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Original Research

Who Restores Hip Biomechanics More Effectively after a Femoral Neck Fracture? Comparison of Total Hip Arthroplasties Performed by Either Hip Surgeons or Orthopaedic Residents

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A B S T R A C T

Background: This study aims to analyze the ability to restore hip biomechanics in patients who undergo total hip arthroplasty for displaced femoral neck fractures operated by either hip surgeons (HSs) or orthopaedic residents (ORs).
Methods: We retrospectively compared 95 patients treated by HSs (group A) with 110 patients treated by ORs (group B). Leg-length discrepancy, femoral offset (FO), center of rotation (COR), acetabular inclination, and acetabular anteversion were evaluated on postoperative radiographs using the healthy contralateral hip as control.
Results: The median leg-length discrepancy was 2 mm for both groups ($P = .74$). The leg length was increased in 54% of the HS group and 57% of the OR group ($P = .13$). The median FO difference of groups A and B were 7 mm and 5.5 mm, respectively ($P = .14$). FO was increased in 80% of the HS group and 69% of the OR group ($P = .19$). Median discrepancies of the horizontal and vertical CORs were not statistically relevant, with P-values of .69 and .14, respectively. The horizontal COR was slightly medialized in 58% of the HS group and 53% of the OR group ($P = .003$). The vertical COR was slightly proximal in 66% of the HS group and 76% of the OR group ($P = .28$). The median acetabular inclination angles of groups A and B were 41° and 40°, respectively ($P = .62$). The median anteversion angle was 19° for both groups ($P = .89$).
Conclusions: The horizontal COR was the only measurement with statistical significance. To conclude, ORs under supervision are as reliable as HSs to properly restore hip biomechanics in patients who undergo total hip arthroplasty for displaced femoral neck fractures.

Introduction

Total hip arthroplasty (THA) is one of the most common surgical procedures taught in every medical residency program in orthopaedics, with hip surgeons (HSs) taking on teaching leading role [1]. It remains challenging for HSs to provide excellence in surgical treatment while training orthopaedic residents (ORs) in the arthroplasty technique [2,3]. In this sense, there is a lack of information regarding comparative radiographic results in patients operated by HSs or ORs.

Abductor strength, component wear, and dislocation rate after THA are highly correlated with anatomical and biomechanical restoration [4-6]. Alterations in the center of rotation (COR) can lead to leg-length discrepancy (LLD) or changes in femoral offset (FO). LLD can affect knee kinematics and lumbosacral spine, being the leading cause of lawsuits in THA [7,8].

The current literature does not include many studies identifying which performing surgeon best restores hip biomechanics. This article aimed to compare the capacity to restore hip biomechanics between HSs and ORs in elderly patients with an acute displaced

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Table 1
Demographic characteristics of the series.

Variable	Series (n = 205)	Group A (n = 95)	Group B (n = 110)	*P*-value
Median age (y)	79 (IQR, 74-84)	79 (IQR, 74-84)	79 (IQR, 73-84)	$P = .97$
Sex	F: 164; M: 41	F: 71; M: 24	F: 93; M: 17	$P = .08$
Median BMI (kg/m^2)	25 (IQR, 22-27)	25 (IQR, 23-27)	25 (IQR, 22-28)	$P = .90$
BMI ≥30 (kg/m^2) (obese) (n / %)	27 (13%)	9 (9%)	18 (16%)	$P = .14$
Grade of Garden FNF displacement (n/%)				
III	6 (3%)	3 (3%)	3 (3%)	
IV	199 (97%)	92 (97%)	107 (97%)	$P = .85$

F, female; M, male; BMI, body mass index.

femoral neck fracture (FNF). A retrospective analysis of postoperative radiographic images was conducted, considering radiographic parameters, such as LLD, FO, COR, acetabular inclination (AI), and acetabular anteversion (AA), using the healthy contralateral hip as control.

Material and methods

After obtaining approval from the institution's research ethics board, we retrospectively studied 811 FNFs operated between 2004 and 2008. One hundred sixty-nine were classified as undisplaced FNFs and were therefore treated with internal fixation; the remaining 642 were displaced FNFs. Two hundred of them were treated with hemiarthroplasty as being household ambulators with low functional demands, and the remaining 442 were community ambulator patients with THA. For this study, we included all patients older than 55 years with a displaced FNF secondary to a low-energy mechanism treated with THA and healthy or incipient osteoarthritis (Tönis 0 or 1) contralateral hip, which was used as a control for biomechanical parameters.

We divided them into 2 groups, according to the performing surgeon. In group A, we included 230 cases treated by HSs and in group B, 212 patients treated by ORs. Sixty-five cases from group A and 53 cases from group B were excluded for having poor-quality radiographs, as for not having a true anterior-posterior (AP) pelvic radiograph or where implants were not fully included. Other exclusion criteria were advanced contralateral osteoarthritis (45 and 32 patients, respectively), bilateral THA, and history of previous surgery of the affected hip (25 and 17 cases), leaving 95 and 110 cases to analyze in groups A and B, respectively.

We collected all the data on each patient registered on the institution's prospectively collected electronic database, which has been digitalized since 2004. These data were reviewed by 4 of the investigators (F.D.D, A.G.M., L.L., and M.B.); none of them were involved in primary patient care. The median age of the series was 79 years (interquartile range [IQR], 74-84), being 79 years old (IQR, 74-84) for group A and 79 years old (IQR, 73-84) for group B ($P = .97$). There were 71 and 93 female patients in groups A and B, respectively ($P = .08$). The median body mass index of the series was 25 kg/m^2 (IQR, 22-27), without significant difference between both groups ($P = .90$). There were 9 and 18 obese patients, defined as having a body mass index ≥30 kg/m^2, in groups A and B, respectively ($P = .14$). We classified displacement with AP- and lateral (L)-view radiographs obtained before surgery, according to the Garden classification (Table 1).

All surgeries were performed in laminar-flow theaters by either 4 senior HSs or ORs in training under close supervision by one of the senior surgeons. Supervision was defined as resident-performed THA with an attending surgeon in the operating room as a silent observer. When the trainee performed the surgical procedure, the supervising surgeon limited to observe without being scrubbed in. Only when an error was made, the HS interfered if it was necessary, and afterward, the resident continued with the surgery. All ORs involved in patient care were senior residents and had previously completed an official 3-month rotation in the Hip Unit service.

The official 3-month rotation requires a full-time availability, with 3 days/week for elective surgeries and 3 days/week for outpatient clinics too. Urgent surgeries, such as FNFs, are performed on the same day of admission, if possible, based on the patient's comorbidities and health insurance approval. The 4 senior HSs are involved in patient care and provide excellence in surgical treatment while training ORs. Residents are encouraged to attend the weekly educational rounds for both educational and teaching purposes, and they are also permitted to attend the Grand Surgical Rounds, including case discussions. As a general rule, the rotation in the Hip Unit is performed in senior years (PGY4/PGY5), and at the end of the trimester, the ORs perform on average 25 primary THAs and at least 3 simple revision surgeries.

As a consequence, they were capacitated to perform the surgery; if not, the HS was responsible for the surgical procedure. When an HS was performing the procedure, the resident's role was limited to retraction in all cases. The most common reason why scrubbed residents did not perform a case was due to the patient's comorbidities. As we all know, FNFs are usually associated with an aging population, and most of the patients have related clinical diseases that sometimes require urgent treatment and shorter surgical time without increasing the risk of complications and mortality rate.

After epidural hypotensive anesthesia, a posterolateral approach was performed in all patients from both groups. Regarding the fixation technique, the acetabular component was cemented in 64 and 95 cases in groups A and B, respectively, while the femoral stem was cemented in all cases in a third-generation technique [9]. A different bone-cement brand was used depending on the implant provider.

In group A, acetabular implantation was performed using a Trilogy cup (Zimmer Biomet, Warsaw, IN) in 6 cases, a Trident cup (Stryker, Newbury, United Kingdom) in 4 cases, a Pinnacle cup (DePuy International, Leeds, United Kingdom) in 21 cases, and an Ogee cup (DePuy International, Leeds, United Kingdom) in the remaining 64 cases. Femoral implantation was performed using a CPT stem (Zimmer Biomet, Warsaw, IN) in 6 cases, an Exeter stem (Stryker, Newbury, United Kingdom) in 4 cases, and a C-Stem (DePuy International, Leeds, United Kingdom) triple-taper polished femoral stem in 85 cases. Similarly, in group B, acetabular implantation was performed using a Trident cup (Stryker, Newbury, United Kingdom) in 1 case, a Pinnacle cup (DePuy International, Leeds, United Kingdom) in 14 cases, and an Ogee cup (DePuy International, Leeds, United Kingdom) in the remaining 95 cases. Femoral implantation was performed using 1 Exeter stem (Stryker, Newbury, United Kingdom) and 109 C-Stem (DePuy International, Leeds, United Kingdom) triple-taper polished femoral stems. The implant selection was made according to the health service

Table 2
Type of implant, fixation technique, and head diameter between both groups.

Variable	Series (n = 205)	Group A (n = 95)	Group B (n = 110)	*P*-value
Acetabular component (n/%)				
Cemented				
Ogee	159 (78%)	64 (67%)	95 (86%)	
Uncemented				
Pinnacle	35 (17%)	21 (23%)	14 (13%)	
Trident	5 (2%)	4 (4%)	1 (1%)	
Trilogy	6 (3)	6 (6%)		N/A
Femoral stem (n/%)				
C-Stem	194 (95%)	85 (90%)	109 (99%)	
Exeter	5 (2%)	4 (4%)	1 (1%)	
CPT	6 (3%)	6 (6%)		N/A
Head diameter (mm) (n / %)				
28	176 (86%)	85 (89%)	91 (83%)	
32	29 (14%)	10 (11%)	19 (17%)	$P = .16$

N/A, not applicable.

provider authorization in both groups. Regarding the femoral-head size, 28-mm or 32-mm femoral-head diameters were used. A 32-mm femoral-head diameter was used in 10 and 19 cases in groups A and B, respectively ($P = .16$). Bigger femoral heads were not available at the time these patients were operated (Table 2).

All patients received prophylactic antibiotics with 3 doses of intravenous cefazolin (1 g every 8 hours) and routine thromboprophylaxis with 40 mg of subcutaneous low-molecular-weight heparin during the first postoperative month. We did not routinely prescribe prophylaxis against heterotopic ossification. The rehabilitation protocol included early mobilization within 24 hours after surgery and ambulation with a walker and full weight-bearing in both groups. After that, we encouraged patients to progressively return to normal activities as tolerated with the use of a cane for at least 1 month, depending on their clinical evolution and findings on follow-up radiographs. AP and L radiographs of the pelvis and the operated side were obtained immediately postoperatively, at 15 days, at 6 and 12 months, and afterward annually.

Radiographs were simultaneously reviewed 2 weeks after surgery, at the first postoperative control, by 4 independent observers twice (F.D.D., A.G.M., L.L., and M.B.), using a digital imaging system (Raim Viewers, Alma-Ortho 5.0., Barcelona, Spain) previously calibrated with the size of the femoral-head implant. The 4 observers analyzed both groups of patients, and the same observer measured the postoperative and the healthy contralateral hip to assess anatomical restoration. In controversial cases, where measurements seemed to be incorrect, an additional analysis was performed by another observer, but the final decision was the responsibility of one of the senior surgeons (B.M.A.).

Both AP and L pelvic views were evaluated using a standardized technique [10]. The AP incidence was used to analyze radiographic measurements, and the L view was used to determine the pelvic tilt. The radiograph distance was 1.20 m for both radiographs. When the AP incidence was performed, the center of the radiograph beam was focused on the center of the symphysis and a line between the anterosuperior iliac spines. Both lower limbs were put in identical internal rotational positions. Internal rotation of both lower limbs was assured to accomplish the correct measurement of the different parameters. Regarding the true L view, the radiograph beam was directed to the tip of the greater trochanter. To assure the correct pelvic positioning, we previously confirmed all radiographs to have a neutral pelvic tilt and rotation. A pelvic inclination of 60° was defined as a neutral pelvic tilt [11]. This angle is measured in the L view and is the result of a horizontal line and a second one beyond the proximal border of the symphysis and the sacral promontory. On the other hand, a neutral pelvic rotation was confirmed when the center of the sacrococcixis was vertically aligned with the center of the pubic symphysis [11].

Postoperative radiographs were scrutinized about the following parameters to depict differences between both groups (Fig. 1a and b).

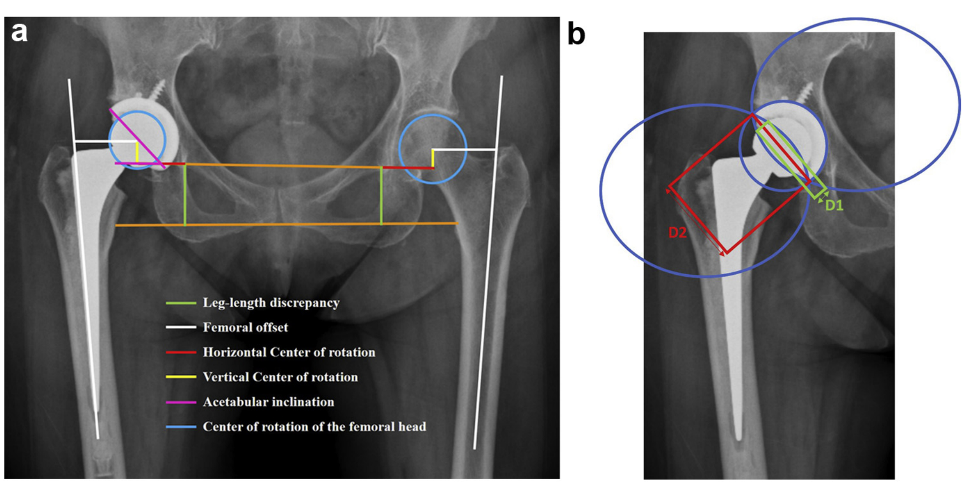

Figure 1. (a and b) AP radiograph of the pelvis (a) showing the measured parameters. Lewinnek's method of measurement of acetabular anteversion on the AP radiograph (b). (Version = arcsine [D1/D2]; D1, the short axis of an ellipse drawn perpendicular to the long axis of the acetabular cup; D2, the long axis, which is considered the maximal diameter of the implant).

Table 3
Statistical analysis of biomechanical parameters by the type of surgeon.

Variable	Series (n = 205)	Group A (n = 95)	Group B (n = 110)	*P*-value
Median LLD (mm)	2 (IQR, 0 to 5)	2 (IQR, 0 to 5)	2 (IQR, 0 to 5)	*P* = .74
Median FO discrepancy (mm)	7 (IQR, 1 to 10)	7 (IQR, 3 to 11)	5.5 (IQR, 0 to 10)	*P* = .14
Median horizontal COR discrepancy (mm)	−1 (IQR, −4 to 1)	−2 (IQR, −5 to 2)	−1 (IQR, −4 to 0)	*P* = .69
Median vertical COR discrepancy (mm)	2 (IQR, 0 to 5)	2 (IQR, 0 to 4)	3 (IQR, 1 to 5)	*P* = .14
Median AI (°)	40 (IQR, 34 to 46)	41 (IQR, 35 to 46)	40 (IQR, 32 to 46)	*P* = .62
Median AA (°)	19 (IQR, 16 to 22)	19 (IQR, 16 to 22)	19 (IQR, 16 to 22)	*P* = .89
Lewinnek's safe zone				
AI (n / %)	155 (76%)	80 (84%)	75 (68%)	*P* = .008
AA (n / %)	182 (89%)	84 (88%)	98 (89%)	*P* = .88
AI and AA (n / %)	139 (68%)	70 (74%)	69 (63%)	*P* = .09

Leg-length discrepancy

LLD was measured on radiographs using the distal end point of the teardrop sign and the lesser trochanter as references. Once the discrepancy value was obtained, discrepancy of the COR was subtracted to exclude the acetabular factor and obtain the discrepancy only from the femur. The operated hips that remained longer than the normal contralateral side took values greater than zero, and the shortened, values less than zero.

Femoral offset

FO was assessed by measuring the distance between the axis of the femoral shaft and the COR of the femoral head. The operated hips that were increased compared with the healthy contralateral side took values greater than zero, and the decreased, values less than zero.

Center of rotation

The horizontal COR was defined as the distance between the COR of the hip and the center of the distal end point of the teardrop sign. The operated hips that were lateralized compared with the healthy contralateral side took values greater than zero, and the medialized, values less than zero. The vertical COR was measured from the COR of the femoral head to a line going through the 2 vertices of the distal end point of the teardrop sign. The operated hips that were proximal compared with the healthy contralateral side took values greater than zero, and the distal, values less than zero.

Acetabular inclination

AI was calculated using the angle between a line passing through the 2 vertices of the distal end point of the teardrop sign and the axis of the acetabular component.

Acetabular anteversion

AA was measured using Lewinnek's method [12] (inverse arcsine of the width of the ellipse over the external diameter of the implant). Based on statistical analyses, it was determined whether the position of the cup was within Lewinnek's safe zone (40° ± 10° inclination and 15° ± 10° anteversion) [13].

Statistical analysis

Continuous variables were expressed as medians and IQRs. Categorical variables were reported as frequencies and percentages. Continuous variables were compared using the independent-samples *t*-test where data were normally distributed and the Mann-Whitney *U* test otherwise. Categorical variables were compared using the chi-squared test and Fisher's exact test. Statistical significance was defined at a *P*-value < .05. All analyses were performed using Stata 13™ statistical software (Stata Corp., College Station, TX).

Results

The median LLD was 2 mm for both groups (*P* = .74). The median FO difference of groups A and B were 7 mm and 5.5 mm, respectively (*P* = .14). The median discrepancies of the horizontal and vertical CORs were not statistically significant, with *P*-values of .69 and .14, respectively. The postoperative horizontal COR appeared to be significantly more precise in the resident's cohort; the OR group had better anatomical restoration (31 vs 10) (*P* < .003). The median AI angle of groups A and B were 41° and 40°, respectively (*P* = .62), and the median AA angle was 19° for both groups (*P* = .89). The detailed analysis of biomechanical parameters by the type of surgeon and differences compared with healthy contralateral hip is shown in Tables 3 and 4, respectively.

Discussion

The anatomic restoration of hip biomechanics in THA is necessary for long-term survivorship [6,14,15]. Good clinical outcomes are associated with optimal FO and leg-length restoration [5,7,16]. To help the surgeon's performance, different types of implants with different shapes, sizes, offset, and modularity have been developed [17]. Nevertheless, anatomical reconstruction continues being a considerable challenge. The current literature works evidence poor

Table 4
Biomechanical parameters of the different groups compared with healthy contralateral hips.

Variable	Group A (n = 95)	Group B (n = 110)	*P*-value
LLD (n / %)			
Lengthened	51 (54%)	63 (57%)	
Anatomic	21 (22%)	32 (29%)	
Shortened	23 (24%)	15 (14%)	*P* = .13
FO discrepancy (n / %)			
Increased	76 (80%)	76 (69%)	
Anatomic	5 (5%)	11 (10%)	
Decreased	14 (15%)	23 (21%)	*P* = .19
Horizontal COR discrepancy (n / %)			
Medialized	55 (58%)	58 (53%)	
Anatomic	10 (10%)	31(28%)	
Lateralized	30 (32%)	21(19%)	*P* = .003
Vertical COR discrepancy (n / %)			
Proximal	63 (66%)	84 (76%)	
Anatomic	9 (10%)	8 (8%)	
Distal	23 (24%)	18 (16%)	*P* = .28

outcomes when a nonanatomical hip reconstruction is associated [17-20].

Plenty of literature has been published in the matter of costs, complications, short-term morbidity, and mortality in surgical procedures, comparing seasoned specialists and trainee surgeons [21-25]. However, most of biomechanical studies published to date have compared implants using the healthy contralateral hip as control, focusing on LLD, FO, and vertical and horizontal CORs [11,26-29]. Nevertheless, evidence comparing hip biomechanics restoration between HSs and ORs remains scarce.

Under strict supervision, ORs can learn and improve their surgical technique, avoiding exposure mistakes, excessive bleeding, component malpositioning, and so forth. Despite close supervision, errors due to the surgeon's inexperience are inevitable.

In our study, we obtained postoperative measurements of both hips in the same patient, using a standardized method. The distal center of the teardrop sign was used, paying particular attention to measuring only the center of the radiograph that had an appropriate radiographic incidence [11].

ORs restored leg length with more precision (29% achieved an anatomic restoration) than HSs (22%). Leg lengthening was more common in the OR group too (57% vs 54%), and leg shortening was reported in 23 patients of the HS group and 15 cases of the OR group. Finally, the median LLD was 2 mm for both groups (Table 3 and 4). When referring to LLD, it is worthwhile to analyze the role of the femoral component. Cemented or uncemented THA allows for different neck and femoral-head implants, with a higher versatility to restore the anatomy more precisely. No statistically significant differences between both groups were noted; in this sense, it is doubtful that 1-2 mm can offer a clinically significant difference. However, it is not reported in the literature the exact number of millimeters necessary to produce clinical symptoms. Sarangi and Bannister included 110 patients into a prospective study of LLD, and they found lengthening of >6 mm and shortening of >10 mm were perceived by all the studied patients [30]. We believe that surgeons should always try to achieve anatomical restoration. Preoperative planning and the correct implant choice should be enough to decrease LLD.

We observed no significant difference in FO measurements between both groups. Nevertheless, the HS group and the OR group tended to increase FO when compared with the contralateral side (Tables 3 and 4).

The postoperative horizontal COR appeared to be significantly more precise in the resident's cohort; the OR group had better anatomical restoration (31 vs 10) ($P < .003$). We observed no significant difference in horizontal COR measurement between groups (−2 mm in the HS group and −1 mm in the OR group, $P = .69$). Nevertheless, both groups tended to medialize it when compared with the contralateral side. No significant difference was found regarding the vertical COR. Although HSs restored the vertical COR more precisely, almost 72% of the series had the vertical COR slightly proximal (Tables 3 and 4).

The anatomical restoration of the COR, the cementation technique, and the femoral stem orientation are important factors related to aseptic loosening [31,32]. A nonanatomical reconstruction produces changes in the mechanical forces transmitted to the implants, associated in the long term with component loosening. Although several authors initially described this theory in experimental, theoretical, and mechanical models [14,33], it was not until the 1980s when it was clinically demonstrated in retrospective studies in primary surgeries [32] and revisions [34]. Although there is no consensus, an excessively medial, L, or superior COR has been associated with increased rates of aseptic loosening of one or both components [31,32]. We believe that without new technologies, correct preoperative planning and precisely knowing bony anatomical landmarks should help achieve anatomic restoration.

Karachalios et al. [31] retrospectively evaluated 95 THAs with an implanted Charnley prosthesis. The maximum tolerated distance for anatomical restoration of the COR without a significant increase of the loosening rate was only 2 mm laterally. In our series, median discrepancies of the horizontal COR were −2 mm (IQR, −5 to 2) in group A and −1 mm (IQR, −4 to 0) in group B ($P = .69$).

Callaghan et al. [25] reported the clinical and radiological results of 100 uncemented porous-coated THAs, analyzing the learning curve associated with the procedure. All surgeries were performed by one or 2 surgeons who had previously performed a total joint arthroplasty fellowship. A definite learning curve was evidenced by obtaining good postoperative outcomes in primary uncemented components. The authors evidenced significant improvement in acetabular placement in the second group of THA. In contrast with our study, it was not a comparison between surgeons, and all THAs were performed by experienced surgeons, not by residents. Another difference was the lack of AA measurement and the implantation of uncemented components. In our study, most of the implants were cemented. This fixation could probably be associated with a better orientation of acetabular cups, evidenced by a similar acetabular position in the 2 groups (Tables 3 and 4). We believe that avoiding mini-open approach, the systematic use of implant tools with offset, the modern cementation techniques, the use of pressurized cups, and the correct patient positioning would reduce the errors related to the version and inclination of the acetabular cup. Lewinnek's safe zone was achieved in 70 (74%) and 69 (63%) patients of groups A and B, respectively ($P = .09$) (Table 3).

Our study was not without limitations. First, its retrospective nature correlated with the biases exclusive to the study design. The sample size of the series resulted in a small number of cases included in both HS and OR groups, restraining the production of more accurate statistical analyses. It can be argued that the lack of statistical significance observed in some of the variables analyzed can be the result of a beta-type error (underpowered study). Second, we did not perform 3-dimensionally reconstructed measurements, which would have allowed us to achieve a more precise and accurate analysis. However, it is one of the largest studies comparing hip biomechanics between these 2 groups in cases of displaced FNFs. Further studies with a multicenter prospective, comparative approach are needed to validate our results.

Conclusions

We observed no significant difference in LLD, FO, vertical COR, AI, and AA measurements between the 2 groups, with only the postoperative horizontal COR significantly more precise in the resident's cohort. According to these results, ORs under strict supervision are as reliable as HSs to properly restore hip biomechanics in patients who undergo THA for displaced FNFs. We believe this study highlights the importance of strict supervision and an active teaching role of experienced HSs to provide excellence in the THA technique due to an FNF.

Conflict of interests

The authors declare there are no conflicts of interest.

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The study was performed at the Italian Hospital of Buenos Aires, Argentina.

References

[1] Fehring TK, Odum SM, Troyer JL, Iorio R, Kurtz SM, Lau EC. Joint replacement access in 2016: a supply side crisis. J Arthroplasty 2010;25(8):1175.
[2] Canal C, Kaserer A, Ciritsis B, Simmen H-P, Neuhaus V, Pape H-C. Is there an influence of surgeon's experience on the clinical course in patients with a proximal femoral fracture? J Surg Educ 2018;75(6):1566.
[3] Haughom BD, Schairer WW, Hellman MD, Yi PH, Levine BR. Does resident involvement impact postoperative complications following primary total knee arthroplasty? An analysis of 24,529 cases. J Arthroplasty 2014;29(7):1468.
[4] Yamaguchi T, Naito M, Asayama I, Ishiko T. Total hip arthroplasty: the relationship between posterolateral reconstruction, abductor muscle strength, and femoral offset. J Orthop Surg (Hong Kong) 2004;12(2):164.
[5] McGrory BJ, Morrey BF, Cahalan TD, An KN, Cabanela ME. Effect of femoral offset on range of motion and abductor muscle strength after total hip arthroplasty. J Bone Joint Surg Br 1995;77(6):865.
[6] Asayama I, Chamnongkich S, Simpson KJ, Kinsey TL, Mahoney OM. Reconstructed hip joint position and abductor muscle strength after total hip arthroplasty. J Arthroplasty 2005;20(4):414.
[7] Asayama I, Naito M, Fujisawa M, Kambe T. Relationship between radiographic measurements of reconstructed hip joint position and the Trendelenburg sign. J Arthroplasty 2002;17(6):747.
[8] Sakai T, Sugano N, Ohzono K, Nishii T, Haraguchi K, Yoshikawa H. Femoral anteversion, femoral offset, and abductor lever arm after total hip arthroplasty using a modular femoral neck system. J Orthop Sci 2002;7(1):62.
[9] Ranawat CS, Ranawat AS, Rasquinha VJ. Mastering the art of cemented femoral stem fixation. J Arthroplasty 2004;19(4 Suppl 1):85.
[10] Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis–what the radiologist should know. AJR Am J Roentgenol 2007;188(6):1540.
[11] Tannast M, Zheng G, Anderegg C, et al. Tilt and rotation correction of acetabular version on pelvic radiographs. Clin Orthop Relat Res 2005;438:182.
[12] Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978;60(2):217.
[13] Hassan DM, Johnston GH, Dust WN, Watson G, Dolovich AT. Accuracy of intraoperative assessment of acetabular prosthesis placement. J Arthroplasty 1998;13(1):80.
[14] Johnston RC, Brand RA, Crowninshield RD. Reconstruction of the hip. A mathematical approach to determine optimum geometric relationships. J Bone Joint Surg Am 1979;61(5):639.
[15] Konyves A, Bannister GC. The importance of leg length discrepancy after total hip arthroplasty. J Bone Joint Surg Br 2005;87(2):155.
[16] Charles MN, Bourne RB, Davey JR, Greenwald AS, Morrey BF, Rorabeck CH. Soft-tissue balancing of the hip: the role of femoral offset restoration. Instr Course Lect 2005;54:131.
[17] Dennis DA, Lynch CB. Stability advantages of a modular total hip system. Orthopedics 2005;28(9 Suppl):s1049.
[18] Hodge WA, Andriacchi TP, Galante JO. A relationship between stem orientation and function following total hip arthroplasty. J Arthroplasty 1991;6(3):229.
[19] Sakalkale DP, Sharkey PF, Eng K, Hozack WJ, Rothman RH. Effect of femoral component offset on polyethylene wear in total hip arthroplasty. Clin Orthop Relat Res 2001:125.
[20] Delp SL, Wixson RL, Komattu AV, Kocmond JH. How superior placement of the joint center in hip arthroplasty affects the abductor muscles. Clin Orthop Relat Res 1996:137.
[21] Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg 2011;212(5):889.
[22] Englesbe MJ, Fan Z, Baser O, Birkmeyer JD. Mortality in medicare patients undergoing surgery in July in teaching hospitals. Ann Surg 2009;249(6):871.
[23] Taylor DH, Whellan DJ, Sloan FA. Effects of admission to a teaching hospital on the cost and quality of care for Medicare beneficiaries. N Engl J Med 1999;340(4):293.
[24] Bohl DD, Fu MC, Golinvaux NS, Basques BA, Gruskay JA, Grauer JN. The "July effect" in primary total hip and knee arthroplasty: analysis of 21,434 cases from the ACS-NSQIP database. J Arthroplasty 2014;29(7):1332.
[25] Callaghan JJ, Heekin RD, Savory CG, Dysart SH, Hopkinson WJ. Evaluation of the learning curve associated with uncemented primary porous-coated anatomic total hip arthroplasty. Clin Orthop Relat Res 1992:132.
[26] Silva M, Lee KH, Heisel C, Dela Rosa MA, Schmalzried TP. The biomechanical results of total hip resurfacing arthroplasty. J Bone Joint Surg Am 2004;86-A(1):40.
[27] Loughead JM, Chesney D, Holland JP, McCaskie AW. Comparison of offset in Birmingham hip resurfacing and hybrid total hip arthroplasty. J Bone Joint Surg Br 2005;87(2):163.
[28] Schmidutz F, Beirer M, Weber P, Mazoochian F, Fottner A, Jansson V. Biomechanical reconstruction of the hip: comparison between modular short-stem hip arthroplasty and conventional total hip arthroplasty. Int Orthop 2012;36(7):1341.
[29] Amstutz HC, Thomas BJ, Jinnah R, Kim W, Grogan T, Yale C. Treatment of primary osteoarthritis of the hip. A comparison of total joint and surface replacement arthroplasty. J Bone Joint Surg Am 1984;66(2):228.
[30] Sarangi PP, Bannister GC. Leg length discrepancy after total hip replacement. Hip Int 1997;7:121.
[31] Karachalios T, Hartofilakidis G, Zacharakis N, Tsekoura M. A 12- to 18-year radiographic follow-up study of Charnley low-friction arthroplasty. The role of the center of rotation. Clin Orthop Relat Res 1993;(296):140.
[32] Yoder SA, Brand RA, Pedersen DR, O'Gorman TW. Total hip acetabular component position affects component loosening rates. Clin Orthop Relat Res 1988:79.
[33] Johnston RC, Fitzgerald RH, Harris WH, Poss R, Müller ME, Sledge CB. Clinical and radiographic evaluation of total hip replacement. A standard system of terminology for reporting results. J Bone Joint Surg Am 1990;72(2):161.
[34] Callaghan JJ, Salvati EA, Pellicci PM, Wilson PD, Ranawat CS. Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982. A two to five-year follow-up. J Bone Joint Surg Am 1985;67(7):1074.