Influence of Spinal Fusion on Acetabular Implant Orientation

Pablo D. López, Luis D. E. Orosco Falcone, Santiago L. Iglesias, Ignacio J. Pioli, José M. Gómez, Bartolomé L. Allende
Orthopedics and Traumatology Service, Sanatorio Allende, Córdoba, Argentina

ABSTRACT

Introduction: Degenerative diseases of the hip and spine are common causes of disability and pain, and the symptoms usually overlap. When a parameter is altered, another one should be modified to avoid femoroacetabular impingement and a potential dislocation. It is believed that lumbar fixation would affect the adaptation of the spinopelvic unit in different postures. This article aims to analyze the spinopelvic behavior in patients with Total Hip Arthroplasty (THA) and lumbar arthrodesis. **Materials and Methods:** A non-randomized retrospective study of cases and controls was carried out in patients with THA, who were assessed using anterior and lateral X-ray views in functional sitting and standing postures, divided into two groups depending on the presence or absence of lumbar arthrodesis. Spinopelvic parameters as well as femoroacetabular parameters were measured. **Results:** A sample of 50 patients was selected, 25 in each group. In total, 15 patients had bilateral THA, and the most common level of lumbar fixation was L5-S1. There was no statistically significant difference in gender and age between both groups. Lumbar arthrodesis patients required more hip flexion to sit, without being associated with a significant increase in the rate of dislocation. **Conclusion:** The ideal composition of the components is still difficult to achieve. The review of the "safe zones" of the components has started to depart from the values of the body plane proposed by Lewinnek. A new approach has been proposed to the safe zones of the sagittal plane, which are more appropriate and accurate in selected patients with severe spinopelvic pathology.

Keywords: Spinopelvic mobility; dislocation; lumbar fixation.
Level of Evidence: III

Influencia de la fusión espinal en la orientación del implante acetabular

RESUMEN

Introducción: Las enfermedades degenerativas de la cadera y la columna vertebral son causas comunes de discapacidad y dolor y los síntomas suelen superponerse. Cuando algún parámetro se altera, otro debe modificarse para evitar el choque femoroacetabular y una posible luxación. Se piensa que la fijación lumbar afectaría la adaptación de la unidad espino-pélvica en las diferentes posturas. El objetivo de este estudio fue analizar el comportamiento espino-pélvico en pacientes con artroplastia total de cadera y artrodesis lumbar. **Materiales y Métodos:** Se realizó un estudio no aleatorizado, retrospectivo, de casos y controles en pacientes con artroplastia total de cadera evaluados con radiografía lumbopélvica de frente y de perfil en posición erecta y en sedestación, divididos en dos grupos: con artrodesis lumbar o sin ella. Se midieron parámetros espino-pélvicos y femoroacetabulares. **Resultados:** La muestra tenía 50 pacientes: 25 en cada grupo. Quince tenían artroplastia total de cadera bilateral y el nivel de fijación lumbar más frecuente era L5-S1. No hubo diferencia estadísticamente significativa en la edad y el sexo entre ambos grupos. Los pacientes con artrodesis lumbar necesitaron más flexión de cadera para sentarse, sin un aumento significativo asociado en la tasa de luxación. **Conclusiones:** La composición ideal de los componentes aún es difícil de alcanzar. La reconsideración de las "zonas seguras" de los componentes ha comenzado a alejarse de los valores del plano coronal de Lewinnek. Se ha propuesto un nuevo enfoque en las zonas seguras del plano sagital más apropiadas y precisas en pacientes seleccionados con enfermedad espino-pélvica grave.

Palabras clave: Movilidad espino-pélvica; luxación, fijación lumbar.
Nivel de Evidencia: III

Received in January 16th, 2021. Accepted after evaluation on April 28th, 2021 • Dr. PABLO D. LÓPEZ • pablopez1292@gmail.com ID https://orcid.org/0000-0001-9722-1317

How to cite this article: López PD, Orosco Falcone LDE, Iglesias SL, Pioli IJ, Gómez JM, Allende BL. Influence of Spinal Fusion on Acetabular Implant Orientation. *Rev Asoc Argent Ortop Traumatol* 2021;86(4):463-474. https://doi.org/10.15417/issn.1852-7434.2021.86.4.1302

INTRODUCTION

Degenerative diseases of the hip and spine are common causes of disability and pain. The diagnosis and treatment of conditions related to the hip and spine are challenging due to the overlap of symptoms. Total hip arthroplasty (THA) and lumbar spine fusion can effectively relieve pain and improve function in appropriately selected patients with a degenerative condition, and as a result, the volumes of these operations are increasing. It is not uncommon to combine spinal fusion and THA.[1-3]

In THA, precise placement of the acetabular cup is essential to achieve a free and stable range of motion. For decades, orthopedic surgeons have relied on the "safe zone" for acetabular implant placement, described by Lewinnek et al. (40 ° ± 10 ° of inclination and 15 ° ± 10 ° of anteversion)[4] to reduce the instability of the prosthesis. However, this concept is currently changing due to new knowledge of the role that the spinopelvic unit plays in acetabular orientation.[5] Additionally, acetabular orientation is a dynamic parameter that can be affected by forces that can originate from the top of the hip joint (e.g., change in spinal alignment), at the hip (e.g., muscle weakness or advanced hip degeneration), or below the hip (e.g., a discrepancy between the extremities).[6]

Recent studies found a high dislocation rate for prostheses that were within Lewinnek's "safe zone," suggesting that other factors may play a role in hip instability.[5,7]

Spinal fusion can alter the adaptation of the spinopelvic junction and can result in anteversion and a less than optimal acetabular implant tilt when sitting and standing as well as dislocation or subluxation.[8]

Spinopelvic motion

Each person is characterized by a "morphological" parameter: the pelvic incidence angle (PI), schematically showing the pelvic thickness. The adaptation of other functional factors, such as pelvic tilt (PT) and spinal parameters (sacral slope [SS], lumbar lordosis [LL], and thoracic kyphosis) allows the center of gravity of the trunk to be positioned specifically to be supported by the femoral heads of the pelvic base, to maintain balance with only minimal muscle effort. Mathematically, all the pelvic parameters are united by the following formula: PI = PT + SS.

The pelvis moves, rotating around the bicoxofemoral axis, leading to the anterior tilt (where the upper portion of the pelvis tips forward) and the posterior tilt (the upper portion of the pelvis tips backward). The variations in the angles of the sacral slope determine the range of this PT.[9]

The standing position corresponds to a forward tilt of the pelvis as a whole. In this situation, the upper endplate of S1, viewed laterally, makes an angle of approximately 35 ° to 45 ° with the horizontal.[9-11] Some subjects have a small SS angle in standing position: we talk then about posterior PT (or pelvic retroversion or pelvic extension) and the sacrum seen on a lateral image appears more vertical than usual. In contrast, other subjects have a very horizontal sacrum in the standing position with a SS angle sometimes much greater than 50° (anterior PT, pelvic anteversion, or pelvic flexion).

In a sitting position, the phenomenon is inversed. The pelvis tilts back as it moves toward a sitting position. The SS diminishes to average values of 20 ° to 25 °.9,10,12 This slope may be slightly positive (5 ° -10 °) or even negative. As a function of the height of the seat, the individual's morphology, or any associated spinal disease, we observe the posterior pelvic tilt (pelvic retroversion or pelvic extension) more or less accentuated with a more or less vertical sacrum.

This is particularly confusing for arthroplasty surgeons who are generally concerned with retroversion in relation to the acetabular cup, which is the opposite movement. For example, with posterior PT or pelvic retroversion, the functional position of the acetabular cup becomes more anteverse.

These modifications in spinopelvic parameters lead to changes in acetabular orientation (acetabular inclination [AI] and acetabular anteversion [AA]). The combined value of these two measurements of acetabular orientation is the anteinclination angle (AIA). In the standing position, the SS value is high and the AA angle value is low. Conversely, in the sitting position, SS decreases and AA increases. Radiographically, in both anteroposterior and lateral positions, the acetabular implant appears more vertical in the sitting position than in the standing position.

For every 1° of posterior PT, the functional AA increases 0.7 ° -0.8 °. The change in functional AI is less significant and nonlinear, depending on the degree of PT. In general, a more posterior PT will appear more like an outlet view, while a more anterior PT will appear more like an inlet view on the anteroposterior pelvic radiograph.

This study aimed to analyze the behavior of THA in patients with and without lumbar arthrodesis.

MATERIALS AND METHODS

We carried out a non-randomized, retrospective, case-control study of patients with THA who were evaluated with anteroposterior and lateral radiographs in a functional standing and sitting position.

The study was carried out jointly with the professionals of the Diagnostic Imaging Service, who were given a protocol explaining the inclusion and exclusion criteria, and the regulations for obtaining radiographs.

In the radiographs, both femoral heads or prostheses with the proximal third of the femur, pubic symphysis in profile, and spine from the endplate of L1 to the endplate of S1 should be clearly visualized.

Patients from our Department of Orthopedics and Traumatology who had undergone a THA were included. Health records were obtained to classify them into two groups, according to whether or not they had spinal pathology: group A (THA plus lumbar fixation) and group B or control (THA without lumbar fixation).

The spinopelvic parameters (LL, PT, PI, SS), the anterior pelvic plane (APP), and the femoroacetabular parameters (AIA, pelvic femoral angle [PFA]) were measured. Measurements were made in standing and sitting positions using the SurgiMap[13] program for Windows (Figures 1 and 2).

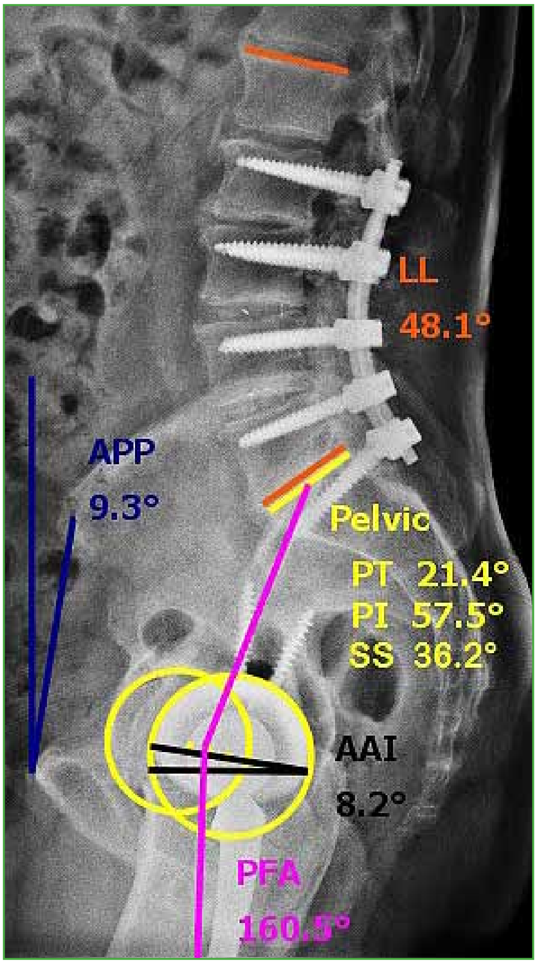

Figure 1. Standing measurement of a patient with four-level spinal fusion.
I = Pelvic Incidence, PT = pelvic tilt, SS = sacral tilt, LL = lumbar lordosis,
AAI = acetabular anteinclination, PFA = pelvic femoral angle,
APP = anterior pelvic plane.

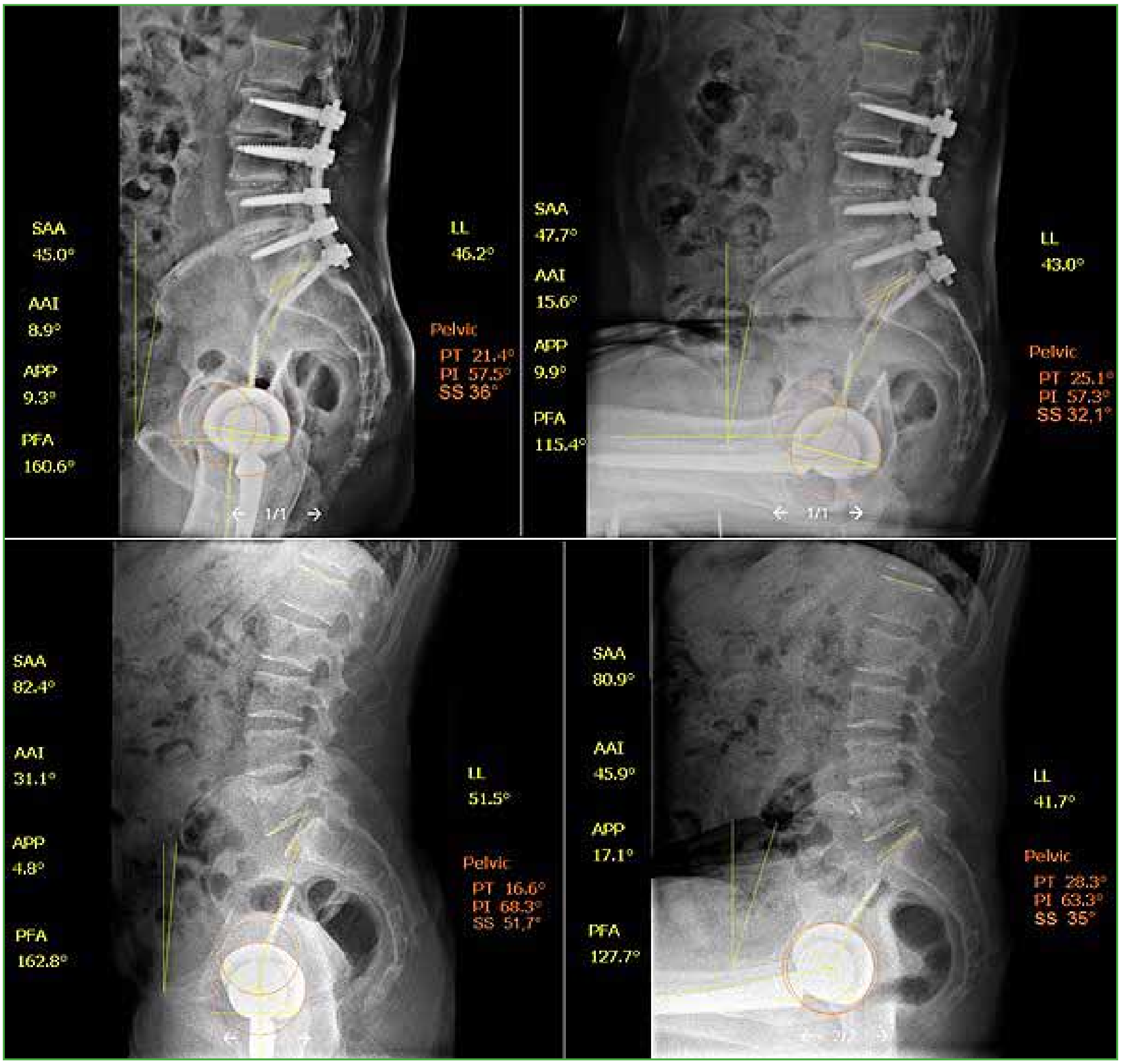

Figure 2. Measurements made to patients in group A (upper image) and group B (lower image).

PI is the angle formed between a line connecting the center of the femoral head to the midpoint on the endplate of S1 and a second line perpendicular to this last point.

PT is the angle obtained between a line that connects the center of the femoral head to a midpoint located on the endplate of S1 and a second vertical reference line at 0 °.

SS is an angle formed between a line drawn parallel to the axis of the endplate of S1 and a second horizontal reference line at 0 °.

APP represents the PT measured laterally as the angle formed by two lines, one from the pubic symphysis to the anterior superior iliac spine and the other vertical at 0 ° from the pubic symphysis.

LL is the degree of lordosis of the lumbar spine measured from the L1 endplate to the S1 endplate.

AIA is measured laterally with a line connecting the acetabular border from the most anterior to the most posterior portion with another reference line at 0 °.

PFA is the angle that represents the flexion of the hip and is measured with a line that connects the center of the femoral head with the femoral shaft and another line from the center of the femoral head towards the midpoint of the S1 endplate.

Statistical analysis

A global descriptive analysis was performed using summary measures and exploratory graphs for each characteristic and in a bivariate manner. To study the relationship between qualitative variables, Pearson's chi-square test was used.

To study the differences between groups of quantitative variables, Student's t-test was used for independent samples. Finally, the SPSS program v.22 for Windows was used for the statistical analyses, and the Excel program to prepare the graphs and tables. The level of significance used in all cases was 0.05.

Ethical aspects

All patients gave verbal and written informed consent to participate in the study. The research protocol was approved by the Institutional Ethics Committee and complies with the Declaration of Helsinki and the Declaration of Good Clinical Practices of ANMAT. It also complies with the Province of Córdoba Act No. 9694 and the Argentine National Act for the Protection of Personal Data No. 25,326.

FINDINGS

A sample of 50 patients was obtained, 25 for each group. In group A, 68% were women, with an average age (standard deviation) of 70 years (9.62) between both sexes. Group B consisted of 56% women, with an average age (standard deviation) of 68 years (11.03) between both sexes. There was no statistically significant difference between the two groups regarding age ($p = 0.566$) and sex ($p = 0.297$).

Eight patients in group A and seven in group B had bilateral THA (15 patients in total [80% women]).

In group A, the most frequent level of lumbar fixation was L5-S1 (7 patients, 28%) (Table 1).

Table 1. Frequency of arthrodesis levels in group A*

Arthrodesis	Absolute frequency	Total	Quotient	Relative frequency	%
L5-S1	7	25	7/25	0.28	28%
L3-L4-L5	3	25	3/25	0.12	12%
L4-L5-S1	3	25	3/25	0.12	12%
L2-L5	2	25	2/25	0.08	8%
L4-L5	2	25	2/25	0.08	8%
L4-S1	2	25	2/25	0.08	8%
L2-S1	1	25	1/25	0.04	4%
L3-L4-L5-S1	1	25	1/25	0.04	4%
L3-S1	1	25	1/25	0.04	4%
T10-S1	1	25	1/25	0.04	4%
T2-S1	1	25	1/25	0.04	4%
T6-S1	1	25	1/25	0.04	4%

*The L5-S1 segment is the most frequent.

When calculating the percentages of patients with dislocation, it was higher in the arthrodesis group than in the control group: 12% vs. 4% (Figure 3); however, the difference was not significant.

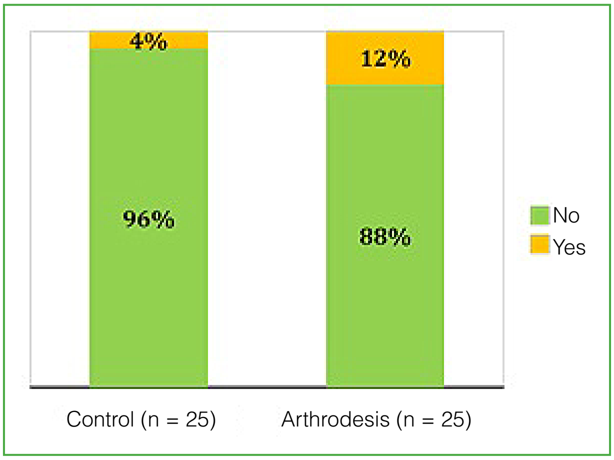

Figure 3. Total hip arthroplasty dislocation according to patient groups ($p = 0.2971$).

Spinopelvic parameters (Table 2)

Control group patients had higher average LL (standing position) and lower average LL (sitting position), but the difference between the groups was not statistically significant ($p > 0.05$). Likewise, they had a lower average PT (standing position), and the difference between the groups was statistically significant ($p = 0.0269$). In contrast, there were no statistically significant differences between the groups concerning PT (sitting position).

Regarding PI, there was a difference in the average between the standing and sitting positions of 1.21 ° in group A and 3 ° in group B, with no statistically significant differences between the two ($p > 0.05$).

Group B patients had a higher average SS (standing position), and the difference between the groups was statistically significant ($p = 0.0002$). The SS was modified, on average, 8.3 ° in patients with lumbar arthrodesis and 20 ° in those without lumbar arthrodesis. This difference in the average between the groups was statistically significant ($p = 0.001$) (Figure 4).

Patients in the group without arthrodesis had a lower average APP in the standing and sitting position, but the difference between the groups was not statistically significant ($p > 0.05$).

Femoroacetabular parameters

Control group patients had a higher average AIA (standing and sitting position), but the difference between the groups was not statistically significant ($p > 0.05$).

The patients with arthrodesis had an average increase of 11 ° in the AIA when going from the standing position to sitting, and in those without lumbar arthrodesis this value increased 17.30 °, without a statistically significant difference (Figure 5).

The patients in the arthrodesis group had a lower average PFA (standing), and the difference between the groups was statistically significant ($p = 0.0049$). In contrast, there were no statistically significant differences between the groups concerning PFA (sitting). When comparing both groups, the patients in the group with lumbar arthrodesis generally flexed their hips 10.50 ° more than those without arthrodesis when moving from the standing position to sitting ($p > 0.05$) (Figure 6).

Table 2. General statistics of the spinopelvic parameters according to the groups.

Variables	Position	Arthrodesis (n = 25)	Control (n=25)	p*
PT	Standing	24.6 ± 10.7	17.8 ± 9.8	**0.0269**
	Sitting	32.0 ± 13.0	35.5 ± 15.4	0.3516
	p **	**0.0001**	**0.0001**	---
PI	Standing	58.7 ± 15.7	64.6 ± 14.0	0.1838
	Sitting	57.5 ± 13.5	61.6 ± 11.8	0.1870
	p **	0.5073	0.0969	---
SS	Standing	34.1 ± 11.7	47.0 ± 10.7	**0.0002**
	Sitting	25.8 ± 10.5	27.0 ± 13.2	0.7196
	p **	**0.0001**	**0.0001**	---
LL	Standing	41.3 ± 17.1	47.4 ± 12.4	0.2142
	Sitting	34.9 ± 14.6	33.7 ± 14.9	0.4668
	p **	**0.0001**	**0.0017**	---
SAA	Standing	68.7 ± 17.2	79.2 ± 14.3	**0.0226**
	Sitting	70.7 ± 15.1	75.7 ± 13.8	0.1806
	p **	0.3872	0.0530	---
AAI	Standing	34.1 ± 12.7	32.7 ± 9.0	0.4550
	Sitting	45.1 ± 11.7	50.0 ± 13.6	0.1936
	p **	**0.0001**	**0.0001**	---
APP	Standing	15.3 ± 33.4	5.4 ± 4.0	0.1402
	Sitting	14.8 ± 10.1	16.4 ± 11.2	0.6836
	p **	0.9408	**0.0001**	---
PFA	Standing	168.4 ± 9.6	159.3 ± 11.2	**0.0049**
	Sitting	131.8 ± 17.0	133.2 ± 17.0	0.6554
	p **	**0.0001**	**0.0001**	---

* T-test for independent samples. ** T-test for paired samples.
PT = pelvic tilt, PI = pelvic incidence, SS = sacral slope, LL = lumbar lordosis, SAA = sacroacetabular angle, AI = ante-inclination angle, APP = anterior pelvic plane , PFA = pelvic femoral angle.

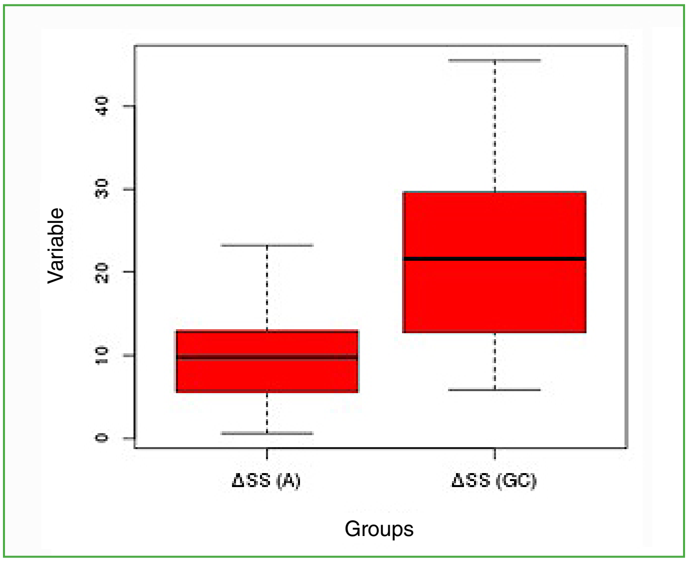

Figure 4. Difference in the average sacral inclination (SS) between the arthrodesis groups (A) and the control group (CG) (statistically significant, p = 0.001).

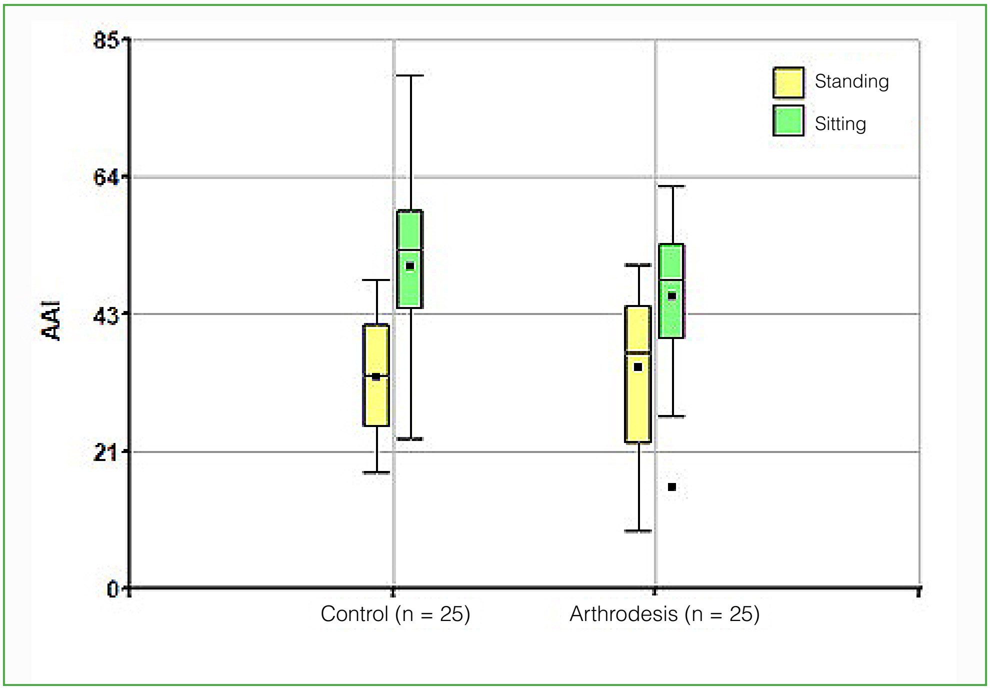

Figure 5. Box plot of the acetabular anteinclination (AI) (standing and sitting) according to patient groups.

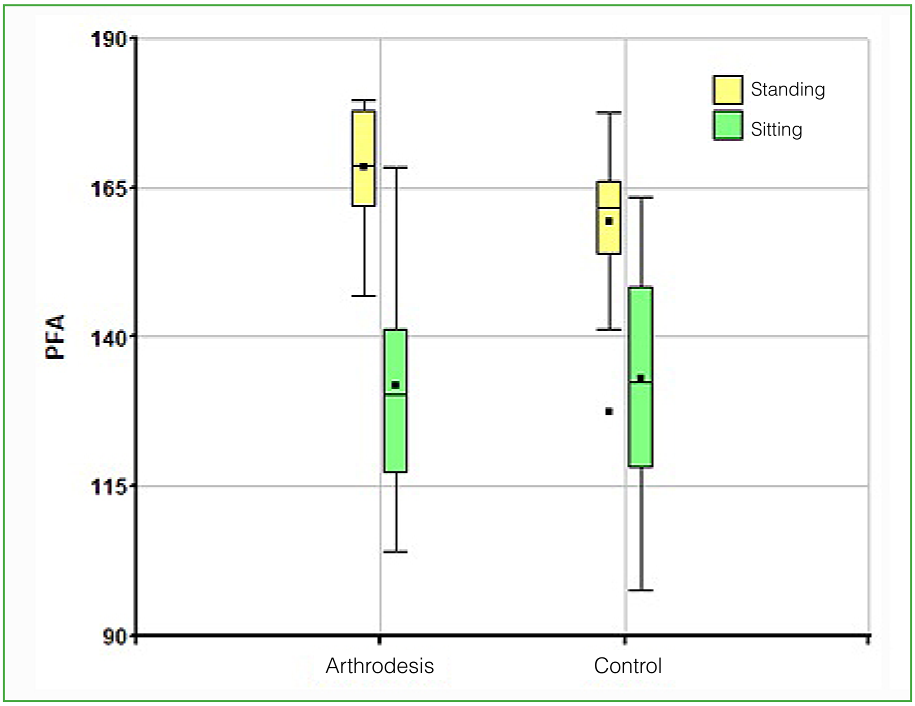

Figure 6. Box plot of the pelvic femoral angle (PFA) (standing and sitting) according to patient groups.

DISCUSSION

Spinopelvic mobility can be confusing. Most surgeons who perform arthroplasties focus on the positioning of the acetabular component according to the static position of the pelvis. However, the functional position should be used instead. This explains the dynamic interplay between the spine, pelvis, and hip. In recent years, research has increased on the influence of spinopelvic mobility and the inclination and anteversion of the acetabular component for THA.[9,10]

Most patients undergoing THA will have normal spinopelvic movement (ΔSS 20 ° -40 ° from standing to sitting) and will not have a clinically significant sagittal imbalance (PT standing ± 10 °). Furthermore, Stefl et al.[14] reported that 16% of patients with preoperative spinopelvic abnormalities recovered normal spinopelvic movement after THA, presumably due to the release of hip flexion contractures. As a result, for most patients, acetabular component placement in the standard coronal plane (Lewinnek's safe zone) has achieved excellent results for many years. Even THAs in patients with minor spinopelvic abnormalities have historically remained free of prosthesis dislocation, because surgeons tend to aim for narrow acetabular inclination and anteversion angles of 30 ° -45 ° and 15 ° -20 °, respectively.[15] However, we must acknowledge that there is a spectrum of instability that includes impingement pain without frank dislocation. For high-risk patients with pathological spinopelvic mobility, several authors have described classification schemes and provided possible solutions.

Dorr et al.[16] classified spinopelvic mobility into three categories based on the difference in SS between standing and sitting. The classification is divided into: normal (20 ° -40 °), hypermobile (> 40 °) and stiff (<20 °). They noted that while normal and hypermobile spinopelvic mobility had almost no risk of impingement and dislocation, rigid spinopelvic mobility had a higher risk of dislocation due to imbalance. In our series, patients with lumbar arthrodesis presented an average of 8.30 ° (stiff) and patients without lumbar arthrodesis, an average of 20 ° (normal).

Stefl et al. and Kanawade et al.[14,17] suggested that normal and hypermobile pelvises tend to tolerate great variability in cup position, shock, and instability due to normal spinopelvic biomechanics. During cup placement, it is recommended to maintain normal surgical technique and implantation of the regular cup safe zone of 15 ° ± 10 ° anteversion and 40 ° ± 10 ° inclination. In turn, they recommended that stiff pelvises, which show <10 ° change in SS between the standing and sitting position, be classified by the acetabular position in which they are found. The standing or anterior tilt position indicates a more horizontal acetabulum and anterior impingement; hence a risk of subsequent dislocation. The sitting or posterior tilt position indicates a possible posterior shock and anterior instability. These classifications help guide the surgeon to the ideal location for the cup implant. These classifications can be useful as general categories, but the degree of sagittal stiffness and imbalance must be determined on a case-by-case basis. Furthermore, as patients age or undergo surgical procedures, they can move from one category to another. Spinal disease is progressive and loss of spinopelvic mobility and sagittal balance may be responsible for late dislocations.

Desired results for cup position in a rigid spinopelvic type are 45 °-50 ° inclination (50 ° in elderly patients and 45 ° in younger patients) and 20 °-25 ° anteversion. A dual mobility prosthesis is considered if a patient's AIA values change <5 ° between sitting and standing, which means that the acetabulum does not adapt to spinopelvic movement and is at risk of dislocation.

A Medicare data review found a 293% increase in lumbar fusion patients undergoing THA over a 12-year period.[18] The prevalence of degenerative lumbar spine disease in patients undergoing primary THA for hip osteoarthritis was approximately 40%.[14] The effect of spinal disease on THA has been largely focused on the risk of dislocation. According to large multicenter studies, postoperative hip instability ranges from 2% to 4%.[19,20] However, contemporary studies focusing on THA in patients with a degenerative spinal disease or a long-segment lumbar fusion have found a risk of dislocation of 8% to 18%.[5,18]

Bedard et al.[21] observed that patients with spinopelvic fusion and THA had a dislocation rate of 20% at their institution and 8.3% in the United States national database. They concluded that this was an alarmingly high rate compared to control rates of 2.9%.

Perfetti et al.[22] noted a seven-fold higher dislocation rate with a previous vertebral fusion, and several authors have reported a positive association with the number of levels fused and the degree of spinal imbalance.[6,23]

Malkani et al.[18] found that lumbar fusion performed within the five years prior to THA was an independent risk factor for dislocation, which corroborates previously published data.[22,23]

There is a possible new set of risks in these patients if lumbar fusion surgery is performed after THA due to posterior PT readjustment, functional acetabular anteversion, and spinal stiffness.

In our series, we had three dislocations in the arthrodesis group (12%) and only one case of prosthesis dislocation in the control group (4%); however, this difference was not significant. There were no statistically significant differences in the parameters measured for this case compared to the rest of the patients in the same group. Therefore, we cannot affirm that this dislocation was due to a spinopelvic or acetabular imbalance.

Dorr et al.[24,25] classified patients with hip dislocations by their underlying etiologies. While most were attributed to an identifiable cause, 17% had no known etiology. This may suggest other risk factors for instability unknown at the time.

As a limitation of this study, we mention the low number of patients and the lack of an adequate radiological method that allows us to reduce the peripheral obliquities of the radiographs by having to maximize the collimator. We believe this can be improved in further studies with better communication between radiologic technologists and physicians.

CONCLUSIONS

Lumbar arthrodesis reduces spinopelvic mobility and, consequently, acetabular adaptation to changes in position; patients with arthrodesis require more hip flexion to sit, without this factor being significantly associated with dislocation of the prosthesis. As our appreciation and understanding progress, we hope to be able to more accurately identify high-risk patients (pathological history of the spine and hip). In turn, less soft tissue damage can also mitigate the risk of instability. Further studies are needed in the future to identify and reduce this proposed sagittal safe zone. However, in some cases of severe pathological movement, dual mobility joint implants may be suggested, particularly in revision surgeries.

Conflict of interests: The authors declare they do not have any conflict of interests.

L. D. E. Orosco Falcone ORCID ID: https://orcid.org/0000-0003-0988-305X
S. L. Iglesias ORCID ID: https://orcid.org/0000-0002-1823-0416
I. J. Pioli ORCID ID: https://orcid.org/0000-0001-8697-1980
J. M. Gómez ORCID ID: https://orcid.org/0000-0002-1162-2708
B. L. Allende ORCID ID: https://orcid.org/0000-0003-2757-4381

REFERENCES

1. Fogel GR, Esses SI. Hip spine syndrome: management of coexisting radiculopathy and arthritis of the lower extremity. *Spine J* 2003;3:238-41. https://doi.org/10.1016/s1529-9430(02)00453-9
2. McNamara MJ, Barrett KG, Christie MJ, Spengler DM. Lumbar spinal stenosis and lower extremity arthroplasty. *J Arthroplasty* 1993;8:273-7. https://doi.org/10.1016/s0883-5403(06)80089-6
3. Saito J, Ohtori S, Kishida S, Nakamura J, Takeshita M, Shigemura T, et al. Difficulty of diagnosing the origin of lower leg pain in patients with both lumbar spinal stenosis and hip joint osteoarthritis. *Spine (Phila Pa 1976)* 2012;37: 2089-93. https://doi.org/10.1097/BRS.0b013e31825d213d
4. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 1978;60:217-20. PMID 641088
5. Abdel MP, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. *Clin Orthop Relat Res* 2016;474:386-91. https://doi.org/10.1007/s11999-015-4432-5
6. Sultan AA, Khlopas A, Piuzzi NS, Chughtai M, Sodhi N, Mont MA. The impact of spino-pelvic alignment on total hip arthroplasty. *J Arthroplasty* 2018;33(5):1606-16. https://doi.org/10.1016/j.arth.2017.11.021
7. Esposito CI, Gladnick BP, Lee YY, Lyman S, Wright TM, Mayman DJ, et al. Cup position alone does not predict risk of dislocation after hip arthroplasty. *J Arthroplasty* 2015;30:109-13. https://doi.org/10.1016/j.arth.2014.07.009
8. Lazennec JY, Clark IC, Folinais D, Tahar IN, Pour AE. What is the impact of a spinal fusion on acetabular implant orientation in functional standing and sitting positions? *J Arthroplasty* 2017;32:3184-90. https://doi.org/10.1016/j.arth.2017.04.051
9. Lazennec JY, Brusson A, Rousseau MA. Hip-spine relations and sagittal balance clinical consequences. *Eur Spine J* 2011;20(Suppl 5):S686-S698. https://doi.org/10.1007/s00586-011-1937-9
10. Lazennec JY, Rousseau MS, Rangel A, Gorin M, Belicourt C, Brusson A, et al. Pelvis and total hip arthroplasty acetabular component orientations in sitting and standing positions: measurements reproductibility with EOS imaging system versus conventional radiographies. *Orthop Traumatol Surg Res* 2011;97(4):373-80. https://doi.org/10.1016/j.otsr.2011.02.006
11. Lazennec JY, Ramaré S, Arafat N, Laudet CG, Gorin M, Roger B, et al. Sagittal alignment in lumbosacral fusion: relations between radiological parameters and pain. *Eur Spine J* 2000;9(1):47-55. https://doi.org/10.1007/s005860050008
12. Lazennec JY, Boyer P, Gorin M, Catonné Y, Rousseau MA. Acetabular anteversion with CT in supine, simulated standing, and sitting positions in a THA patient population. *Clin Orthop Relat Res* 2011;469(4):1103-9. https://doi.org/10.1007/s11999-010-1732-7
13. Lafage R, Ferrero E, Henry JK, Challier V, Diebo B, Liabaud B, et al. Validation of a new computer-assisted tool to measure spino-pelvic parameters. *Spine J* 2015;15(12):2493-502. https://doi.org/10.1016/j.spinee.2015.08.067
14. Stefl M, Lundergan W, Heckmann N, McKnight B, Ike H, Murgai R, et al. Spinopelvic mobility and acetabular component position for total hip arthroplasty. *Bone Joint J* 2017;99-B(1 Suppl A):37e45. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0415.R1
15. Ike H, Dorr LD, Trasolini N, Stefl M, McKnight B, Heckmann N. Spine-pelvis-hip relationship in the functioning of a total hip replacement. *J Bone Joint Surg Am* 2018;100(18):1606-15. https://doi.org/10.2106/JBJS.17.00403
16. Lum ZC, Coury JG, Cohen JL, Dorr LD. The current knowledge on spinopelvic mobility. *J Arthroplasty* 2018;33:291-6. https://doi.org/10.1016/j.arth.2017.08.013
17. Kanawade V, Dorr LD, Wan Z. Predictability of acetabular component angular change with postural shift from standing to sitting position. *J Bone Joint Surg Am* 2014;96:978-86. https://doi.org/10.2106/JBJS.M.00765

18. Malkani AL, Garber AT, Ong KL, Dimar JR, Baykal D, Glassman SD, et al. Total hip arthroplasty in patients with previous lumbar fusion surgery: are there more dislocations and revisions? *J Arthroplasty* 2018;33(4):1189-93. https://doi.org/10.1016/j.arth.2017.10.041
19. Patel PD, Potts A, Froimson MI. The dislocating hip arthroplasty: prevention and treatment. *J Arthroplasty* 2007;22(4 Suppl 1):86-90. https://doi.org/10.1016/j.arth.2006.12.111
20. Delaunay C, Hamadouche M, Girard J, Duhamel A, Group S. What are the causes for failures of primary hip arthroplasties in France? *Clin Orthop Relat Res* 2013;471(12):3863-9. https://doi.org/10.1007/s11999-013-2935-5
21. Bedard NA, Martin CT, Slaven SE, Pugely AJ, Mendoza-Lattes SA, Callaghan JJ. Abnormally high dislocation rates of total hip arthroplasty after spinal deformity surgery. *J Arthroplasty* 2016;31:2884-5. https://doi.org/10.1016/j.arth.2016.07.049
22. Perfetti DC, Schwarzkopf R, Buckland AJ, Paulino CB, Vigdorchik JM. Prosthetic dislocation and revision after primary total hip arthroplasty in lumbar fusion patients: a propensity score matched-pair analysis. *J Arthroplasty* 2017;32(5):1635-40.e1. https://doi.org/10.1016/j.arth.2016.11.029
23. Buckland AJ, Puvanesarajah V, Vigdorchik J, Schwarzkopf R, Jain A, Klineberg EO, et al. Dislocation of a primary total hip arthroplasty is more common in patients with a lumbar spinal fusion. *Bone Joint J* 2017;99-B(5):585-91. https://doi.org/10.1302/0301-620X.99B5.BJJ-2016-0657.R1
24. Dorr LD, Wan Z. Causes of and treatment protocol for instability of total hip replacement. *Clin Orthop Relat Res* 1998;355:144-51. https://doi.org/10.1097/00003086-199810000-00015
25. Dorr LD, Wolf AW, Chandler R, Conaty JP. Classification and treatment of dislocations of total hip arthroplasty. *Clin Orthop Relat Res* 1983;173:151-8. https://doi.org/10.1097/00003086-198303000-00019