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Research Article

Sacro-Femoral-Pubic Angle and Acetabular Cup Anteversion in Total Hip Arthroplasty

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Abstract

Purpose: Acetabular cup anteversion (ACA) is related to pelvic orientation in total hip arthroplasty (THA). Sacro-femoral-pubic angle (SFP) is a coronal radiographic parameter related to sagittal pelvic tilt (PT) by the formula: PT = 75 - (SFP). Aim of the study is to measure SFP, ACA and clinical outcome to establish the relation between ACA and SFP and SFP variations in patients affected by hip osteoarthritis before and after arthroplasty.

Methods: Forty-three patients were operated with THA surgery for hip osteoarthritis and were retrospectively reviewed of their anterior-posterior (AP) pelvis X-ray view and clinical function. SFP have been digitally measured before and after surgery and at 6 months of follow-up. ACA angle was measured with the ellipse method on the latest radiograph. Clinical evaluation was performed with the Oxford Hip Score (OHS) 6 months after surgery.

Results: Preoperative SFP has had a mean value of 57.2° and PT 17.8°. Postoperative SFP has been 62° and PT 13°. At 6 months follow-up, SFP has been 57.9°, PT 17.1° and ACA 19.3°. Comparison of pre vs postoperative and postoperative vs follow-up for SFP have showed significant differences ($p < 0.05$). Comparison of SFP vs OHS ($R = 0.054$, $R2 = -0.0029$), OHS vs ACA ($R = 0.18$ $R2 = 0.031$) and SFP vs ACA at follow-up ($R = -0.21$, $R2 = 0.0439$) was not statistically significant. OHS it was satisfactory in all cases.

Conclusion: SFP and ACA are measurable on pelvis AP X-ray view. In our study we have not found relation among clinical result and SFP measurements. SFP is a stable angle before and after THA. Relationship between SFP and ACA must be considered especially when osteoarthritis of the hip and disorders of the spine coexist in the same patient. To improve THA preoperative planning and acetabular cup placement further evaluation of the sagittal plane has to be examined.

Level of Evidence: Level III, retrospective study.

Keywords: *Sacro-Femoral-Pubic Angle; Acetabular Cup Anteversion; Total Hip Arthroplasty; Pelvic Tilt; Pelvic Orientation*

Introduction

Total hip arthroplasty (THA) in patients from 65 to 74 years old is mainly indicated for hip osteoarthritis (OA) [1]. However, OA is often present in the hips and spine simultaneously in elderly, and degenerative joints changes can alter pelvic biomechanics and gait [2]. The effects of aging, disc degeneration and osteoarthritis can lead, mostly in the elderly, to a sagittal imbalance of the spine with compensatory mechanism that modify posture and gait [3]. In elderly patients hip and spine osteoarthritis are often simultaneous and postural compensatory mechanism change pelvic orientation with different orientation of bones landmarks. Spinopelvic alignment relies with acetabular orientation and it may influences THA surgical procedure because spinopelvic malalignment influence pelvic anteversion or retroversion with consequent increase or decrease respectively of the acetabular anteversion [4]. Pelvic retroversion, defined as backward tilt of the pelvis on the sagittal plane, can be seen on a lateral X-ray view of the pelvis; it causes an increase pelvic tilt (PT) and

it modifies acetabular orientation [5]. Acetabular cup positioning in THA has to reproduce acetabular version to prevent dislocation and impingement of the implant. The safe zone described by Lewinnek to define the acetabular cup orientation is 40° ± 10° of inclination on the frontal plane and 15° ± 10° of anteversion on the sagittal plane [6]. Hip surgeons focus mainly on the pelvis anterior-posterior (AP) X-ray view in preoperative planning of THA, while relationships between pelvic retroversion and acetabular cup anteversion (ACA) angle on sagittal plane is often underestimated. Sacro-femoral-pubic angle (SFP) is a coronal radiographic parameter related to sagittal pelvic tilt (PT) by the formula: PT = 75 - (SFP). SFP on an AP view X-ray of the pelvis directly relate with pelvic inclination.

Aim of the Study

Aim of this study is to evaluate the relation between ACA and SFP angles and the SFP variation before and after THA procedure in subject affected by primary hip OA.

Methods

Forty-three patients (16 female, 27 males) aged 50 to 91 years old (mean age 68,8) have been evaluated. All patients suffered from primary hip OA and underwent THA surgery (20 right THA, 23 left THA), performed by the same surgical equipe. Exclusion criteria have been secondary hip OA, contralateral THA, previous hip or spine fractures or surgical procedures.

Six months after surgery, patients have been evaluated clinically and radiographically. Oxford Hip Score (OHS), self-assessed pain and disability index have been measured for clinical results [7]. OHS ranges from 12 to 60, with high value indicating disability. Four grades of disability have been considered: from 12 to 20 points satisfactory joint function, from 21 to 30 mild-moderate hip function, from 31 to 40 moderates-severe, from 41 to 60 severe. The AP X-ray view of the pelvis has been evaluated for each patient preoperatory, post-operatory and at 6 months after surgery. The measured pelvic parameters have been the sacro-femoral-pubic angle. Blondel et al. defined SFP as the angle between the midpoint of the upper sacral endplate to the centroid of the acetabulum and to the upper midpoint of the pubic symphysis [8] (Figure 1). Radiographic measurements has been done by a single investigator using DICOM-PACS RadiANT Viewer© 2.2.9 (Medixant, Poznan, Poland), for SFP angle in each phase of the study. For THA, the femoral head component of the prosthesis was used as vertex of SFP angle instead of using the geometrical center of acetabulum (Figure 2).

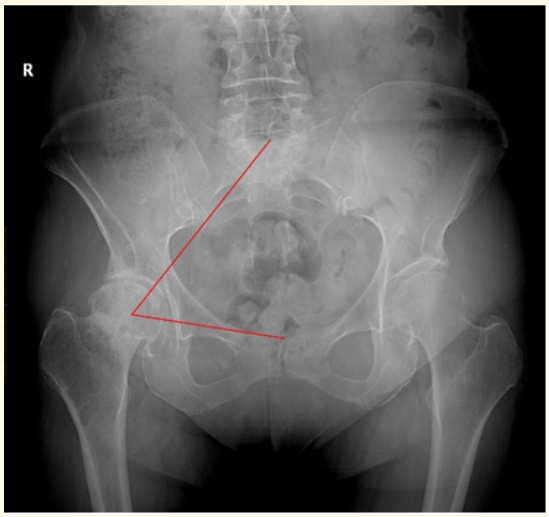

Figure 1: *Sacro-femoral-pubic angle (SFP).*

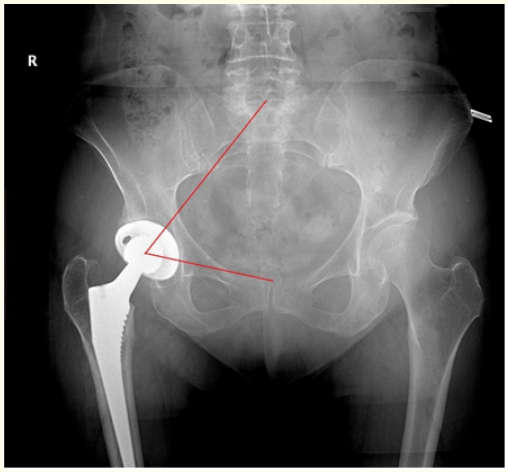

Figure 2: *Postoperatory Sacro-femoral-pubic angle.*

Pelvic tilt (PT) is the angle between the vertical line passing through the center of bicoxofemoral axis and the line drawn from this point to the center of S1 endplate. PT values have been obtained through the formula: PT = 75 - (SFP) [7]. Acetabular cup anteversion (ACA) has been measured on the 6 months follow-up on AP pelvis X-ray view, it has been calculated by the Lewinnek's ellipse method: ACA = arcsin (short axis/long axis) [6]. In the sagittal plane, ACA is the angle formed by the line tangent to the anterior and posterior edges of the acetabulum and the horizontal plane. In the transverse plane, it is the angle formed by the line tangent to the anterior and posterior edges of the acetabulum and the sagittal axis [9] (Figure 3).

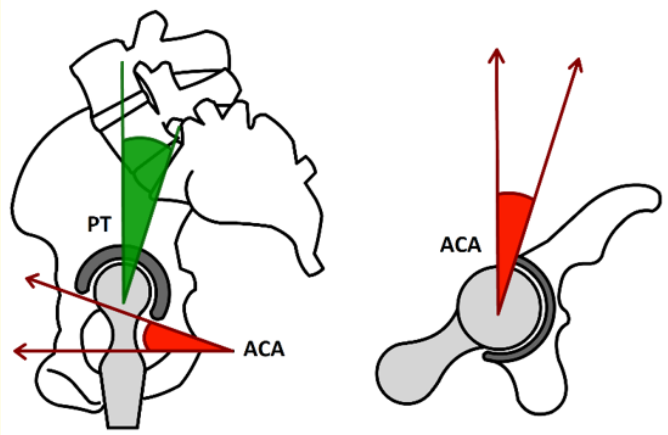

Figure 3: *Acetabular cup anteversion (ACA) and Pelvic tilt (PT) (sagittal plane and transverse plane).*

Statistical analysis

The relationship between SFP and ACA has been evaluated with the Pearson coefficient of correlation (R) and linear regression analysis (R^2), using R commander© software. Each correlations have been drawn with scatter-plot graphs. Difference among preoperative SFP, postoperative SFP and 6 months follow-up SFP have been analyzed using two tailed paired Student's *t*-test analysis.

Results

Clinical assessment: OHS values at 6 months after surgery was less than 20 points in each patient, with satisfactory joint function, and no significant statistical differences between female and male ($p > 0.05$).

Radiographic assessment: On the whole series of AP radiographs, SFP mean value before surgery was 57.2° (SD = 6.9), 62° (SD = 5.7) the day after surgery, and 57.9° (SD = 6.7°) at 6 months of follow up. On the whole series of AP radiographs, PT mean value was 17.8° before surgery, 13° the day after surgery, and 17.1° at follow up, respectively. Acetabular cup anteversion angle ACA mean value was 19.3° (SD = 8.5°).

Comparisons of SFP pre *vs* postoperative, preoperative *vs* follow-up, pre-postoperative *vs* preoperative-follow-up showed statistically significant differences ($p < 0.05$) (Figure 4-6). SFP had no significant variation at 6 months follow-up. Linear relation and regression between ACA *vs* SFP follow-up was not statistically significant ($R = -0.21$ $R^2 = 0.0439$ $p = 0,18$), with no correlation between variables (Table 1 and Figure 7). Linear relation and regression between OHS *vs* ACA was not statistically significant ($R = 0,18$ $R^2 = 0.031$ $p = 0.7$), with no relation between variables. Linear relation and regression between SFP *vs* OHS was not statistically significant ($R = 0.054$, $R^2 = -0.0029$, $p = 0.98$).

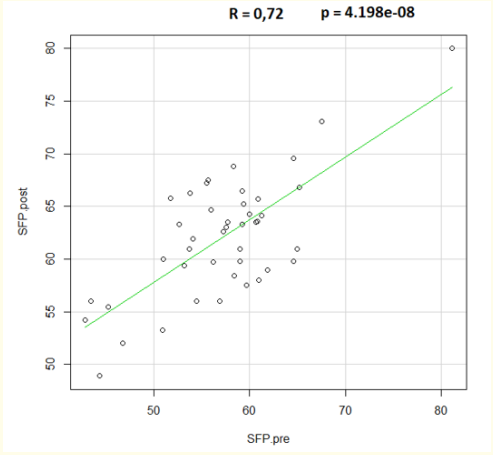

Figure 4: *Preoperative-SFP vs postoperative-SFP.*

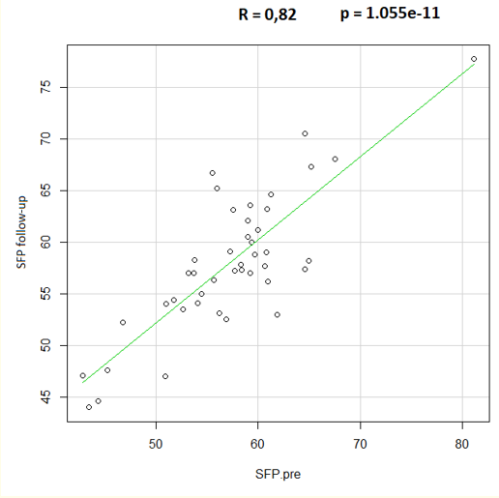

Figure 5: *Preoperative-SFP vs follow-up-SFP.*

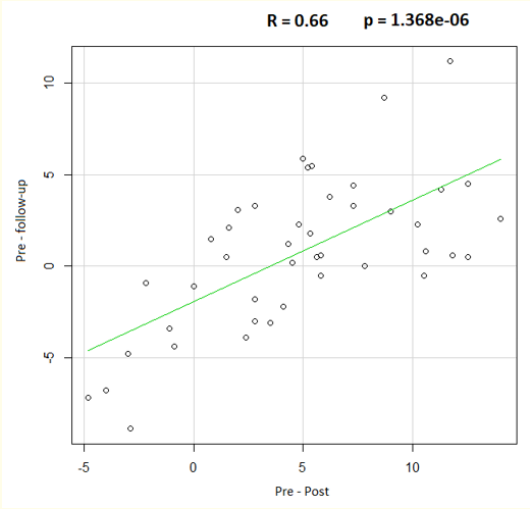

Figure 6: *SFP preoperative-postoperative vs SFP preoperative-Follow up.*

	SFP pre- vs SFP post	SFP pre- vs SFP F-up	SFP pre-post vs SFP pre-F up	SFP F-up vs ACA
R	0.72	0.82	0.66	-0.21
R^2	0.52	0.68	0.44	0.04
R^2_{adj}	0.51	0.67	0.42	0.02
p value	$4.2^{-0.8}$	1.1^{-11}	$1.4^{-0.6}$	0.18

Table 1: *SFP angle variation in pre-operative, post-operative and follow-up and acetabular cup anteversion correlation with SFP angle. SFP pre: SFP Pre-Operative; SFP post: SFP Post-Operative: SFP F-up: SFP Follow-Up; ACA: Acetabular Cup Anteversion.*

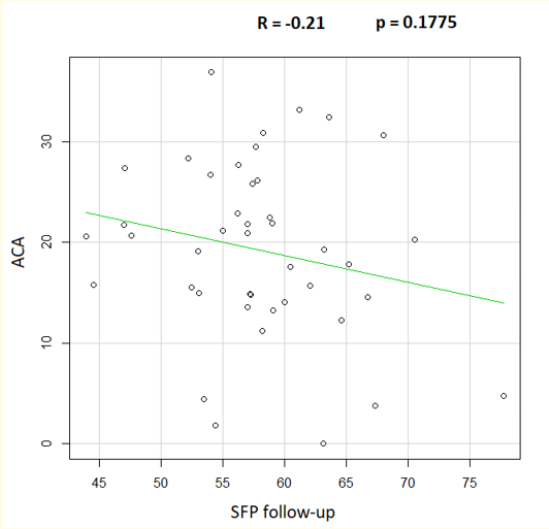

Figure 7: *Follow-up SFP vs Acetabular cup anteversion ACA.*

Discussion

In 1983 Offierski., *et al.* describe for the first time the hip-spine syndrome, defining it as a syndrome characterized by a concurrent pain symptom of the hip and spine that poses diagnostic difficulties and which can lead to possible incorrect therapeutic treatments [10]. In 2004, Lazennec., *et al.* describe the relationship between hip and spine, considering the acetabular cup anteversion as an essential parameter for the implantation of THA in patients with spinal sagittal anomalies and with marked reduction of movement [9]. Although the hip is a highly mobile joint, today's surgical concepts are based on the static AP vision of the pelvis standing or supine to assess the orientation of the acetabular cup, which is a factor to be carefully evaluated to avoid complications such as wear, dislocation or conflict of the prosthetic components [11]. The transverse orientation of the acetabulum is expressed by its anterior or anteversion opening angle.

For the positioning of the acetabular cup, a position with 40 ± 10° inclination and 15 ± 10° of anteversion is considered as a safe zone by Lewinnek., *et al.* [6] Incorrect positioning of the acetabular cup is an important cause of post-operative complications such as component displacement, accelerated wear of materials, implant impingement and reduction of joint ROM [11]. Several studies have quantified the impact of pelvic tilt on acetabular anteversion, establishing that at each grade of the increasing pelvic tilt, there is an approximate increase in acetabular anteversion of 0.7° [5,13].

Hip osteoarthritis, which has a high incidence in old age, is the most common cause for hip replacement. Osteoarthritis is a systemic disease that in old age often affects both spine and hip simultaneously. The resulting degenerative changes alter walking and spino-pelvic alignment [5].

The measurement of the ratios and orientation of the pelvis is a subject of great debate in reconstructive orthopaedic surgery, in particular for the orientation of the pelvis on the horizontal and sagittal planes respect to the spine. This is determined by the physiological curvature of the spine and the relationship between the spine and pelvis and can be measured from the vertical sagittal axis (sagittal vertical axis - SVA), a parameter introduced in 1994 by Jackson., *et al*. SVA is defined as the horizontal distance between the plumb line falling from the vertebral body of C7 to the postero-superior angle of the sacral plate, a value lower than 50 mm ± 2.5 cm is considered physiological, beyond this value, the condition of sagittal imbalance is configured [14-16]. Sagittal balance is the manifestation of posture and can differ greatly from one person to another [4]. The musculoskeletal system implements spinal-pelvic compensatory response mechanisms to change the segmental, regional or global structure of the spine along with the high mobility of the hip joint. One of the most efficient mechanisms to reduce sagittal imbalance is through pelvic retroversion ("pelvic rotation or backward fall"). The pelvic retroversion increases the value of the pelvic tilt (PT). Various pathological conditions of the spine, such as spondyloarthrosis, osteoporotic intervertebral collapses, disc degeneration, lead to a reduction in the physiological lumbar lordosis, with a consequent retroversion of the pelvis as a compensation mechanism, followed by the extension of the coxofemoral joints and knee flexion [15]. Lamartina and Berjano describe eight compensatory mechanisms related to eight deformity models [3].

The variation of the PT influences the acetabular cup anteversion [4] and a detailed analysis of the individual sagittal equilibrium allows a precise evaluation of the sagittal balance and of the pelvic orientation, which influencing the orientation of the acetabular cup allows its preventive regulation or potential for cup positioning [13].

SFP angle is a reliable measurement to study pelvic orientation in AP pelvis X-ray view in standing position and our study confirms it [17]. The analysis of postoperative SFP angles has shown that it increases of a mean value of 5° compared to the preoperative and at the 6 months follow-up it decrease to the preoperative values.

SFP angle is a stable parameter, which is maintained after THA. However, increases in SFP angle postoperatively can be caused by the altered pelvis X-ray acquisition obtained in the supine position, instead of the standard standing position. Other causes of viewing alteration, that have been prevented in our study, can be an erroneous positioning of the patients during X-ray examination caused by

pain or muscular contracture in postoperative. The decrease of SFP angle measured at 6 months follow-up can be explained by the pelvis X-ray view obtained in standard standing position and by a return to the previous balance due to the recovery of gait and the ending of rehabilitation period. PT obtained with Blondel's formula [7] from the values of SFP preoperative, postoperative and at 6 months follow-up, was always less than 20°. According to Schwab., *et al.* [18], a value of PT inferior than 20° should be the goal to be reached in the corrective surgery of the spinal sagittal alignment to reduce back pain. The results of PT in our study have shown that THA surgery does not increase PT beyond values that could be index of spine disorders. This confirm that THA surgery does not deteriorate the spinopelvic balance but rather can provide to improve global spinal balance [19].

Linear correlation, multiple regression and Student's *t*-test have shown that there is no statistical significant correlation between ACA and SFP angles at 6 months follow-up. This reflect the limitation of the study, which is a retrospective analysis and it shows the results of THA surgery without evaluation of SFP angle on preoperative planning; that anyway does not change clinical outcome after THA in primary hip OA patients.

SFP angle is a useful tool to predict ACA and global pelvic orientation in THA preoperative planning and its variation in the follow up could be an index of a failed THA or acetabular malposition. This should be evaluated in further studies in larger cohorts. Lack of relationship between ACA and SFP angle can be justified by the inter-individual changes in pelvic bones morphology [20] and by the limitations of retrospective study. The evaluation of spino-pelvic alignment before THA could be a useful preoperative screening especially in the lateral decubitus on the surgical table during posterior-lateral approaches to the hip joint, because in this position the pelvis can have a tilt of different degrees with possible malposition of the acetabular cup [21]. Recent works have emphasized the relation between pelvic orientation and acetabular cup positioning and several methods have been described to study this relation (obturator foramen ratio-OF [22], anterior pelvic plane-APP [23], transverse pelvic plane-TPP [24]). Therefore, it could be useful to have a lateral pelvis and lumbar spine X-ray view in patients with simultaneous hip OA and spine disorders to have a better preoperative THA planning. SFP angle is a constant parameter that is maintained after good positioning of THA components, so this procedure does not affect spino-pelvic alignment in patients without spine disorders. It could be helpful to have a lateral X-ray view of pelvis and lumbar spine in THA preoperative planning in patients with low back pain and spine disorders [25].

Surgeons of the hip focus mainly on the anterior-posterior X-ray view of the pelvis to plan THA, while ante/retro-version of the pelvis is often underestimated. Cup orientation in THA is crucial for well-functioning hip replacement and X-ray SFP angle evaluate relationship between acetabulum and pelvic tilt on an anterior-posterior view. The study of associations between SFP angle and acetabular cup anteversion in patients affected by spine disorders and simultaneous hip OA can provide further data to improve THA preoperative planning, especially in acetabular cup placement. SFP could be a useful parameter to evaluate the relation between THA and PT, avoiding the use of lateral X-ray view.

Conclusion

SFP and ACA are measurable on pelvis AP X-ray view. In our study we have not found relation among clinical result and SFP measurements. SFP is a stable angle before and after THA. Relationship between SFP and ACA must be considered especially when osteoarthritis of the hip and disorders of the spine coexist in the same patient. To improve THA preoperative planning and acetabular cup placement further evaluation of the sagittal plane has to be examined.

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