Narrative Review of the Mechanism of Hip Prosthesis Dislocation and Methods to Reduce the Risk of Dislocation

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Total hip arthroplasty (THA) is one of the most effective surgical procedures. It improves quality of life, increases range of motion, and reduces pain in patients with hip joint degeneration. THA allows patients to return to everyday social and professional activities. Therefore, today it is the best approach to treatment of several chronic conditions affecting the hip joint, including advanced degenerative diseases, avascular necrosis, and some traumatic events. The aim of this study was to present the mechanism of hip prosthesis dislocation, associated risk factors, and the factors reducing the risk of dislocation, as well as its consequences and methods of risk minimization.

Hip dislocation is a common complication following THA. It is responsible for up to 2% to 3% failures of primary replacements, increasing even to 10% in extreme cases of patients highly predisposed to this condition. In most cases, technical errors during implant placement are responsible for the incidence. The measures taken to prevent complications include activities aimed at correct implant insertion and the selection of the most appropriate type of implant for the patient, depending on individual needs.

We summarized the current knowledge of implant dislocation to help surgeons understand the changes in biomechanics of the hip after its replacement and the impact of each particular element that participates in it. This knowledge can enable a surgeon choose the most favorable surgical method and the most appropriate implant to reduce the risk of implant dislocation.

Keywords: Arthroplasty, Replacement, Hip • Hip Dislocation • Hip Joint • Hip Prosthesis

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Background

Total hip arthroplasty (THA) is one of the most effective orthopedic procedures. It relieves pain, restores joint mobility, and improves patient quality of life. It allows patients to return to their everyday social and professional activities. Consequently, today it is the best approach to treat several chronic conditions affecting the hip, including advanced degenerative diseases, avascular necrosis, and some traumatic events [1].

Nevertheless, despite the various unquestionable benefits, THA is not free from complications, with dislocation being among the most frequent, responsible for 1.4% to 5.0% of primary THA. Although much effort has been devoted to dislocation prevention, the percentage of dislocations that leads to adverse sequelae after revision procedures is even higher, reaching up to 25% [2].

Dislocation, whose problem lies within the loss of contact between the prosthetic head and its acetabulum, is due to an extreme position of the joint caused by the impact of excessive mechanical forces on the involved lower limb. It can occur with or without implant loosening, periprosthetic fractures, and infection [1].

The aim of the paper was to summarize the mechanism of hip endoprosthesis dislocation, the risk factors, and the factors preventing it, as well as its consequences and methods of risk minimization.

Mechanisms of Dislocation

Dislocation occurs when forces acting over the implant in a detrimental direction reach amplitudes that overcome those keeping it intact. It usually takes place as a consequence of unintended external forces that act on a limb placed in an unfavorable position. However, it can also be due to excessive, uncoordinated muscle contractions, such as during epileptic seizures [2,3]. Anatomically, the durability of the articular capsule, which is strengthened by several ligaments, namely the iliofemoral, pubofemoral, and ischiofemoral ligaments, and that of the head of the femur, prevent joint dislocation. After arthroplasty, the postoperative scar formed around the joint partly takes over the function of these ligaments. The scar is supported by negative pressure in the joint cavity, imposing suction force of the value proportional to the contact surface between adherent parts of the prosthesis, and the net force of muscles acting on the pelvic girdle that protects implant integrity (Figure 1A, 1B). The implant is far more prone to dislocation than of the joint capsule and the ligaments supporting it. It is especially prone to dislocation shortly after the procedure, when maturation of the scar is not complete [4].

The amplitude of the net force that stabilizes the hip is highest when its vector is parallel to the acetabular axis. Under such conditions, it presses the prosthetic head toward the acetabulum, protecting it from dislocation. However, when it acts at the same angle, it distributes 2 component forces: the first acting parallel, and the second acting perpendicular to it. The first force presses the head against the acetabulum, supporting its stability, whereas the second force promotes dislocation. The amplitude of the second force is proportional to the sine value of this angle.

Anatomical distribution of the femoral muscles indicates that standing on both legs with the thighs abducted and internally rotated generates net force, which acts almost approximately on the acetabular axis, in both the frontal and the sagittal planes. Thus, in this position, dislocation of the prosthesis is unlikely. However, when the hip is flexed and externally rotated, its distal attachments move anteriorly, changing the direction of their vectors. Consequently, the vector of the net force runs obliquely, generating component force that promotes dislocation. Several routinely performed everyday activities involve limb adjustment in positions that provoke dislocation, including forbidden ones. These include sitting in a cross-legged position, deep squats with heels down, high amplitude swings, and external rotations of maximally abducted and flexed hips. Inappropriate alignment of an artificial prosthetic acetabulum, namely inclination above 70°, retroversion, and too deep positioning, relocates its axis, leading to generation of the component force that dislocates the implant. Therefore, even a relatively small muscular contraction can result in dislocation. Additionally, in those cases, skew distribution of forces acting on the acetabulum contributes to faster loosening and tear-off and fragmentation of its polyethylene insert [2].

Positioning of the Acetabulum

Inappropriate positioning of the acetabulum is the most frequent iatrogenic causative factor of dislocation [5-7]. Based on decade-long observations, the parameters of the optimal positioning of the acetabulum have been defined. They include 45±15° inclination, 15±10° antversion, and restoring anatomical axis of the joint by its proper location in terms of depth and height [7]. Deviation by more than 3 mm in height and medialization above 5 mm result in asymmetric distribution of mechanical loads, contributing to dislocation [8]. Thus, too steep inclination above 70° positioning of the acetabulum with too high (above 30°) or too small (less than 10°) antversion are recognized as the causative factors of dislocation; especially, when they are associated with its excessive medialization [9].
Figure 1. (A, B) Schematic presentation of the net force of the main muscle groups (gluteal (1), iliopsoas (2), adductors (3) and represented together piriformis, quadrature femoris, both obturatory and both gemmeli (4)) acting over the proximal femur. Anteroposterior (A) and lateral (B) views.
It is noteworthy that attentiveness to the recommended parameters reduced the incidence of dislocations, loosening of the acetabulum, and acetabular displacement. Therefore, they are generally accepted and widely applied. However, despite their unquestionable usefulness, they do not exclude the risk of dislocation owing to the negative impact of other factors.

**Muscular Disorders Favoring Dislocations**

Muscular imbalance due to muscle dysfunction or inappropriate coordination of the muscle groups affecting the hip results in inappropriate mechanical loads exerted on the prosthesis. Muscular imbalance can be due to changes in muscle length, such as elongation or shortening, as a consequence of altered anatomical positions of muscular attachments, or by muscles being stretched or relaxed, which leads to their relative mechanical insufficiency. Surgical release of muscular attachments can result in their absolute insufficiency, if not healed. Muscular fibrosis and denervation can also impair their function, usually because of excessively brutal or inappropriate surgical techniques [10,11].

Several analyses revealed that the posterior approach to hip replacement requiring release of external rotators and the posterior aspect of joint capsule increases the risk of dislocation in comparison to lateral, anterolateral, and anterior approaches. The meta-analysis comparing over 13 000 primary hip arthroplasties showed that dislocations complicate 3.23% of procedures performed using the posterior approach, but only 0.55% and 2.18% of those performed using the lateral and anterolateral approaches, respectively. Nevertheless, the percentage of dislocations can be decreased to 0.7% after anatomical reconstruction of the posterior capsule and external rotators [12]. In several studies, postoperative reconstruction of the joint capsule reduced the number of dislocations by almost 90% [13,14]. The lateral approach leads to an increased risk of functional weakening of abductors owing to partial detachment of the medial glutal muscle and the greater trochanter, being responsible for 36% of postoperative dislocations [15]. It has been established that dislocation of the greater trochanter above 1 cm is connected with a 6-fold increased risk in prosthesis dislocation [16].

**Inappropriate Positioning of the Stem**

In most cases, inappropriate positioning of the stem leads to an excessive anteversion, too deep placement, or varus deformity [10,17]. Excessive anteversion draws back the axis of the prosthetic neck from the acetabular axis, while a too deep placement weakens the muscles whose proximal and distal attachments converge, and varus deformity can lead to the conflict between the medial aspect of the remaining femoral neck and the lesser trochanter with ischial tuberosity which, forming a 2-sided lever, can dislocate the prosthesis in a forcedly adducted and internally rotated limb.

It has been established that the lowest risk of dislocation occurs when the stem is positioned in 10° to 15° anteversion and at an appropriate depth to support it on the Adam's arch and to restore the calve line [18]. Inappropriate anteversion results in conflict between the stem and the cup and between bony prominences of the pelvis and femur, provoking conflicts that disrupt the balance between elements of the prosthesis and aggravating the risk of its dislocation and loosing. It is far more important in non-cemented prostheses, since the fixation of their acetabula pivots much more on the balance of forces that press it directly into its pelvic lodge. It has been noticed that the anteversion of the stem has to correspond with the anteversion of the acetabulum, summarized by the term “combined anteversion” [19]. This combined anteversion has been primarily assessed with values varying between 25° and 35° in men and up to 45° in women [20], and is currently qualified as 25° to 45° (mean 35°). The easiest way to implant a prosthesis according to those requirements is to implant primarily the stem with required anteversion, compensating the combined anteversion by strictly defined positioning of the acetabulum with computer navigation [21]. Implant setting also entails the risk of complications. Cemented stems have twice the lower risk of periprosthetic fractures than cementless ones [22].

**Impact of Stiffness of the Lumbar Spine**

A limited range of motion of the lumbosacral spine enforces increased compensatory loads of the hip, thus being one of the risk factors for endoprosthesis dislocation. A limited range of pelvic tilt during typical everyday activities, including those requiring flexion and extension of the hip (sitting on the chair, standing), reinforces a compensatory range of motion in the prosthesis, which can contribute to its dislocation. Thus, hip arthroplasties performed in patients with ankylosing spondylitis have an extremely high risk of dislocation and loosening of the prosthesis in comparison to those in patients with osteoarthritis [23,24].

One study conducted in a sample of 1000 patients 1 year after primary THA showed that the patients who sustained dislocations had a substantially decreased range of motion in the lumbar spine and sacral slope, while, during standing and sitting, the differences between the involved and the uninvolved lower limb were significantly lower. The results indicated that 92% of patients with dislocations previously underwent surgeries of the lumbar spine, including spine fusions [25]. Analogous
results have been obtained from the analysis of the biomechanical reasons for late prosthetic dislocations, in which the study found that the decrease of sacral tilt while changing the body position from standing to sitting forces a decrease in the range of hip motion by 0.9° per each 1.0° of limited spine mobility. The above findings explain the mechanism of late dislocations in patients with decreased spine mobility.

Pelvic retroversion predisposes patients to anterior dislocations, forcing hyperextension of the hip, while standing and anteverision predisposes to posterior dislocations due to excessive flexion in the sitting position [26]. It has been assessed that spondylodesis is the greatest independent risk factor for dislocations of hip prostheses during the first 6 months after arthroplasty [27].

**Patient-Dependent Factors that Predispose to THA Dislocation**

The patient-dependent factors that predispose patients to dislocation are shown in Table 1. Secondary injuries due to patient noncompliance with postoperative recommendations markedly increase the risk of dislocations. This is especially common in the early postoperative period, when an immature scar provides weak mechanical support of joint congruence. Dislocation can occur from leg crossing, squatting, and even performing movements in an excessive range of motion. During the first 3 months after surgery, inordinate movements increase the risk of dislocation owing to insufficient scar resistance [28]. However, an excessive scar formed around the joint can contribute to dislocation, levering the prosthetic’s head from the acetabulum during contracture of muscles adjacent to the trochanteric area. This usually occurs in cases of repeated surgical interventions. Thus, revision procedures have a significantly higher risk of dislocations, reaching up to 28% of performed procedures. It is most prominent in wide tissue injuries, both traumatic and iatrogenic, that heal leaving an excessive scar and heterotopic ossification [29]. Deficits of skeletal tissues of the acetabulum and the proximal end of the femur form an other group of risk factors for displacement [10].

In such cases, education of patients focused on elimination of movements leading to dislocation, carried out by an experienced physiotherapist, can reduce the risk of complication.

Dislocations can also occur in late periods after arthroplasty. Unfortunately, events such as falls, stumbling, and even car accidents, can result in dislocations and associated soft-tissue injuries [30]. Locomotor disability, including stiffness of

| Numbers | the section | Patients-dependent factors that predispose to THA dislocation |
|---------|-------------|-------------------------------------------------------------|
| 1.      | Insubordinate, alcohol, drug abused – corresponds with brawls |
| 2.      | Patients with neurologic and psychiatric disorders, including epilepsy, dementia, disorientation, ataxia, impaired consciousness, coma and delusions. Also - paresis and nerve palsy affecting the lower limb that impairs muscular balance of the pelvic girdle |
| 3.      | Undertaking professional risky activities that promote injuries to the hip joint: a. Stuntmen’s b. Professional sportsmen’s c. Soldiers, policemen’s |
| 4.      | Very active amateur sportsmen a. Skiing b. Horse riding c. Football players d. Squash players e. Parachuting |
| 5.      | Bedridden patients that have an advanced muscular atrophy due to persistent disuse (lack of congruency of the hip joint) |
| 6.      | Lumbar sacral pathology |
| 7.      | THA with low-diameter femoral head |
| 8.      | Technical errors in THA – inexperienced surgeon |
| 9.      | Advanced age (includes several of the factors mentioned above) |
| 10.     | Obesity (BMI >30 kg/m²) |
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Recently, obesity, especially morbid obesity, has been identified as one of the factors that increase the risk of dislocation. The relationship between body mass index (BMI) and the degree of THA instability, with a BMI of 40 kg/m\(^2\) and higher, is noticeable. The circumference of the thigh, not the BMI itself, is a factor that directly reduces the stability of the joint. Moreover, the rate of THA dislocation in women with obesity is higher than that in men with obesity owing to the differences in fat deposition (women store fat mainly around the hips and thighs, whereas in men it is mostly distributed at the abdomen) [34,43].

Factors Preventing Hip Prosthesis Dislocation
Anatomically, the hip is protected from dislocation by active and passive stabilizers. Active stabilizers are the joint capsule and the pubofemoral, ischiofemoral, and iliofemoral ligaments supporting it. Additionally, the femoral head is powered by its own ligament and suction, which is the effect of negative pressure in the joint cavity during dislocation. Active stabilizers form muscles of the pelvic girdle [44,45]. Their net force presses the head of the prosthesis to its acetabulum, increasing congruency of the joint.

Surgical procedures deprive joints of some of the abovementioned elements. The surgical approach requires dissection, excision, and removal or release of the joint capsule and its ligaments and ligaments of the femoral head, and non-physiological limb movements overstretch muscles of the pelvic ring. The forthcoming fibrosis impairs their contractility, decreasing their strength [46,47]. Several recently introduced techniques preserve anatomical structures with a limited surgical intervention and reconstruction of joint capsule and muscle attachments [48,49]. However, the question of whether it is able to reduce the risk of complications is still controversial [50]. The range of iatrogenic lesions highly depends on the selected surgical approach, patient’s constitution-related factors (obesity), previously performed interventions (scarring), and an excessive (even brutal) surgical technique. Unfortunately, even the most delicate, tissue-protecting technique does not guarantee preservation of anatomical structures. This especially concerns advanced stiffness of the hip, its wide scarring after previously performed procedures and injuries, and the question of when it is necessary to restore biomechanics in dysplastic high hip dislocations with the formation of the secondary acetabulum [51].

An inappropriate size of the prosthetic head can increase the risk of dislocation and accelerate the damage of its acetabulum. Unquestionably, heads with a greater diameter decrease the risk of dislocation and accelerate the damage of its acetabulum. At the same time, however, they decrease the range of motion, jeopardizing implant levering in extreme joint positions [52].

A very specific group of patients predisposed to dislocations includes vigorously physically active individuals, who do sport and undertake risky activities. The generation of much higher loads increases prosthesis wear, implant loss, and the risk of dislocation. Nevertheless, an appropriate selection of an implant that would be adequate for this particular group (low-friction working elements, head diameter 32 mm) and patient education eliminates the risk of this complication to the value of that in patients with low activity [37].

The unpredictable and often also irrational behavior of alcohol and drug abusers and mentally ill patients increases the risk of implant dislocation and periprosthetic fractures [37,38]. In those groups, both complications are the most frequent reasons for revision procedures [3,39]. Very strict preoperative planning, precise implant positioning, and careful postoperative care combined with an intensive rehabilitation program and education allow patients to reduce the risk of dislocations to an accepted level [40].

Patients with soft-tissue imbalance, joint deformities around the hips, and bilateral pathological hips seem to be more predisposed to implant dislocation. Recently identified risk factors include preoperative hip adduction deformity combined with limb lengthening of 2 cm postoperatively, knee valgus combined with pelvic obliquity deformity, and bilateral pathology of the hip that require arthroplasty. If the procedure is planned carefully and has proper postoperative management, dislocation after THA can be prevented [41].

Patients with Crowe type IV developmental dysplasia of the hip are at a high risk of dislocation after THA. Nevertheless, in those cases, implantations of an implant with higher size of the femoral head (28 instead of 22 mm) reduces the risk of dislocation. Risk can be lowered by improvement of the strength of the abductors in properly planned preoperative and postoperative rehabilitation [42].
Outcomes of Hip Prosthesis Dislocation

Dislocation leads to severe consequences. It can cause vast soft-tissue injury, including scar formation around the joint and the remainders of its capsule, muscles, and their attachments, contributing to bone fractures, the loss of bone, and the integrity and stability of the implant. When repositioned, deprivation of stabilizers can easily reoccur. The consequences of dislocation also include avulsion fractures, vast scarring, and heterotopic ossification [29,53].

Preoperative Planning

Careful preoperative planning, the use of the most suitable implant and surgical approach for the particular case, and an adequate postoperative rehabilitation program combined with education of patients play the most important role in prevention of dislocation.

Several meta-analyses determined that the most effective and least risky surgical approaches are suitable minimally invasive implantation techniques that preserve soft tissues and have implants with bigger diameters of the head [54], as their dislocation requires a bigger force to destabilize the implant [55,56]. Therefore, bipolar prostheses and prostheses with large heads are less prone to dislocation [57]. Hence, they are commonly implanted in patients with neuromuscular disorders [58,59]. Their additional advantage is an increased surface of the contact area between working parts, decreasing the net loading over the surface (pressure), thus minimizing the risk of their abrasion, fragmentation, and creep. Abrasion and fragmentation of a polyethylene insert compromise the congruity of an implant, decreasing its resistance to dislocation. Under such circumstances, the implant should be replaced as soon as possible. Unfortunately, in THA, a higher diameter of the head decreases the range of motion in joints. Its impingement with the acetabular edge in extreme joint positions can lever the head, leading to dislocation.

Heads of higher diameter (eg, 32 mm) conflict with the acetabulum easier than smaller ones (28 mm). Moreover, their application imposes the use of polyethylene inserts of a smaller thickness, jeopardizing its durability [60-62]. Therefore, according to Kelley et al [63], each size of the head should be assigned to an accurate diameter of the acetabulum. Thus, heads of 22 mm diameter could be used with an acetabulum with a diameter up to 50 mm; heads of 26 mm in diameter are suitable with acetabular head diameters of 52 of 54 mm; heads of 28 mm in diameter are suitable with acetabular head diameters of 56 to 60 mm; and a head diameter of 32 mm requires an acetabulum with a diameter greater than 62 mm. Also noteworthy, the relationship between the diameter of the prosthesis head and the width of the neck of its stem should be preserved, as a combination of a small head with a wide neck of the stem increases the risk of implant dislocation [64].

The most common complication of THA is dislocation manifested by instability of the prosthesis, which requires further revision procedures. To avoid the risk of instability, the concept of dual mobility of hip prostheses has been developed. Multiple studies have shown that dual mobility has a statistically significant lower incidence of dislocations, when compared to standard THA. Its use is particularly promising in patients at high risk of femoral neck fractures. Dual mobility is less expensive and more usable than standard THA bearings [6,65].

Conclusions

In conclusion, the idea of implant choice individualization involving the selection of implants that would be most suitable for a patient undergoing THA and his or her activity level and expectations is becoming increasingly popular. A careful biomechanical analysis has shown that widely accepted rules of the recommended implant selection and implantation do not exclude the conflict between its elements or between the femur and the pelvis. The “safety area” introduced by Lewinnek (inclination 40±10° and anteversion 15±10°) of acetabulum positioning does not exclude the risk of ischiofemoral conflict, despite the fact that its placement outside this zone is responsible for up to 70% of dislocations [66]. A careful and delicate preparation of tissues, preserving muscles and their attachments, avoiding the release of muscle attachments and osteotomies, and their careful reattaches and stabilization avoid later dysfunctions leading to dislocation. Muscular insufficiency, when present, as well as joint congruency could be improved by the correction of an implant offset. Proper postoperative care focused on elaboration and strengthening of the desired locomotor habits, patient education on implant displacement and adequate preventive measures, risk minimization, and the negative impact of concomitant diseases that increase the risk of additional injuries can prevent this complication.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.
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