POSTERIOR TRANSOSSEOUS CAPSULOTENDINOUS REPAIR IN TOTAL HIP ARTHROPLASTY

A CADAVER STUDY

BY W. SIOEN, MD, J.P. SIMON, MD, PHD, L. LABEY, IR, AND R. VAN AUDEKERCKE, MSC, PHD

Investigation performed at the Department of Orthopaedics, University of Louvain, Louvain, Belgium

Background: While recent clinical articles have reported a dramatic reduction in rates of total hip dislocation after posterior transosseous repair, we are not aware of any published biomechanical data to support this finding. The objectives of this study were to investigate the functional anatomy of the posterior transosseous repair and its effect on stability after total hip replacement.

Methods: Six total hip prostheses were implanted into three fresh cadavera. Three different repair situations (no repair, soft-tissue repair, and transosseous fixation) were then consecutively tested on each hip. Values for torque resistance and the angular range of motion at dislocation were recorded. Each repair was tested twice, yielding a total of thirty-six torque values and thirty-six angles of rotation.

Results: The transosseous repair was superior with regard to both torsion strength (four times stronger than that after no repair [$p = 0.0002$] and more than twice as strong as that after soft-tissue repair [$p = 0.002$]) and the magnitude of the angle of rotation observed prior to dislocation (an increase of 83% in comparison with that after no repair [$p = 0.0005$] and an increase of 46% in comparison with that after soft-tissue repair [$p = 0.004$]).

Conclusions: In a cadaver model, posterior transosseous repair provides superior stability of a total hip replacement. Optimal surgical technique with a slightly modified approach allows greater retention of capsule and tendon length and a more anatomical reinsertion of the soft tissues.

Dislocation after total hip replacement is a serious complication, and if possible it should be prevented rather than treated[1-5]. Its causes, which are multifactorial, include aspects of patient compliance, surgical technique, and implant design[1,6-14]. Many authors have noted that the risk of dislocation may be higher after the posterior approach to the hip than it is after other approaches[5-7,9,11,12,14]. However, many surgeons prefer the posterior approach because of decreased blood loss and operative time, excellent exposure, quick and uneventful recovery, and a very low risk of heterotopic ossification[15-17]. Furthermore, there is evidence that this approach may result in superior long-term survival of the implant[18]. In an attempt to overcome the drawback of a higher dislocation rate, several authors have recommended use of a transosseous repair of the posterior capsulotendinous structures or fixation of an osteotomized part of the upper-inner portion of the greater trochanter[5,9,10,15,17], but we are not aware of any biomechanical data to support these recommendations.

The specific goal of this study was to evaluate the functional anatomy of the posterior stabilizing anatomical structures, to optimize the surgical technique of posterior tissue repair, and to test it with regard to both torque resistance and rotational stability.

Materials and Methods

Three fresh, unpreserved cadavera were used in this experiment. Two of the three cadavera were stored at 3°C for a maximum of one week before testing, and one was kept at <0°C until testing. Six total hip prostheses were implanted in the three cadavera. All components were cemented. A VerSys femoral component (Zimmer, Warsaw, Indiana) and a Richards cup (Smith and Nephew Richards, Memphis, Tennessee) with a wall that was elevated 10° were used.

Anatomical Considerations

The posterior stabilizing hip structures comprise two major capsuloligamentous structures (the orbicular ligament and the ischiofemoral ligament) and four muscles (the piriformis, the obturator internus-gemelli complex, the obturator externus, and the quadratus femoris).

eC A commentary is available with the electronic versions of this article, on our web site (www.jbjs.org) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

The piriformis tendon has a distinct insertion at the anterosuperior tip of the greater trochanter. This insertion site is in the same coronal plane as the center of the head of the femur (the center of rotation of the hip). As a consequence, the piriformis musculotendinous unit maintains its length during flexion and extension. The obturator internus muscle, the ischiofemoral ligament, and the orbicular ligament have a common fan-shaped insertion at the base of the greater trochanter. Slight pretensioning of these structures occurs in flexion, allowing for less internal rotation of the hip in flexion than in extension.

At the intertrochanteric region, the bursa pectinea separates the posterior aspect of the capsule from the femoral neck, allowing the necessary sliding motion of the capsule during flexion. The obturator externus and quadratus femoris muscles have an attachment at the intertrochanteric ridge.

Because of their specific insertions, these strong capsulotendinous structures are only minimally strained in the flexion-extension arc.

Surgical Technique

A standard posterior approach was used with slight modifications. The cadaver was positioned in lateral decubitus with a dual anterior pelvic support and a sacral support. With the hip in 45° of flexion, a straight skin incision was centered over the posterior third of the greater trochanter, with the proximal part of the incision slightly longer than the distal part. The fascia lata was incised in line with the femur, and the gluteus maximus muscle was bluntly split along its fibers, in the line of the skin incision. The piriformis tendon was dissected from capsular fibers of the gluteus minimus muscle, and a retractor was inserted deep to the gluteus minimus muscle, exposing the insertion of the piriformis and the obturator internus muscles.

Maximizing the length of the capsulotendinous flap: While one cannot detach the piriformis tendon at its anterior insertion onto the greater trochanter, maximum length can be obtained by flexing the hip 90°. With this maneuver, the anterior side of the greater trochanter moves backward into the operative field. With the hip in this position, the capsule was then cut at the level of the piriformis tendon from the neck of the femur to the acetabulum, with the surgeon cutting through the capsule and tendon in one layer. While the capsule and muscle were reflected from the neck of the femur, the hip was progressively brought back into extension and internal rotation. In this way, a capsulotendinous envelope of maximum length was obtained, almost at the level of the anatomical insertion. Another cut in the capsule was made at the inferior pole, onto the transverse acetabular ligament. The quadratus femoris muscle was cut as much as necessary for adequate visualization, but its distal insertion onto the intertrochanteric ridge was left untouched. All other structures were left intact, and no more releases were done.

After reaming of the acetabulum, a cemented Richards cup with an outer diameter ranging from 49 to 55 mm was implanted with the aid of a mechanical insertion guide, to achieve a position of 45° of abduction and 20° of anteversion. The femoral canal was prepared, trial implants were inserted, and the hip was reduced and then checked for limb length, stability, and osseous impingement. The appropriate VerSys stem (size 14 or 15, with a normal or extended offset) was implanted in 10° to 15° of anteversion. A femoral head of appropriate length (28 mm, with a 0 to +3.5-mm neck) was then selected to achieve optimum soft-tissue tension.

Soft-tissue repair: The piriformis tendon was sutured into the gluteus medius muscle, and the quadratus femoris muscle was sutured into its base.

Transosseous repair: Four absorbable sutures (number-2 Vicryl; Ethicon, Johnson and Johnson, Somerville, New Jersey) were placed through the posterior capsulotendinous envelope and through four drill-holes that had been made through the greater trochanter. Two drill-holes were situated proximally in an anteroposterior direction, and two were situated posteriorly in line with the longitudinal axis of the femur. The sutures were passed through these drill-holes and tied to each other (Fig. 1). This repair closed the posterior structures almost anatomically.

Experimental Setup

The cadavera were positioned in lateral decubitus with the lower limb in which the operation had been performed on top. Both the hip and the knee were kept at 90° of flexion with the limb horizontal and parallel to the table. A steel rod (10 mm in diameter) was drilled through the femoral condyles in

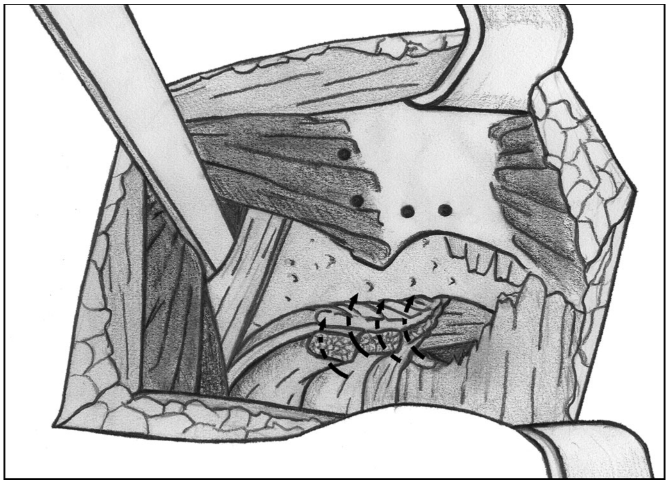

Fig. 1

Line drawing of the capsulotendinous flap and the position of the transosseous drill-holes in a right hip. Left is proximal, right is distal, and top is anterior. A retractor is placed underneath the gluteus medius and minimus muscles. The proximal two sutures (dotted lines) are placed through the piriformis tendon and the superior part of the capsule, and they are passed through the proximal drill-holes, at the tip of the greater trochanter, where the gluteus medius insertion is located. The distal two sutures are placed through both capsule and tendon along the capsulotendinous flap, and they are tied to each other through the two distal drill-holes.

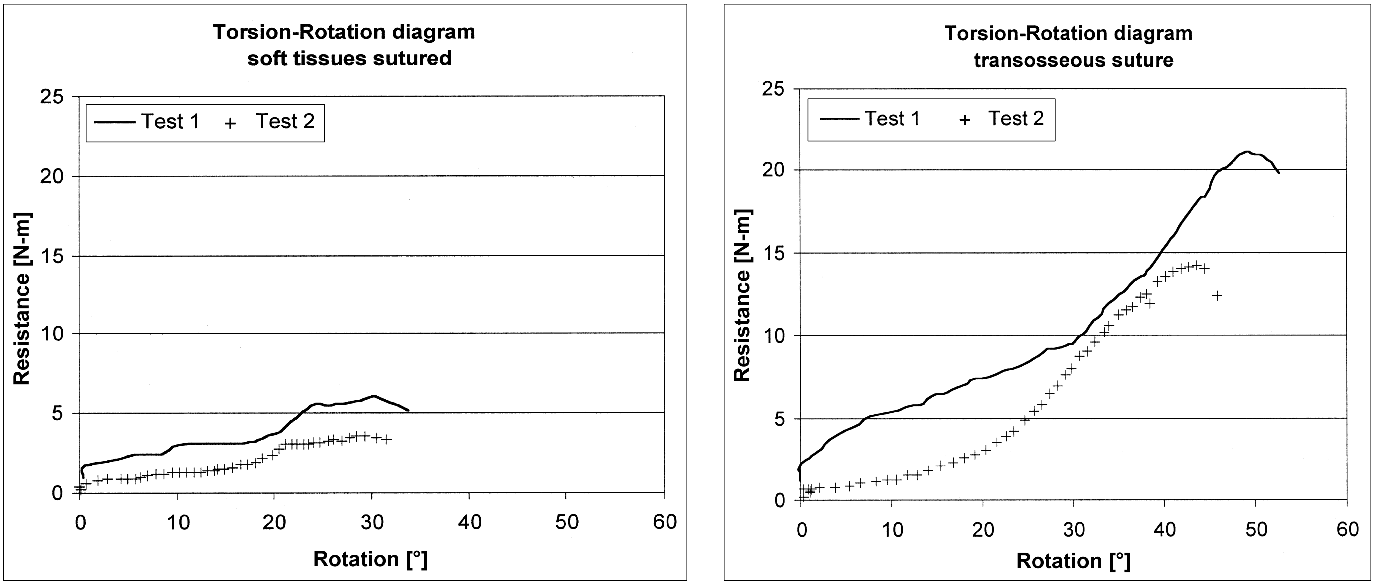

Fig. 2-A

Fig. 2-B

Diagrams showing the torsion resistance versus rotation at the time of dislocation following soft-tissue repair (Fig. 2-A) and following transosseous repair (Fig. 2-B) in the same hip.

a mediolateral direction. Both ends of the rod were fixed in a clamp mounted on top of the operating table. The clamp was free to rotate in a plane that coincided with the longitudinal femoral axis. A custom-made, calibrated torsion load cell was fastened between the bar and the clamp to measure the resistance against dislocation. A potentiometer attached on top of the clamp was used to measure the rotation angle.

Each hip was tested with the limb in a horizontal position and the hip and knee in 90° of flexion; the femur was slowly rotated internally while torsion resistance and the rotation angle were continuously monitored. The measurement was halted when dislocation was observed visually. Immediately after the measurement was made at the time of dislocation, the hip joint was reduced and, without any repair of the tissues, a second measurement was performed. These measurements were carried out for each of the three repair scenarios in each hip. The tests were always carried out in the same sequence: first after no repair, then after the soft-tissue repair, and finally after the transosseous repair.

During data processing, the moment due to the weight of the leg was subtracted from the input of the torsion load cell. The maximal torsion resistance and rotation angle were then determined for each measurement. A standard analysis of variance was used to compare the mean values for maximum resistance and rotation angle among the three techniques and between the first and second dislocations.

Results

Following the total hip arthroplasty, the cadaver was radiographed and the positions of the cups were analyzed. Cup abduction ranged from 38° to 54° and anteversion, from 10° to about 35°; the majority of the cups showed less anteversion radiographically than had been indicated with use of the insertion guide.

A summary of all test results is presented in the Appendix. The measurements made after the dislocation of the right hip of one cadaver, after no repair, were lost as a result of a computer problem, so that there were only ten results for this technique, instead of twelve.

Figures 2-A and 2-B show a typical resistance versus rotation curve obtained during the tests. At the start of the measurements made after the soft-tissue repair and the transosseous repair, there was already some resistance due to pretensioning of these structures in flexion. The behavior of the system was nonlinear. The rotational stiffness gradually increased as the rotation angle increased, when elements that had been slack at first tightened and contributed to the torsion resistance. Small ripples in the curves are due to tears and damage that occurred in the soft tissues or sutures and led to transient reductions in resistance before complete dislocation took place.

In Figures 3 and 4, the average torsion resistance and rotation angle at dislocation are shown for each of the three repair techniques. Analysis of variance revealed that the posterior transosseous repair provided significantly greater torsion strength and a larger rotation angle before dislocation than did the techniques without repair or with only soft-tissue repair. The transosseous repair resulted in torsion strength that was, on average, four times greater than that measured after no repair ($p = 0.0002$) and more than twice as great as that measured after soft-tissue repair ($p = 0.002$).

There was a significant reduction in torsion resistance after the first dislocation following all three techniques, but the reduction was largest after the posterior transosseous repair. Nevertheless, the residual resistance remained greater than the

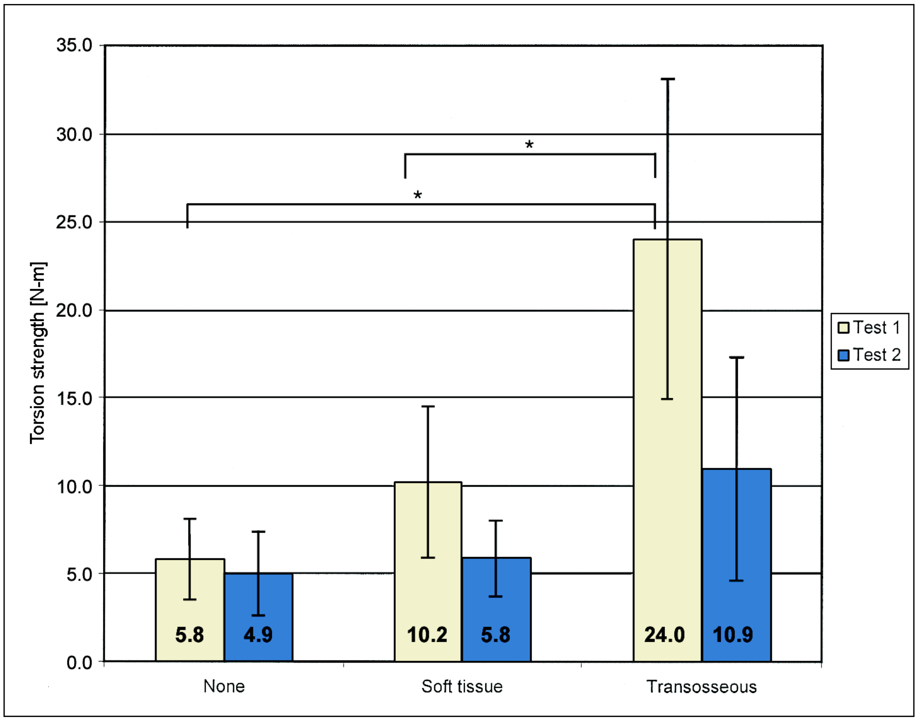

Fig. 3

The mean and range of the torsion values at the time of dislocation after the three surgical repairs. An asterisk indicates a significant difference between two different repair techniques.

original resistance measured after no repair (p = 0.06) and equal to the original resistance measured after soft-tissue repair.

Several modes of failure were seen during testing. In most cases, there was gradual tearing and stretching of the ligamentous structures without a clearly identifiable cause of failure. In a minority of instances, we saw complete pull-out of either the piriformis or the obturator internus muscle origin at the pelvis. The inferior portion of the transosseous repair was always more slack and more stretched than the more anatomical superior portion. In one case, the inferior knot cut its way through the bone. In another case, the knot itself did not hold and became untied. We never identified a torn suture as a mode of failure.

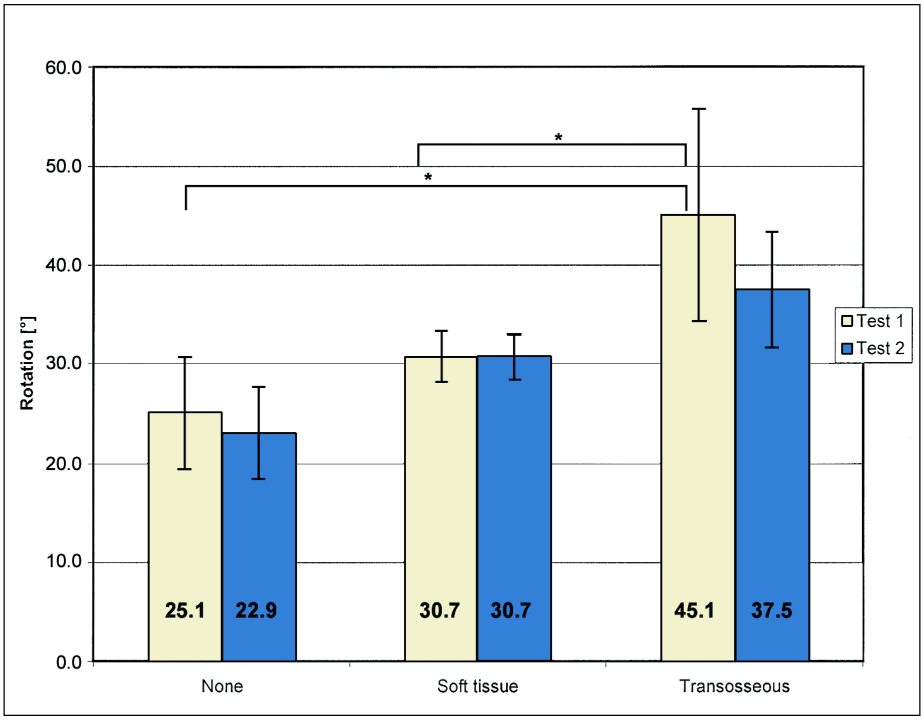

Fig. 4

The mean and range of the rotation angles at the time of dislocation after the three surgical repairs. An asterisk indicates a significant difference between two different repair techniques.

Discussion

From a mechanical viewpoint, a dislocation can be described as a translation of the center of the head first perpendicular to the surface of the cup and then parallel to the surface of the cup. Forces acting on the hip joint can either act in favor of (a dislocating force) or against (a containment force) dislocation. It is generally assumed that perpendicular translation is caused by forces that cause rotation around a fulcrum—the so-called impingement phenomenon. During a range of motion, impingement may occur between suboptimally oriented components or between the femur and adjacent bone or soft tissue. Once sufficient translation has occurred, forces that normally contain the hip (e.g., the abductor force) now further dislocate the hip as a result of the orientation and position of the implant. In order to increase stability, therefore, one must either increase horizontal and vertical translation before dislocation (e.g., by increasing the head and inner cup diameters or by using an elevated wall) or increase containment forces (e.g., by increasing offset). We suggest that a capsulotendinous repair works in the latter way.

The purposes of our study were to optimize the surgical technique of capsular resection and reattachment and to test various repair methods with regard to their ability to provide both torque resistance and rotational stability. Our results confirm that a transosseous repair of the capsule to the greater trochanter provides the most stable construct in terms of torque resistance and rotational stability. Since the transosseous repair was always tested last, we concluded that the damage to the tissues caused by the previous measurements led to an underestimation of the strength provided by this repair.

One weakness of our study is that all cadavera had normal hips with excellent mobility and without evidence of osteoarthritis. One might question how applicable these findings are to patients with osteoarthritis. Furthermore, all of the donors had been thin, making the surgical technique easier.

Although we believe that the repair should reproduce normal anatomy as closely as possible, this goal can be only partially accomplished. The superior part of the repair is placed at or near the center of the femoral head, and thus it directly inhibits the head from dislocating while in internal rotation and either flexion or extension. Its location also increases torque resistance. However, the inferior or intertrochanteric part of the repair is not restored to its original site, so it does not allow sliding of the posterior part of the capsule. We believe that, by cutting the capsule both inferiorly and superiorly and by fixing it to the bone, we transform an annular ligament into a pouch ligament, similar to the inferior glenohumeral ligament, that undergoes pretensioning in flexion. This phenomenon causes a positive torque value in flexion even before the hip is internally rotated, as can be seen in Figures 2-A and 2-B. This also explains why the inferior portion of the repair was always more stretched than the superior portion after dislocation. Our technique increased stability, especially in the immediate postoperative phase, although its effect in the long term could be smaller as a result of repetitive strain. Placement of two independent sutures allows one suture to protect the other.

In our experimental apparatus, dislocation occurred at rotation angles that were much smaller than those encountered clinically. We offer the following explanation for this discrepancy. In our test setup, the limb is fastened to a clamp, which causes some degree of axial preload. As soon as impingement starts to take place, dislocation is precipitated as a result of this preload. When stability is tested in the clinical situation, there is no axial preload and more subluxation can occur before dislocation. Furthermore, hip stability is not frequently tested at a full 90° of flexion because of the position of the pelvic support. Finally, a surgeon is in a difficult position to judge the exact degree of hip flexion and internal rotation as he or she is looking from above and behind. Positioning a cup in more anteversion than was used in our experiment may allow more impingement-free internal rotation, but impingement may be initiated earlier in external rotation and extension. The rotation angles of impingement and subsequent dislocation in our experiment are within the range that Jaramaz et al. calculated with use of a range-of-motion simulator in a series of implanted cups[6].

Surprisingly, we found that internal rotation increases approximately 20° (range, 10° to 30°) after a transosseous repair. One might expect a checkrein to be created in internal rotation. In the clinical situation, increasing torque resistance creates the impression of a checkrein[16], but the repair is never tested to the point of failure or dislocation. In a natural hip, tensioning of the posterior structures around the femoral head stops internal rotation at about 10° to 20°. However, insertion of a total hip replacement greatly reduces this volumetric effect because the head and inner cup diameters are now 28 mm. Hence, less strain is provoked by internal rotation, allowing more internal rotation before failure. Although the moment of impingement cannot be altered, we think that more subluxation is allowed before true dislocation takes place.

There was a large variation in both the torsion resistance and the rotation angle in our series. As a result of this variability, the ranges of results for each of the techniques overlap slightly. Nevertheless, in each artificial joint, the maximum torsion resistance and rotation angle provided by the transosseous repair were always larger than those provided by the soft-tissue repair or no repair. The variation was due not only to variation in soft-tissue balancing and tensioning of the transosseous suture, but also to variation in cup position, as this has the most profound effect on impingement and dislocation. This variation also occurs in the clinical setting[6], but it can be addressed by increasing clinical experience or using navigational tools. Interestingly, the hip that was seen to have the most anteverted cup radiographically (the right hip of the first cadaver) also benefited the most from the transosseous repair (see Appendix).

Our test results suggest that transosseous repair is valuable, at least immediately following primary total hip replacement. However, the effects of healing and the possible migration of the muscle reinsertion still must be investigated clinically.

Appendix

eA A table presenting the data derived from the dislocation tests in the six hips is available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

W. Sioen, MD
J.P. Simon, MD, PhD
Department of Orthopaedic Surgery, Pellenberg Orthopaedic Hospital, University of Louvain, Weligerveld, 1, B-3212 Pellenberg, Belgium. E-mail address for W. Sioen: wouter.sioen@skynet.be

L. Labey, Ir
R. Van Audekercke, MSc, PhD
Division of Biomechanics and Engineering Design, Celestijnenlaan, 200A, B-3001 Heverlee, Belgium

The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

References

1. **Daly PJ, Morrey BF.** Operative correction of an unstable total hip arthroplasty. *J Bone Joint Surg Am.* 1992;74:1334-43.
2. **Dorr LD, Wan Z.** Causes of and treatment protocol for instability of total hip replacement. *Clin Orthop.* 1998;355:144-51.
3. **Li E, Meding JB, Ritter MA, Keating EM, Faris PM.** The natural history of a posteriorly dislocated hip replacement. *J Arthroplasty.* 1999;14:964-8.
4. **Joshi A, Lee CM, Markovic L, Vlatis G, Murphy JC.** Prognosis of dislocation after total hip arthroplasty. *J Arthroplasty.* 1998;13:17-21.
5. **Morrey BF.** Difficult complications after hip joint replacement. Dislocation. *Clin Orthop.* 1997;344:179-87.
6. **Jaramaz B, DiGioia AM 3rd, Blackwell M, Nikou C.** Computer assisted measurement of cup placement in total hip replacement. *Clin Orthop.* 1998;354:70-81.
7. **Kelley SS, Lachiewicz PF, Hickman JM, Paterno SM.** Relationship of femoral head and acetabular size to the prevalence of dislocation. *Clin Orthop.* 1998;355:163-70.
8. **Ali Khan MA, Brakenbury PH, Reynolds IS.** Dislocation following total hip replacement. *J Bone Joint Surg Br.* 1981;63:214-8.
9. **Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR.** Dislocation after total hip-replacement arthroplasties. *J Bone Joint Surg Am.* 1978;60:217-20.
10. **Paterno SA, Lachiewicz PF, Kelley SS.** The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. *J Bone Joint Surg Am.* 1997;79:1202-10.
11. **Ritter MA.** Dislocation and subluxation of the total hip replacement. *Clin Orthop.* 1976;121:92-4.
12. **Scifert CF, Brown TD, Pedersen DR, Callaghan JJ.** A finite element analysis of factors influencing total hip dislocation. *Clin Orthop.* 1998;355:152-62.
13. **Scifert CF, Brown TD, Lipman JD.** Finite element analysis of a novel design approach to resisting total hip dislocation. *Clin Biomech (Bristol, Avon).* 1999;14:697-703.
14. **Woo RY, Morrey BF.** Dislocations after total hip arthroplasty. *J Bone Joint Surg Am.* 1982;64:1295-306.
15. **Hedley AK, Hendren DH, Mead LP.** A posterior approach to the hip joint with complete posterior capsular and muscular repair. *J Arthroplasty.* 1990;5 Suppl:S57-66.
16. **Pellicci PM, Bostrom M, Poss R.** Posterior approach to total hip replacement using enhanced posterior soft tissue repair. *Clin Orthop.* 1998;355:224-8.
17. **Robinson RP, Robinson HJ Jr, Salvati EA.** Comparison of the transtrochanteric and posterior approaches for total hip replacement. *Clin Orthop.* 1980;147:143-7.
18. **Malchau H, Herberts P, Söderman P, Odén A.** Prognosis of total hip replacement; update and validation of results from the Swedish national hip arthroplasty registry, 1979-1998. Scientific Exhibition presented at the Annual Meeting of the American Academy of Orthopaedic Surgeons; 2000 Mar 15-19; Orlando, FL.