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Fluoroscopy improves femoral stem placement in cementless total hip arthroplasty

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Abstract
Fluoroscopy is routinely used in trauma cases to evaluate alignment and reduction quality. Because conventional templating has a high mismatch rate, we sought to explore whether we could use intraoperative fluoroscopy while implanting the femoral stem. Sixty patients with Croft 3-4 coxarthrosis were included in this study. No preoperative templating was performed in either of the two groups. The final conformations of the stem sizes and positions were achieved freehand intraoperatively using anatomic landmarks. In the second group, after surgeons intraoperatively agreed on the final stem size, C-arm fluoroscopy images are obtained with the last rasp size before the stem implantation. The alignment of femoral stem according to the femoral canal, the lower leg discrepancy (LLD) and the lateral offsets were evaluated with X ray. The stem/endosteal areas at 2 cm above the trochanter minor (T+2) and 2 cm below the trochanter minor (T-2) and the deviation of the stem tip from the center of the femoral canal were evaluated in CT images. The stems that were implanted under fluoroscopic control filled the medullary cavity better at both the T+2 and T-2 levels. On fluoroscopy, in the control group, the malpositioning of the femoral stems were less, the centralizations were better, and the restorations of the lateral offset and LLD were more accurate. The use of fluoroscopy while rasping the femoral canal leads to proper alignment and press fitting of the stem and provides the opportunity to intraoperatively correct malpositionings of the stem.

Keywords: Stem position, fluoroscopy, hip prosthesis, limb length discrepancy

Introduction

The primary stability of a cementless hip stems plays a critical role in the success of prosthesis [1]. A cementless stem with inadequate stability is at risk for early loosening and subsidence [2]. If a stable fixation is achieved, osseointegration occurs [3]. The primary stability of a cementless hip stem relies on the mechanical interlocking of the stem and surrounding bone. To achieve this goal, the stem bone contact area must be maximized using the appropriate size and correctly positioning the stem in the femoral canal [4]. Loose stems lead to increased micromotion at the stem and bone interface and may lead to fibrous ingrowth and the failure of osseointegration [3,5].After all primary total hip replacement, one-third of stems subside by more than 1 mm in first two years, and loose implanted stems subside more, which leads to a higher rate of stem failure in the early period after primary surgery [6].

Lower leg discrepancies (LLDs) and component malpositionings are also common problems after hip arthroplasty [7].

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Only 6% of patients achieve equal leg lengths following hip prosthesis, and 82% of patients limbs were lengthened in the course of THA [8]. Malpositioning is a risk factor for increased micromotion and periprosthetic fractures [2].

Preoperative planning and templating are basic steps to overcome loose implantation, malpositioning and LLD in total hip replacement. However, many studies in the literature have reported that the accuracy of conventional 2D templating can be as low as 16% in terms of stem sizing, and poor accuracy is especially common with cementless stems [9,10]. Some researchers have even found preoperative planning to be useless [11]. Accuracy has increased as 3D CT-guided systems have become more frequently used [9,12]. However, such systems are associated with extra costs to the health care system, prolonged operative times, and increased radiation exposures for the patients, and surgical and other complications, including femoral perforations and trochanteric fractures, can be seen following the use of 3D CT-guided systems [13-16].

Whereas conventional templating is may be of little value and results in high mismatch ratios, and 3D CT-guided templating is expensive and difficult to reach, we believe that fluoroscopy could increase the primary stability and decrease the malpositioning of the femoral stem in cementless hip arthroplasty.

Materials and Methods

This study was approved by the institutional ethic committee of our hospital (IRB no:2015-366). Prospectively two groups of patients with hip osteoarthritis were included in the study. Senior surgeons decided wheatear to use fluoroscopy or not before the operation without a randomization. Hip osteoarthritis was classified according to the Croft classification [17]. Our primary goal is to evaluate T+ 2 results between the two groups, where T+2 stands for the most appropriate side for proximal calcar geometry of femur [18]. Standard effect sizes (standard effect size) assumed to be at least 0.75. 30 cases for each group took power with 80% margin of 5% error. Patients with malignant tumors, previously known bone disease, drug consumption affecting bone mineralization or Crowe type III hip dislocations with greater than 4 cm of LLD were excluded. Prior to the operation, all patients underwent an X ray investigation to exclude any bone abnormalities. All patients were operated by the same team, which was composed of two senior surgeons and 2 fellows. All patients were operated on the lateral decubitus position. Hip and shoulder aligned in the same axis and both shoulders were vertically aligned to the table. Additional supports were also placed to lumbo-sacral junction level from anterior and posterior side of patient. All patients were operated with a posterior approach. All patients received the Summit stem (Depuy Orthopaedics, Warsaw, Ind), a proportionate titanium implant with a porous coating over approximately the proximal third. The midthird portion of the stem has a grit blast finish, and the tip is polished. In the first group, no preoperative templating was performed. The femoral canal was prepared using reamers and then broached up to the appropriate size, defined as absence of visible cancellous bone at some part of the proximal canal. Trial reductions were performed to assess leg length, range of motion, and stability for confirmation of the stem size and position.

In the second group, there was also no preoperative templating, but after both senior surgeons agreed on the final stem size and positon as described in first group, intraoperatively, C-arm fluoroscopy images were obtained with the last rasp size before stem implantation. The alignment and stem fitting of the femoral canal were evaluated. While evaluating the limb leg discrepancy anterior – posterior fluoroscopy image must include both hips and both lesser trochanters. Once this was achieved, the interteardrop line was used and vertical distance between interteardrop line and lesser trochanters measured for limb length discrepancy. The perpendicular distance of a line extending from the femoral canal axis to the center of rotation of the femoral head, drawn at the level of the greater trochanter extremity was evaluated as lateral offset. For stem alignment, the femoral stem axis being parallel with the axis of the femoral canal was assessed. Also centralization of femoral stem tip in the femoral canal was assessed. Determination of stem was assessed according to full contact of broach teeth in sub trochanteric region. The stem was size changed unless all criteria above was achieved on fluoroscopy. After the operation, all patients were evaluated with X ray and CT. (Figure 1)

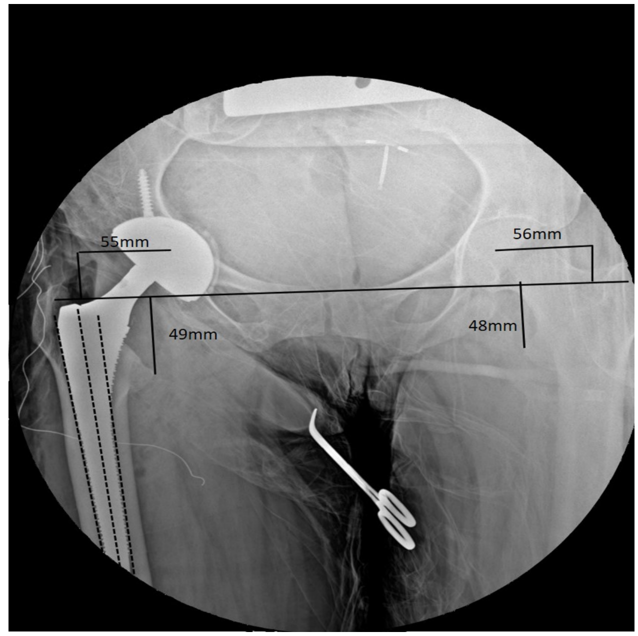

Figure 1. Evaluation of final rasp under fluoroscopy. Interteardrop line was drawn between to tear drops and vertical distance between interteardrop line and trochanter minor was evaluated for lower leg discrepancy, perpendicular distance of a line extending from the femoral canal axis to the center of rotation of the femoral head was evaluated for lateral offset (black lines). The axis of femoral stem is parallel to medullary axis of femur and full contact of broach teeth in sub trochanteric region (trim lines).

The metaphyseal canal flare index (MCFI) described by Laine and colleges was used to evaluate the stem fitting [18]. MCFI can be used for metaphyseal lacking femoral stems. The alignment of the femoral stem with the femoral canal, the LLD and the lateral offsets were evaluated on X ray. The stem/endosteal areas at 2 cm above the trochanter minor (T+2) and 2 cm below the trochanter minor (T-2) and the deviation of the stem tip from the center of the femoral canal were evaluated on CT images (Figure 2).

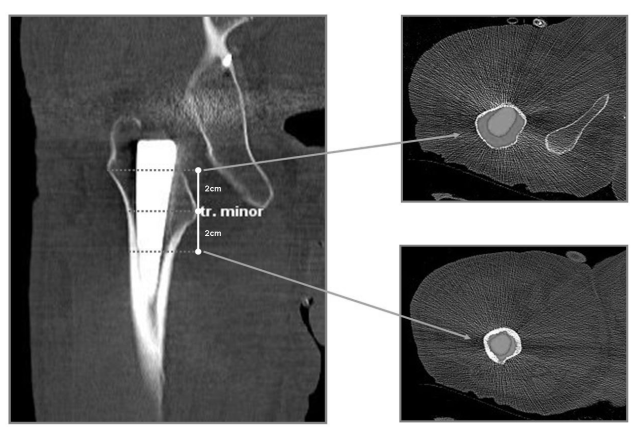

Figure 2. Calculation of stem area/ endosteal area in CT images.

The distributions of the variables were examined with Kolmogorov-Smirnov tests. The Mann-Whitney U test and independent samples t-test were used for the quantitative data analysis. The qualitative data were analyzed with the chi-square test. Spearman correlation analyses were used to examine the correlations between variables. The SPSS 22.0 software was used for the analyses. P values of 0.05 or less were considered significant

Results

Sixty patients with Croft grade 3 and 4 coxarthrosis were included in this study. In the fluoroscopy group, 15 patients (50%) were female and 15 patients (50%) were male. In the control group, 14 patients (47%) were female and 16 patients (53%) were male. In the fluoroscopy group, 13 stem (%43) were changed after evaluation with fluoroscopy. 11 out of 13 were changed with one size over 2 were changed with 2 size over. Only in one case a small fissure was seen while increasing the stem size which can be controlled with a Doll-Milles cable without changing the femoral stem. The demographic characteristics of the patients are illustrated in table 1.

None of the demographic characteristics were statistically important. The stems that were implanted under fluoroscopic control filled the medullary cavities better at both the T+2 and T -2 levels (p=0.00 and p=0.00, respectively). The malpositioning of the femoral stems were less severe in the fluoroscopy group. The malposition in the coronal plane was more pronounced in the control group (p=0.00). The centralization of the stem tip was better in the fluoroscopy group (p=0,00).

The correction of the LLD was better in the fluoroscopy group. The mean difference between the healthy side and operated side was 2.8 mm in the fluoroscopy group, and this value increased to 5.6 mm in the non-fluoroscopy group (p=0.00). Moreover, the lateral offset was better in the fluoroscopy group (p=0.00; Table 1). Because the filling of stem at the T+2 and T-2 levels increased, the alignment of the femoral stem in the femoral cavity improved. Moreover, the lateral offset and LLD restorations improved as the filling of the stem increase (Figure 3).

Table 1. Demographic characteristics of patients (T+2: Stem area/ endosteal area from 2 cm above trochanter minor, T-2: Stem area/ endosteal area from 2 cm below trochanter minor, LLD: Lower leg discrepancy)

		Fluoroscopy (+)		Fluoroscopy (-)		p
		Mean±s.d./n-%	Med(Min-Max)	Mean±s.d./n-%	Med(Min-Max)	
Sex	Male	15 50%		16 53%		0,796
	Female	15 50%		14 47%		
Age		65,3 ± 9,3	65 41 - 81	62,7 ± 9,8	63 41 - 85	0,304
BMI		27,3 ± 3,7	27 22 - 33	27,0 ± 3,3	27 22 32	0,694
Side	Right	16 53%		16 53%		1,000
	Left	14 47%		14 47%		
Stem	(+)	13 43%		0 0%		
Exchange	(-)	17 57%		30 100%		
T+2		55,5 ± 4,7	54 49 - 66	44,1 ± 3,3	44 37 - 52	***0,000***
T-2		67,2 ± 5,9	69 50 - 74	53,4 ± 9,2	55 33 - 70	***0,000***
Malalignment		0,5 ± 0,5	0,4 0,0 - 1,3	1,4 ± 0,7	1,3 0,4 - 3,4	***0,000***
Deviation of stem tip		0,3 ± 0,3	0,2 0,0 - 1,0	1,4 ± 1,2	1,0 0,0 - 4,5	***0,000***
Lateral Offset		0,4 ± 0,7	0,2 -1,5 - 2,8	2,8 ± 2,2	2,9 -2,7 - 7,0	***0,000***
LLD		2,9 ± 2,5	2 0 - 10	5,6 ± 5,8	4 -4 - 20	***0,043***

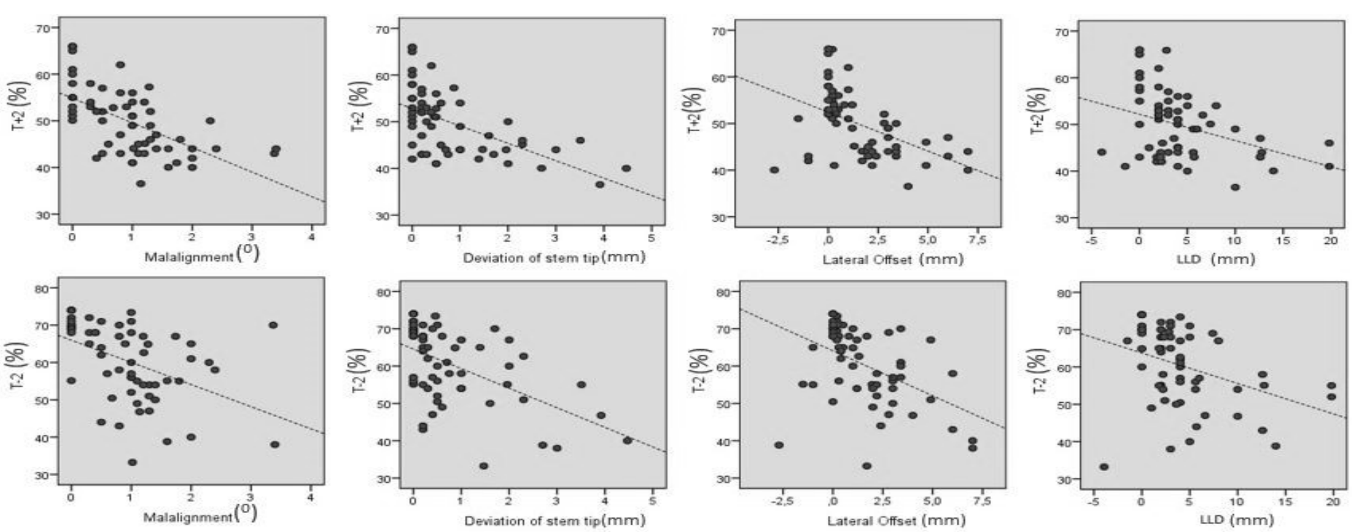

Figure 3. As the filling of stem increases in T+2 and T -2, stem alignment and LLD become more accurate in both fluoroscopy (+) and fluoroscopy (-) patients.

Discussion

The long-term success of a cementless hip prosthesis relies on its primary stability [1]. To achieve primary instability, the reduction of the micro motion in the bone-stem interface via appropriate rasping and the positioning of the stem are important. Although both conventional and CT-guided preoperative templating systems are available, no currently available system allows the surgeon to preoperatively determine whether the correct stem size has been selected, and thus surgeons are always forced to intraoperatively estimate the stem size [4,15]. We frequently use fluoroscopy to examine the reduction and alignment in trauma cases. Fluoroscopy can also be used in acetabular component positioning [19]. In the present study, we used fluoroscopy during cementless hip prosthesis implantation and found that it decreased stem malpositioning and increased the filling of the bone by the stem. This technique is an easy, inexpensive, and repeatable procedure that can be used during prosthesis surgeries.

The MCFI is used to estimate the fitting of the stem. The MCFI is a good parameter for distinguishing the various types of proximal femoral canal shapes and positively influences stem selection [18]. The MCFI is computed as the ratio of the endosteal diameters 20 mm above and 20 mm below the center of the lesser trochanter and is indicative of the actual morphology of the metaphyseal region, which enables better stem fixation in the medullary canal [20]. We modified the MCFI and used the ratio of the stem area to the endosteal area at 20 mm above and 20 mm below the center of the lesser trochanter to evaluate stem filling. This modified ratio provided 3D rather than two-dimensional data.

Aseptic loosening is one of the most common reasons for revision in total hip arthroplasty [21]. Early revisions due to aseptic loosening in femoral stem account for 17% of all revisions after primary hip arthroplasty [21]. Different implant designs, custom-made prostheses, and templating programs are used to increase the primary stability, but these techniques are either expensive or ineffective. The reliability of conventional two-dimensional templating has been reported to be very low in the literature [9,10]. Mismatches between transparent templates and printed images, magnification problems on digital X-rays, and reading the digital templates from different manufacturers are the main problems associated with conventional templating [12]. To overcome these problems in conventional templating, 3D CT-guided systems are in use [9]. However, even with 3D CT-guided systems, there is still a 12% risk of malposition and a 13% increase in micro motion due to the malpositioning of the stem [1]. Three-dimensional navigation also results in longer operating times and extra costs to the health care system [13,15]. Increased radiation exposure for preoperative templating with CT images is another weakness associated with 3D navigation [16]. 3D navigation is also associated with a slow learning curve. Early complications, including femoral canal perforations and greater trochanter fractures, are common following the use of 3D navigation [14]. Steinberg also indicated that 3D templating is not necessary for simple osteoarthritis and should be avoided in such cases due to the high cost and radiation exposure and that 3D templating should mostly be used for the planning of dysplastic hip procedures [2]. We did not use preoperative templating in either groups, but the intraoperative fluoroscopic evaluations of the rasp during the final stage before the original stem implantation increased the alignment and improved the bone stem interface.

In our study, centralization of the stem tip was better in the fluoroscopy group The direction of the stem tip deviation, medial or lateral indicates, respectively, valgus or varus positioning of the implant. Such malpositioning may be the result of critical details of the surgical technique, which may influence the occurrence of complications and also affect the choice of the appropriate size of the femoral stem. The varus positioning, caused for example by a more medial entry point in the femoral canal, may cause an impact between the stem tip and the anterolateral cortex of the femur, thus resulting in an choice for undersized implant with all its associated consequences. On the other hand, the valgus positioning may result in greater invasion of the greater trochanter and thus predispose to intraoperative fractures, and also may lead to improper filling of the proximal femoral canal.

Primary stability can increase via the use of custom-made prostheses. Custom-made prostheses exhibited less micro motion than classic stems [22], but they are expensive, and patients are exposed preoperative radiation during stem design. Götze et al found that if implanted properly, classical stems can exhibit interface motions that are similar to those of custom-made stems [22].

Different stem types can be used as cementless femoral stems. The greatest incidence of revision (nearly 1/3) occurs with metaphyseal locking stem types [21]. In our study, we also used metaphyseal locking stems. Femoral metaphyseal openings vary across individuals, and different stems are needed for different metaphyseal morphologies. With the metaphyseal locking stem system, we observed that the alignment was not good in the freehand group. In contrast, the fitting of the prosthesis at the T-2 level was good in the fluoroscopy-guided group, but the fitting at the metaphyseal medullar entrance (T +2) was not good at the T-2 level. Therefore, we thought that a metaphyseal locking stem could be locked at the T-2 level to enable a hinged motion above and below the T-2 level; this motion could be the reason for early losing.

Limb length discrepancy is also a problem in cementless hip arthroplasty [23]. Only 6% of patients achieve equal lengths after cementless hip arthroplasty, and the discrepancies in the other patients are primarily due to the malpositioning of the femoral stem [8]. LLDs following cementless hip arthroplasties range from 3 mm to 8 mm [24, 25]. Computer navigation systems do not reduce LLDs compared with even simple manual measurement devices [24]. Different intra-operative methods, such as the use of abductor shucks, transosseous pins with calibrated calipers and patella electrocardiogram leads, can be used to assess LLD, but none of the resultant values correlate with the postoperative radiographic measurements [25]. We observed LLDs of 2.87 mm in the fluoroscopy-guided group and 5.6 mm in the freehand group. Both of these values are comparable to those in the literature, which demonstrates that fluoroscopy can be used to decrease the LLD following cementless hip prosthesis implantation.

This study has weak points. First, all of the patients had simple primary coxarthrosis or traumatic fractures; therefore, the results do not include patients with secondary coxarthrosis due to the development hip dysplasia or hip deformity. Second, we used the same stem type in all patients to maintain the homogeneity of the groups, and the use of different stem designs might have produced different results. Because this study investigated early postoperative parameters we cannot make any estimations regarding long-term results.

The use of fluoroscopy during the rasping of the femoral canal for the implantation of cementless hip prostheses can lead to the proper alignment and press fitting of the stem and provides the opportunity to correct malpositioning of the stem intraoperatively.

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