DOI: https://doi.org/10.53555/nnmhs.v9i2.1552 Publication URL: https://nnpub.org/index.php/MHS/article/view/1552

THE IMPACT OF LUMBAR SPINE DISEASE ON HIP-SPINE RELATIONSHIP IN TOTAL HIPARTHROPLASTY: A SYSTEMATIC REVIEW

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Abstract

Since 1983, when the hip-spine condition was proposed for the first time, a substantial amount of research has been conducted on the hip-spine connection. Tilt-related lumbar spine disease, commonly known as LSD, has been the focus of much research and is now recognized as an independent risk factor for dislocation, which can lead to an increased likelihood of revision total hip arthroplasty (THA). Due to the inflexible sacroiliac attachments, normal spinopelvic motion consists of the pelvis tilting backwards in a seated posture and forwards in a standing position. In addition, the common lumbar illnesses, such as degenerative disc disease (DDD), degenerative lumbar spondylolisthesis (DSPL), ankylosing spondylitis (AS), and lumbar spinal fusion (LSF), have various spinal-hip-femoral compensatory processes. Even with the appropriate placement of the prosthesis, these mechanisms can contribute to intraoperative complications, such as difficulty in hip implantation and the potential for hip repositioning. For the evaluation of spinopelvic mobility, LSD is a significant element. To achieve a satisfying THA with a low rate of dislocation and wear, the surgeon should pay closer attention to the correlation between lumbar disease and sagittal spinal balance, and then develop treatment strategies based on the patients' risk classifications.

Keyword: *Hip-Spine Relationship; Lumbar Spine Disease; Total Hip Arthroplasty*

INTRODUCTION

When the hip-spine syndrome was first hypothesized in 1983, a significant amount of study has been done in recent years to investigate the link between the hip and the spine.[1] Tilt-related lumbar spine disease, also known as LSD, has been the subject of much research and is now known to be an independent risk factor for dislocation, which can result in an increased chance of undergoing revision total hip arthroplasty (THA). Because of the rigid sacroiliac attachments, normal spinopelvic motion involves the pelvis tilting backwards when the individual is in a seated position and forwards when the individual is in a standing position.[2,3]

This directly translates to changes in the lumbar spine curvature and the biological opening of the acetabulum. The increased posterior pelvic tilt that occurs when a person is seated helps prevent anterior impingement and posterior hip dislocation. This is accomplished by providing clearance for a flexed and internally rotated femur, which is made possible by opening the acetabulum. Anterior pelvic tilt in a standing position extends the superior covering of the acetabulum, which helps prevent posterior impingement as well as anterior hip dislocations.[4,5]

Loss of sacroiliac joint mobility, which occurs when LSD develops, causes an increase in hip flexion while the patient is seated and an increase in hip extension while the patient is in a standing posture. This can cause pathologic impingement of bones or components. It is difficult for us, in practice, to address THA patients who also have this disease by recommending an appropriately positioned prosthesis. This is because of the different postural positions on the operating table, related technical issues, and the presence of a fixed pelvic tilt or pelvic tilt.[5–7]

Also, the common lumbar diseases, such as degenerative disc disease (DDD), degenerative lumbar spondylolisthesis (DSPL), ankylosing spondylitis (AS), and lumbar spinal fusion (LSF), have different compensatory spinal-hip-femoral mechanisms. These mechanisms can lead to intraoperative difficulties, even with the optimal placement of the prosthesis, such as difficulty in hip placement and the possibility of hip repositioning. Unfortunately, a significant number of hip surgeons are unaware of the fact that the influence of various lumbar disorders on the interaction between the hip and the spine is extremely distinct.[8–11]

This is one of the reasons why the risk of wear and dislocation after THA surgery is so much higher. There is currently no broad agreement among medical professionals regarding the connection between particular spinal disorders and the pelvis, and there is no all-encompassing analysis available in the relevant scientific literature.[12] In total hip arthroplasty, the purpose of this paper was to investigate the effect that lumbar spine pathology has on the interaction between the hip and the spine.

METHODS Protocol

We made this article using the principles of Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020. We did this so that the research we received later to include in this article is accurate and reliable.

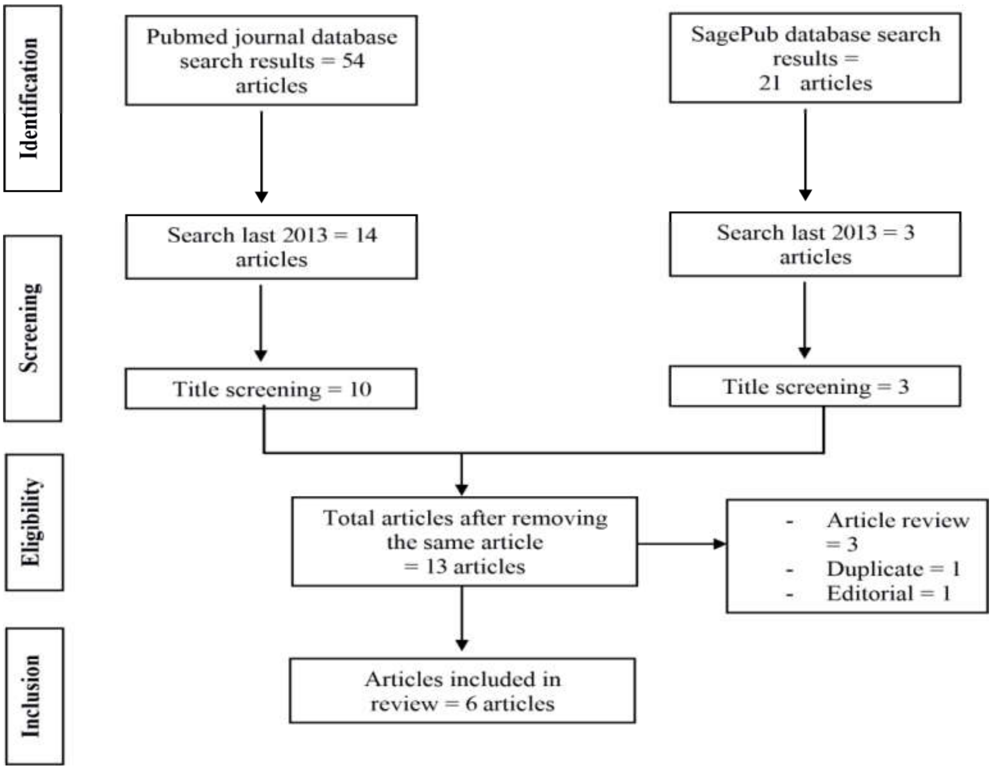

Figure 1. Article search flowchart

Search Strategy

We use “lumbar spine disease” and “hip-spine relationship”. The search for studies to be included in the systematic review was carried out from February, 16th 2023 using the PubMed and SagePub databases by inputting the words: ("lumbar vertebrae"[MeSH Terms] OR ("lumbar"[All Fields] AND "vertebrae"[All Fields]) OR "lumbar vertebrae"[All Fields] OR ("lumbar"[All Fields] AND "spine"[All Fields]) OR "lumbar spine"[All Fields]) AND ("disease"[MeSH Terms] OR "disease"[All Fields] OR "diseases"[All Fields] OR "disease s"[All Fields] OR "diseased"[All Fields]) AND "hip-spine"[All Fields] AND ("relationship"[All Fields] OR "relationships"[All Fields]) is used as search keywords.

Criteria for Eligibility

The aim of this literature review was to investigate and analyze the findings of previous studies addressing the impact of lumbar spine disease on the hip spine relationship in total hip arthroplasty. Ongoing literature review has revealed significant problems that must be addressed in order to make recommendations for therapy.

Research included in this article must meet one or more of the following requirements: 1) the publication submitted must be written in English and address the impact of lumbar spine disease on hip spine relationships in total hip arthroplasty. 2) This analysis includes articles published after 2015, but before the time period considered in this systematic review. Editorials, submissions without DOI, previously published review articles, and entries that are substantially identical to those that have been published in journals are some of the studies we excluded in this study.

Data retrieval

Following an examination of the titles and abstracts of a number of additional studies, the authors came to the conclusion that the inclusion criteria needed to be modified. Specifics regarding the recently defined criteria are included as part of the additional resources for study. This demonstrates how big and complicated the issue is, pointing to the necessity of conducting deeper research on the subject. This result was reached after looking at a large number of research that were all structured in the same way.

In the systematic review, only those papers that were considered limited met all inclusion criteria. This makes it easier to target specific items that matter. Our research team does not accept research suggestions because they do not meet the standards we have set. As a result, it is certain that the probe will be completed. During this investigation, we found many items including name, author, publication date, location, study activity, and parameters. We selected them in order to provide evidence regarding the impact of lumosacral disease on hip spine syndrome after undergoing THA.

Quality Assessment and Data Synthesis

Each author independently reviews the research studies offered in the title and abstract of the paper before making a decision on which article to analyze. After that, we will look at all papers that have the potential to be included in a systematic review. Articles to be evaluated will be selected based on the findings we made. This is how the posts to be reviewed are pre-selected. Contribute to making it easier to rate various articles. Which previous studies can be included in the review, and how can this be done?

RESULT

Stefl, et al (2017)[13] showed the ante-inclination and sacral acetabular angles of 133 hips (83.1% of total) were found to be within the normal range following surgery. A total of seven hips, which represented 4.4% of the sample, exhibited pathological imbalance and were either organically or surgically fused. In total, the potentially hazardous spinal imbalance that existed prior to surgery was corrected in 23 out of 24 hips. The patients at most risk are those with a biological or surgical spinal fusion; patients with a severe spinal imbalance can be kept safe with the precise positioning of the acetabular component.

Shen, et al (2021)[14] showed patients with degenerative lumbar spondylolisthesis (DSPL) had significantly increased preoperative pelvic tilt (24° in DSPL vs. 8° in controls; $p < 0.01$), pelvic-femoral angle (194° in DSPL vs. 174° in controls; $p < 0.05$), decreased lumbar lordosis (35° in DSPL vs. 43° in controls; $p < 0.05$), increased postoperative pelvic tilt (22° in DSPL vs. 7° in controls; $p < 0.01$), pelvic-femoral angle (187° in DSPL vs. 179° in controls; $p < 0.05$), and acetabular anteversion (31° in DSPL vs. 23° in controls; $p < 0.05$). There were positive correlations between preoperative standing pelvic tilt and postoperative standing acetabular anteversion, pelvic-femoral angle, and combined sagittal index (CSI) in DSPL (R2 = 0.8416; R2 = 0.9180; R2 = 0.9459, respectively, $p < 0.01$) and in controls (R2 = 0.6872; R2 = 0.6176; R2 = 0.7129, respectively, $p < 0.01$).

Hu, et al (2017)[15] showed sagittal vertical axis, global kyphosis, and pelvic tilt were corrected after lumbar PSO from 15.7 ± 6.7 cm, 66.8° ± 17.5°, and 38.6° ± 9.0° to 2.9 ± 4.9 cm, 21.3° ± 8.2°, and 23.2° ± 8.2°, respectively ($p < 0.001$). Of note, acetabular abduction and anteversion decreased from 59.6° ± 4.6° to 31.4° ± 6.5° before surgery to 51.4° ± 6.5° and 20.2° ± 4.4° after surgery, respectively ($p < 0.001$). Moreover, the changes in acetabular abduction and anteversion were observed significantly correlated with the change in pelvic tilt ($r = 0.527$, $p = 0.002$; $r = 0.586$, $p < 0.001$).

Table 1. The litelature include in this study

Author	Origin	Method	Sample Size	Result
Stefl, 2017[13]	United State of America	Retrospective study	160 hips (151 patients)	Following surgery, the anteinclination and sacral acetabular angles of 133 hips (83.1% of total) were found to be within the normal range. A total of seven hips, which represented 4.4% of the sample, exhibited pathological imbalance and were either organically or surgically fused. In total, the potentially hazardous spinal imbalance that existed prior to surgery was corrected in 23 out of 24 hips.
Shen, 2021[14]	China	Retrospective study	91patients who underwent primary THA	While the imbalance of seated sagittal plane is typically small and compensable, the process by which DSPL patients acquire a standing posture differs from that of control patients, with more hip extension and pelvic posterior tilt. Therisk ofimpingement produced by the increase in acetabular anteversion in the postoperative standing position should be given special consideration.
Hu, 2017[15]	China	Cross sectional	33consecutive ankylosing spondylitis (AS)	After lumbar PSO, sagittal vertical axis, global kyphosis, and pelvic tilt were corrected from 15.7 ± 6.7 cm, 66.8° ± 17.5°, and 38.6° ± 9.0° to 2.9 ± 4.9 cm, 21.3° ± 8.2°, and 23.2° ± 8.2°, respectively (p < 0.001). Of note, acetabular abduction and anteversion decreased from 59.6° ± 4.6° to 31.4° ± 6.5° before surgery to 51.4° ± 6.5° and 20.2° ± 4.4° after surgery, respectively (p< 0.001). Moreover, the changes in acetabular abduction and anteversion were observed significantly correlated with the change in pelvic tilt (r = 0.527, p = 0.002; r = 0.586, p < 0.001).
Zheng, 2014[16]	China	Retrospective study	22 patients	The mean duration of follow-up was 3.5 years (2 to 9). The spinal sagittal Cobb angle of the vertebral osteotomy segment was corrected from a pre-operative kyphosis angle of 32.4 (SD 15.5°) to a post-operative lordosis 29.6 (SD 11.2°) (p <0.01). Significant improvements in pain, function and range of movement were observed following THR.
Ranawat, 2016[17]	USA	Cross sectional	68 patients	The mean standing and sitting SPTA was 3.7° anterior tilt and 17.7° posterior tilt (change of 21.4 ± 12.5°). 75% had flexible pelvises, all of which tilted posteriorly from standing to sitting. One fixed pelvis patient (1.4%) lost posterior tilt from standing to sitting. The mean change in SPTA from standing to sitting in the fixed and flexible pelvis groups was 5.9 ± 3.5° to 26.7 ± 9.6° of posterior tilt (P < 0.05).
Blizzard, 2017[18]	USA	Cross sectional	144 patients	The 4 lumbar disorders had greater risk ratios for prosthetic hip dislocation, revision THA, periprosthetic fracture, and infection than controls at all times. At 90 days, lumbosacral spondylosis had 1.59 complication risk ratios, disk herniation 1.62, spondylolisthesis 1.65, and degenerative disk disease 1.53. At 2 years, lumbosacral spondylosis had 1.66 complication risk ratios, disk herniation 1.73, spondylolisthesis 1.65, and degenerative disk disease 1.59. At 2 years, prosthetic hip dislocation was the most prevalent complication in all 4 spinal illness cohorts, with risk ratios from 1.76 to 2.00.

Zheng, et al (2014)[16] The mean duration of follow-up was 3.5 years (2 to 9). The spinal sagittal Cobb angle of the vertebral osteotomy segment was corrected from a preoperative kyphosis angle of 32.4 ± 15.5° to a post-operative lordosis 29.6 ± 11.2° (p <0.01. Following THR, significant improvements in pain, function, and range of motion were observed. In group 2, two out of six patients presented with an anterior dislocation. The osteotomy of the spine was performed two weeks following the THR. At follow-up, neither group required revision of the hip. Notwithstanding the small sample size of this non-comparative trial, we believe that a spinal osteotomy should be performed prior to a THR, unless the deformity is so severe that the treatment cannot be performed.

Ranawat, et al (2017)[17] showed mean standing SPTA was 3.7° of anterior tilt and the mean sitting SPTA was 17.7° of posterior tilt (change of 21.4 ± 12.5°). Seventy-five percent had flexible pelvises, with all exhibiting a posterior tilt from standing to seated positions. One patient (1.4%) with a fixed pelvis lost posterior tilt from standing to sitting. The mean shift in SPTA from standing to sitting in the fixed and flexible pelvis groups was statistically significant (P <0.05): 5.9 ± 3.5° to 26.7 ± 9.6° of posterior tilt. The sagittal pelvic tilt changed significantly from standing to sitting, particularly in patients with flexible spines, whose functional anteversion increased with sitting.

Blizzard conducted a study with comparison to controls, the risk ratios for prosthetic hip dislocation, revision THA, periprosthetic fracture, and infection were considerably greater for all four lumbar illnesses at all time points. At 90 days, the average complication risk ratios for lumbosacral spondylosis, disk herniation, spondylolisthesis, and degenerative disk disease were 1.59, 1.62, 1.65, and 1.55, respectively. At 2 years, the average complication risk ratios for lumbosacral spondylosis, disk herniation, spondylolisthesis, and degenerative disk disease were 1.66, 1.73, 1.65, and 1.59, respectively. In all four spinal illness cohorts, prosthetic hip dislocation was the most prevalent consequence at 2 years, with risk ratios ranging from 1.76 to 2.00. This study demonstrates a considerable increase in the risk of complications in patients with lumbar spine illness who undergo THA.[18]

DISCUSSION

The number of patients with hip and spine degenerative disorders is growing, as is our understanding of hip-spine interactions. Database research has contributed significantly to understanding the effects of the interplay between the spine and hip joint, particularly as it relates to total hip arthroplasty. When compared to replacement patients without spinal disease, patients with lumbar spinal pathology who undergo subsequent THA are at an increased risk for adverse outcomes such as dislocation, aseptic loosening, fracture, lower patient reported outcome measures, and revision, according to database studies.[19]

Correct component placement is critical for achieving the best results in total hip arthroplasty (THA). To optimize acetabular orientation, the Lewinnek plane has traditionally been referred to as an adequate "safe zone" formed between the anterior superior iliac spines and public tubercles. Recent evidence suggests, however, that the positioning of this plane may vary due to the biomechanical relationship between the lumbar spine and hip. As a result, the intraoperative plane may not accurately recreate the actual functional plane and acetabular orientation encountered outside of the intraoperative setting.

Sagittal spinal balance or imbalance and flexibility or rigidity classify spinopelvic motion into four categories. Due to unconstrained spinopelvic mobility, patients with no prior spinal problems were classed as flexible and balanced (F&B). The rigid and balanced group (R&B) occurs after substantial degeneration or long lumbosacral fusion. Stefl et al. defined such patients as “stuck standing” who have ΔSS≤10°and SS >30°when in both sitting and standing positions.[13] To avoid anterior impingement and posterior displacement, these patients should place the cup more anteverted.[13,14]

Due to postlaminectomy kyphosis and neuromuscular kyphosis or DSPL, flexible and unbalanced patients (F&U) have a higher posterior pelvic tilt while standing, which may cause posterior impingement and anterior dislocation during hip extension. This pathological change is known as kyphotic (SS <5°with undefined mobility) in Stefl et al.’s classification. They consider another flexible type of hypermobility, not induced by kyphosis of the spine, as a variety of normal with higher mobility (ΔSS>30°). Ankylosis or lengthy lumbosacral fusion can be seen in rigid and unbalanced (R&U) patients, as can an unbalanced spine in both the seated and standing positions.[13,14]

Stefl et al.[13] defined such patients as “stuck sitting” who have ΔSS≤10° and SS <30° when in both sitting and standing positions. These patients have a pelvis that is always "trapped" in the posteriorly inclined sitting position, which can cause posterior impingement and anterior dislocation during standing due to femur hyperextension for balance. Due to greater acetabular anteversion, the sitting movement arc will vary less, but the original imbalance may remain impinge. In the final two types of patients, the initial therapeutic option is to surgically change the spinal deformity to stiff and balanced, which has a more predicted dislocation rate.[13,14]

The second possibility is to execute THA with the acetabular component in a posture that is extremely analogous to that of a patient who is in a balanced position. Yet, in the absence of a balanced spine, the patient is still at risk of requiring hip revision surgery.[14] Stefl et al. concluded that severe spinal imbalance increased the danger of impingement and dislocation, even if most spinopelvic abnormalities could be corrected for by cup anteversion and inclination. Pathological spinal imbalance patients have a higher risk of impingement and dislocation, even though most spinopelvic imbalances can be addressed by altering the cup's anteversion and inclination.[13]

In most cases, patients diagnosed with AS also suffer from hip deterioration. Because of this, it is necessary to use a treatment cohort that is homogenous in order to study the connection between the spine and the pelvic region. It has been established that healthy people have an acetabular anteversion of about 20°, but patients with thoracolumbar kyphosis caused by AS have a mean anteversion of 31.4°.[15] AS is distinguished by a spinal deformity known as thoracolumbar kyphosis. As a direct consequence of the aberrant modifications that have taken place, the rigid spinopelvic connections have assumed an upright position.[8,9]

As our population ages, more people will need THA and lumbar spinal fusion (LSF) at the same time as they experience hip and spinal diseases. Recent research has demonstrated that LSF contributes to spine stiffness and is a significant risk factor for dislocation after THA, particularly when lumbar and lumbosacral spinal fusion is involved.[16] LSF reduces standing-to-sitting pelvic tilt, which affects acetabular anteversion. Hence, the pelvis/hip joint is weaker against prosthesis impingement and dislocation. As the spine is decompensated due to limited lumbar mobility, the femur must bend more to sit, increasing prosthetic impingement risk.[20]

Patients who have degenerative disc disease (DDD) have a decreased lumbar spine/hip flexion ratio and increased hip joint flexion while they are seated to compensate for the reduced lumbar flexion. This is a phenomenon that is also seen in patients who have undergone spinal fusion. Moreover, patients with multilevel DDD may experience a reduction in the motion of their lumbar spine as well as a reduction in the variance in pelvic tilt that occurs between standing and sitting. It is important to note that patients who have DDD have a more flexed forward torso and a bigger compensatory pelvic posterior angle while they are standing compared to patients who do not have DDD.[17]

This causes the opening of the acetabular cup to become more spacious as a result. A recent study found that patients who have severe DDD have a higher posterior pelvic tilt during locomotion. This, in turn, results in a greater cup anteversion and inclination than those who did not have severe DDD. In contrast, if the prosthesis is turned inward an excessive amount, the wearer may have a posterior impingement when they are standing. While doing THA on patients with severe DDD, it is important to avoid tilting the head too far forward. This is especially important for patients who have sagittal imbalance.[17]

Many study have found sagittal alignment in degenerative spondylolisthesis patients (DSPL).[21] Current studies indicate that patients with degenerative spine disease have a considerable decrease in lumbar lordosis and sacral slope and a large rise in pelvic tilt.[22,23] As stated previously, lumbosacral pelvic connection alignment is crucial to comprehending the entire spine alignment. The relationships between pelvic incidences, sacral slope, and lumbar lordosis in the sagittal alignment of the spine have been thoroughly demonstrated in the normal population. These spinopelvic characteristics largely explain the pathophysiology of DSPL.[24]

LSD is a significant component that needs to be considered while evaluating spinopelvic mobility. In order to achieve a THA that is satisfactory and has a low rate of dislocation and wear, the surgeon needs to pay closer attention to the connection between lumbar illness and sagittal spinal balance, and then develop treatment regimens according to the risk classifications of the patients.

CONCLUSION

The evaluation of spinopelvic mobility relies heavily on LSD. THAs with low rates of dislocation and wear can be achieved if the surgeon pays more attention to the correlation between lumbar illness and sagittal spinal balance, and then customizes treatment strategies for patients based on their risk levels.

REFERENCE

[1]. Devin CJ, McCullough KA, Morris BJ, Yates AJ, Kang JD. Hip-spine syndrome. JAAOS-Journal Am Acad Orthop Surg. 2012;20(7):434–42.
[2]. Ben-Galim P, Ben-Galim T, Rand N, Haim A, Hipp J, Dekel S, et al. Hip-spine syndrome: the effect of total hip replacement surgery on low back pain in severe osteoarthritis of the hip. Spine (Phila Pa 1976). 2007;32(19):2099–102.
[3]. Redmond JM, Gupta A, Hammarstedt JE, Stake CE, Domb BG. The hip-spine syndrome: how does back pain impact the indications and outcomes of hip arthroscopy? Arthrosc J Arthrosc Relat Surg. 2014;30(7):872–81.
[4]. 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.
[5]. 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(5):585–91.
[6]. Phan D, Bederman SS, Schwarzkopf R. The influence of sagittal spinal deformity on anteversion of the acetabular component in total hip arthroplasty. Bone Joint J.2015;97(8):1017–23.
[7]. Rivière C, Lazennec J-Y, Van Der Straeten C, Auvinet E, Cobb J, MuirheadAllwood S. The influence of spine-hip relations on total hip replacement: a systematic review. Orthop Traumatol Surg Res. 2017;103(4):559–68.
[8]. Tang WM, Chiu KY. Primary total hip arthroplasty in patients with ankylosing spondylitis. J Arthroplasty. 2000;15(1):52–8.
[9]. Tang WM, Chiu KY, Kwan MFY, Ng TP. Sagittal pelvic mal-rotation and positioning of the acetabular component in total hip arthroplasty: three-dimensional computer model analysis. J Orthop Res. 2007;25(6):766–71.
[10]. Bala A, Chona D V, Amanatullah DF, Hu SS, Wood KB, Alamin TF, et al.
[11]. Timing of lumbar spinal fusion affects total hip arthroplasty outcomes. JAAOS Glob Res Rev. 2019;3(11). Esposito CI, Miller TT, Kim HJ, Barlow BT, Wright TM, Padgett DE, et al. Does degenerative lumbar spine disease influence femoroacetabular flexion in patients undergoing total hip arthroplasty? Clin Orthop Relat Res. 2016;474:1788–97.
[12]. Mancino F, Cacciola G, Di Matteo V, Perna A, Proietti L, Greenberg A, et al. Surgical implications of the hip-spine relationship in total hip arthroplasty. Orthop Rev (Pavia). 2020;12(Suppl 1).
[13]. 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(1_Supple_A):37–45.
[14]. Shen K, Lin L, Feng E, Zhang Y, Xiao L, Lin F, et al. Influence of sagittal degenerative spondylolisthesis on anteversion of the acetabular component in total hip arthroplasty. Orthopade. 2021;50(8).
[15]. Hu J, Qian B, Qiu Y, Wang B, Yu Y, Zhu Z-Z, et al. Can acetabular orientation be restored by lumbar pedicle subtraction osteotomy in ankylosing spondylitis patients with thoracolumbar kyphosis? Eur Spine J [Internet]. 2017;26(7):1826–32. Available from: https://doi.org/10.1007/s00586-016-4709-8
[16]. Zheng GQ, Zhang YG, Chen JY, Wang Y. Decision making regarding spinal osteotomy and total hip replacement for ankylosing spondylitis: experience with 28 patients. Bone Joint J. 2014;96(3):360–5.
[17]. Ranawat CS, Ranawat AS, Lipman JD, White PB, Meftah M. Effect of spinal deformity on pelvic orientation from standing to sitting position. J Arthroplasty. 2016;31(6):1222–7.
[18]. J. BD, Z. SC, M. ST, T. PC, R. KM, A. GM, et al. The Impact of Lumbar Spine Disease and Deformity on Total Hip Arthroplasty Outcomes. Orthopedics [Internet]. 2017 May 1;40(3):e520–5. Available from: https://doi.org/10.3928/01477447-20170327-03

[19]. Barry JJ, Hansen EN. The hip-spine relationship and its effect on total hip arthroplasty outcomes: What do the databases show? Semin Arthroplasty[Internet]2018;29(4):290–8.Availablefrom: https://www.sciencedirect.com /science/article/pii/S1045452719300495
[20]. Onggo JR, Nambiar M, Onggo JD, Phan K, Ambikaipalan A, Babazadeh S, et al. Comparable dislocation and revision rates for patients undergoing total hip arthroplasty with subsequent or prior lumbar spinal fusion: a meta-analysis and systematic review. Eur Spine J. 2021;30:63–70.
[21]. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J. 2007;16(9):1459–67.
[22]. Mehta VA, Amin A, Omeis I, Gokaslan ZL, Gottfried ON. Implications of spinopelvic alignment for the spine surgeon. Neurosurgery. 2015;76(suppl_1):S42–56.
[23]. Vaz G, Roussouly P, Berthonnaud E, Dimnet J. Sagittal morphology and equilibrium of pelvis and spine. Eur spine J. 2002;11:80–7.
[24]. Charosky S, Guigui P, Blamoutier A, Roussouly P, Chopin D. Complications and risk factors of primary adult scoliosis surgery: a multicenter study of 306 patients. Spine (Phila Pa 1976). 2012;37(8):693–700.