth lumbar vertebra. Line 3 was the line connecting the bottom of two ischia ramus. Angle 1 was the iliolumbar angle that between Lines 1 and 2. Angle 2 was between Lines 2 and 3. We defined that intra-pelvic obliquity angle was the mean of Angles 1 and 2.

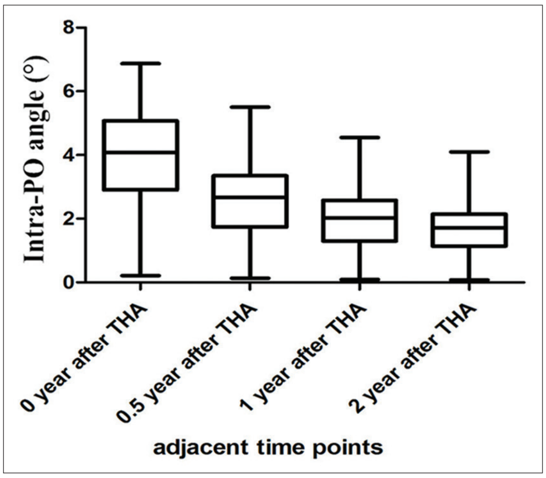

Figure 2: Change of the intra-pelvic obliquity angle within 2 years.

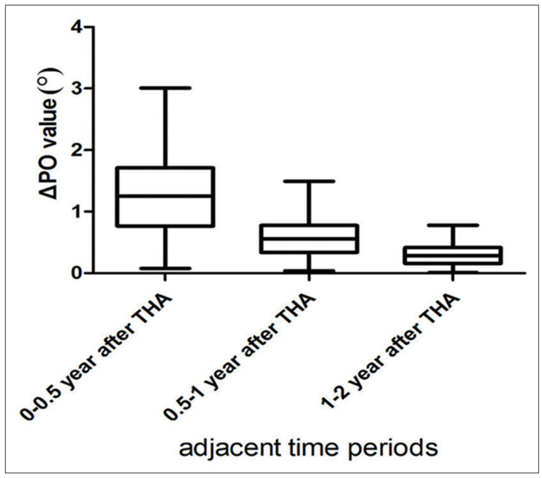

Figure 3: Mean changing value of the intra-pelvic obliquity (ΔPO) within 2 years.

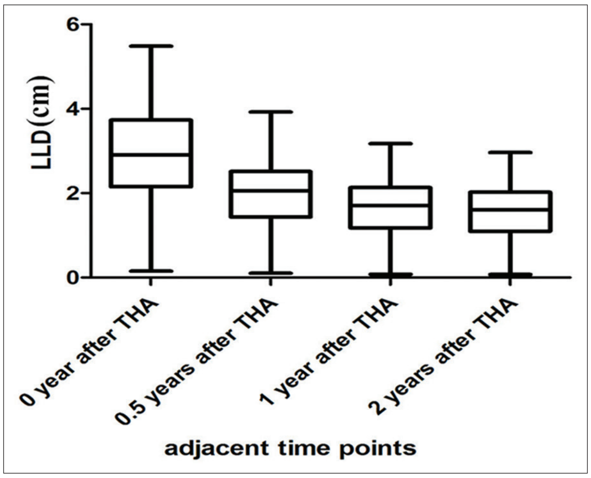

Figure 4: Change of the leg length discrepancy within 2 years.

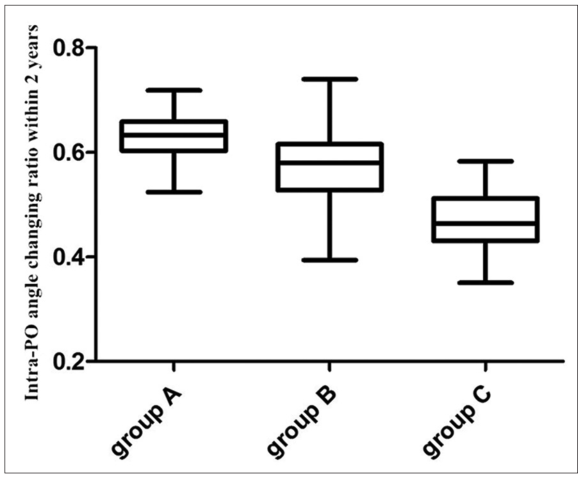

Figure 5: Relationship between postoperative intra-pelvic obliquity angle change and aging within 2 years.

Discussion

In our research, we demonstrated the variation in the intra-PO angle among DDH patients 2 years after THA surgery. Compared with pelvic tilt, the relationship between THA surgery and PO has not been well studied. Through PubMed, we found only a few reports focusing on this phenomenon.[4,8,11-13] Among them, only one study revealed the relationship between PO and its influences on the acetabular component orientation during surgery,[4] which was also from our institution. There were many studies focused on the variation in the pelvic tilt angle after THA surgery and its influences on the prosthetic orientation.[14-17] Similarly, intra-PO angle changed after THA. To the best of our knowledge, this study first focused on this phenomenon during follow-up period.

Pelvic obliquity can be caused by many pathologies, such as LLD, degenerative scoliosis, poliomyelitis, DDH, and even carrying a backpack in the wrong posture.[9,18-21] In other words, intra-PO angle is changeable. Some researchers have used man-made LLDs to stimulate PO models.[9] After analysis, we divided these pathologies into two groups. One is primary pathological changes in the spine, for instance ankylosing spondylitis that PO is a compensatory reaction to scoliosis. The other includes leg length difference, pain or imbalance of muscular strength. In DDH patients, PO is mainly caused by leg length difference and pain, but THA surgery could only solve hip structure-related problems. Therefore, our research focused primarily on the latter group.

Our results revealed that intra-PO angle decreased after THA surgery. The angle decreased continuously, but the rate of change slowed down over 2 years. Meanwhile, LLD also demonstrated a narrowing trend over time. Considering that an LLD over 2 cm typically led to patient perception of the discrepancy and discomfort, we found out that patients with an LLD larger than 2 cm experienced reductions from 80.77% (63/78) to 21.79% (17/78) within 2 years postoperatively. We assumed that LLD and PO might be interrelated. In these DDH patients, the main causes of LLD were dislocation and subluxation of the hip joint, which could be corrected by THA surgery. After surgery, the absolute length of the lower limbs was balanced. PO is another cause of LLD beside of spinal pathologies. According to an experiment by Wild *et al.*,[9] PO can be simulated by changing the LLD. Similarly, by reconstructing the leg length in THA surgery, intra-PO angle can also be changed to adapt to the new leg length. This hypothesis was strongly supported by our results. Another cause of PO is pain. When patients experience osteoarthritis pain on one side of the hip, they often lean to the other side to reduce stress. After THA surgery, the pain will also be relieved.

Leg length reconstruction is always difficult for DDH patients. In our research, over 20% patients had an LLD of more than 2 cm. In patients with fracture and osteonecrosis, the leg length should be balanced just after surgery. We have many new surgical techniques, such as navigation, to improve accuracy. However, this postoperative variation had not been taken into consideration in all these strategies, especially when treating PO patients. Blindly pursuing short-term leg length balance would lead to unnecessary bone cutting and soft tissue releasing. In addition, "balanced" leg length would fix the pelvis at an unnatural angle, which might lead to low back pain or degenerative scoliosis.[22] With an ever longer prosthetic lifetime, the long-term survival rate and outcome are much more important than the short-term. Our findings revealed that within 2 years after THA surgery, intra-PO angle narrowed. However, in most patients, this angle did not disappear completely. This result provided some reference instructions for leg length balancing to DDH patients. We should fix the leg length according to the physiological structure, not just to meet the apparent balance. When facing instability related to acetabular coverage or sciatic nerve damage related to lengthening, we would rather sacrifice leg length balance.

Another meaningful finding of our research was that intra-PO angle reduction range was age-related. Elderly patients had a smaller intra-PO angle reduction after THA surgery. However, in Wild *et al*.'s research,[9] when stimulating PO, age was not an influential factor. We divided our patients into three groups with boundaries at age 50 and 60. Fifty is the average age of menopause, and 60 is the retirement age; both are important time points when vitality decreases. In our results, younger patients demonstrated a faster rate of intra-PO angle change postoperatively. A possible explanation was that postoperative physical activities affect intra-PO angle reduction. In addition, lumbar flexibility might be another important influential factor.

The postoperative outcome was highly impacted by PO. One of the most important impacts is its effects on the acetabular orientation. Our former research indicated that PO might influence the orientation of the acetabular component during the operation,[4] and this angle would change afterward. Our follow-up research was inspired by these results and indicated that intra-PO angle would be ameliorated postoperatively. The acetabular inclination would also change relatively. During THA surgery, the acetabular prosthesis should be put in the safe zone. While after the change of PO, the inclination might become too large or too small from the safe zone. Excessive inclination might accelerate acetabular wearing, while insufficient inclination might cause limited hip abduction.[23-28] To improve the outcome and survival, we should estimate the postoperative intra-PO angle change in advance.

There were also some limitations in our study. The sample size was relatively small, and because part of the follow-up was conducted via the internet, we lost many elderly patients who were not familiar with computers. This might add some bias to the results. Designing a subjective scoring for physical activity, such as the MOS 12-item Short Form Health Survey, would be very helpful to this analysis. The blocking test was used to measure LLD, and though the test is convenient, it is not as accurate as long-leg radiographs and may be influenced by patient proprioception. With long-leg radiographs, we could also rule out other lower limb deformity in addition to those of the hip joint. However, because follow-up was conducted via telemedicine, the blocking test was the only choice. This method has been widely accepted by most researchers.[7] Also, LLD caused by lower limb deformity other than deformities of the hip joint were excluded in the preoperative physical examination. In addition, the causes of intra-PO angle change had not been well studied in our research, which were complex. Nevertheless, with our research, preoperative evaluation of postoperative intra-PO angle change could be feasible, which would provide valuable instructions in leg length balancing. This will be our research direction in the future.

In conclusion, through the follow-up of postoperative intra-PO angle change range and rate, our study provided some new points of view for leg length balancing during THA surgery. Intra-PO angle and LLD were shown to decrease over time postoperatively. This change was more obvious in younger patients.

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References

1. Godley DR. Assessment, diagnosis, and treatment of developmental dysplasia of the hip. JAAPA 2013;26:54-8.
2. Bracken J, Tran T, Ditchfield M. Developmental dysplasia of the hip: Controversies and current concepts. J Paediatr Child Health 2012;48:963-72.
3. Kosuge D, Yamada N, Azegami S, Achan P, Ramachandran M. Management of developmental dysplasia of the hip in young adults: Current concepts. Bone Joint J 2013;95-B: 732-7.
4. Zhou X, Wang Q, Zhang X, Chen Y, Shen H, Jiang Y. Effect of pelvic obliquity on the orientation of the acetabular component in total hip arthroplasty. J Arthroplasty 2012;27:299-304.
5. Lee DY, Choi IH, Chung CY, Cho TJ, Lee JC. Fixed pelvic obliquity after poliomyelitis: Classification and management. J Bone Joint Surg Br 1997;79:190-6.
6. Harris I, Hatfield A, Walton J. Assessing leg length discrepancy after femoral fracture: Clinical examination or computed tomography? ANZ J Surg 2005;75:319-21.
7. Sabharwal S, Kumar A. Methods for assessing leg length discrepancy. Clin Orthop Relat Res 2008;466:2910-22.
8. Nakanowatari T, Suzukamo Y, Suga T, Okii A, Fujii G, Izumi S. True or apparent leg length discrepancy: Which is a better predictor of

short-term functional outcomes after total hip arthroplasty? J Geriatr Phys Ther 2013;36:169-74.
9. Wild M, Kühlmann B, Stauffenberg A, Jungbluth P, Hakimi M, Rapp W, *et al.* Does age affect the response of pelvis and spine to simulated leg length discrepancies? A rasterstereographic pilot study. Eur Spine J 2014;23:1449-56.
10. Betsch M, Wild M, Große B, Rapp W, Horstmann T. The effect of simulating leg length inequality on spinal posture and pelvic position: A dynamic rasterstereographic analysis. Eur Spine J 2012;21:691-7.
11. Mendes DG. Total hip arthroplasty in congenital dislocated hips. Clin Orthop Relat Res 1981;161:163-79.
12. Schörle CM, Fuchs G, Manolikakis G. Total hip arthroplasty in cerebral palsy. Orthopade 2006;35:823-33.
13. Ranawat CS, Rodriguez JA. Functional leg-length inequality following total hip arthroplasty. J Arthroplasty 1997;12:359-64.
14. Taki N, Mitsugi N, Mochida Y, Akamatsu Y, Saito T. Change in pelvic tilt angle 2 to 4 years after total hip arthroplasty. J Arthroplasty 2012;27:940-4.
15. Murphy WS, Klingenstein G, Murphy SB, Zheng G. Pelvic tilt is minimally changed by total hip arthroplasty. Clin Orthop Relat Res 2013;471:417-21.
16. Parratte S, Pagnano MW, Coleman-Wood K, Kaufman KR, Berry DJ. The 2008 Frank Stinchfield award: Variation in postoperative pelvic tilt may confound the accuracy of hip navigation systems. Clin Orthop Relat Res 2009;467:43-9.
17. Ishida T, Inaba Y, Kobayashi N, Iwamoto N, Yukizawa Y, Choe H, *et al.* Changes in pelvic tilt following total hip arthroplasty. J Orthop Sci 2011;16:682-8.
18. Fann AV. Validation of postural radiographs as a way to measure change in pelvic obliquity. Arch Phys Med Rehabil 2003;84:75-8.
19. Tannast M, Pfannebecker P, Schwab JM, Albers CE, Siebenrock KA, Büchler L. Pelvic morphology differs in rotation and obliquity between developmental dysplasia of the hip and retroversion. Clin Orthop Relat Res 2012;470:3297-305.
20. Smith B, Ashton KM, Bohl D, Clark RC, Metheny JB, Klassen S. Influence of carrying a backpack on pelvic tilt, rotation, and obliquity in female college students. Gait Posture 2006;23:263-7.
21. Winter RB, Pinto WC. Pelvic obliquity. Its causes and its treatment. Spine (Phila Pa 1976) 1986;11:225-34.
22. Ben-Galim P, Ben-Galim T, Rand N, Haim A, Hipp J, Dekel S, *et al.* Hip-spine syndrome: The effect of total hip replacement surgery on low back pain in severe osteoarthritis of the hip. Spine (Phila Pa 1976) 2007;32:2099-102.
23. D'Lima DD, Urquhart AG, Buehler KO, Walker RH, Colwell CW Jr. The effect of the orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios. J Bone Joint Surg Am 2000;82:315-21.
24. Little NJ, Busch CA, Gallagher JA, Rorabeck CH, Bourne RB. Acetabular polyethylene wear and acetabular inclination and femoral offset. Clin Orthop Relat Res 2009;467:2895-900.
25. Georgiades G, Babis GC, Kourlaba G, Hartofilakidis G. Effect of cementless acetabular component orientation, position, and containment in total hip arthroplasty for congenital hip disease. J Arthroplasty 2010;25:1143-50.
26. Hart AJ, Buddhdev P, Winship P, Faria N, Powell JJ, Skinner JA. Cup inclination angle of greater than 50 degrees increases whole blood concentrations of cobalt and chromium ions after metal-on-metal hip resurfacing. Hip Int 2008;18:212-9.
27. De Haan R, Pattyn C, Gill HS, Murray DW, Campbell PA, De Smet K. Correlation between inclination of the acetabular component and metal ion levels in metal-on-metal hip resurfacing replacement. J Bone Joint Surg Br 2008;90:1291-7.
28. Bernasek T, Fisher D, Dalury D, Levering M, Dimitris K. Is metal-on-metal squeaking related to acetabular angle of inclination? Clin Orthop Relat Res 2011;469:2577-82.

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