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REVIEW

Acetabular screws placement in primary and revision total hip arthroplasty: a narrative review

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Abstract

Introduction Total Hip Arthroplasty (THA) is one of the most successful procedures in orthopedic surgery. Today, arthroplasties are performed using minimally invasive techniques, with excellent long-term outcomes. However, complex cases, such as dysplastic hips, acetabular fractures, or revision surgeries involving bone loss, continue to represent significant challenges for surgeons in achieving primary stability. In such situations, acetabular screws can be used to improve stability, although this increases technical difficulties and the risk of neurovascular complications. This review aims to describe the optimal techniques for acetabular screw placement in THA, focusing on ensuring primary stability while minimizing risks. It also discusses the safe zones for screw placement based on acetabular anatomy and evaluates different acetabular component designs. A narrative review of the literature was conducted, addressing acetabular screw placement in the ilium, ischium, and pubic bone. A clock-face method and graphics are used to illustrate the optimal entry points for screws. The risk associated with various zones (e.g., the "death zone" and "caution zone") is highlighted. The iliac bone offers the best tolerance for screw placement, with a wide range of safe angles, whereas the ischium and pubis present narrower safety angles due to proximity to vital structures. Progressively more invasive types of prostheses are also discussed for severe cases of bone loss and reduced stability. The review emphasizes the importance of surgeon expertise and anatomical knowledge, particularly in high-complexity cases where bone stock is severely compromised.

Conclusions Proper acetabular component selection and placement and screw fixation techniques are crucial for the success of both difficult primary and revision THA. Surgeons must be aware of the technical difficulties and the anatomical variations that can occur in difficult cases, to avoid complications, namely neurovascular injuries.

Keywords Total hip arthroplasty · Revision surgery · Acetabular screws · Complications · Screw placement zones

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Introduction

Total hip arthroplasty (THA) has been defined as the "operation of the century" [1]. Since its introduction at the end of 19th century, THA revolutionized the orthopedics practice. Since 1960s the procedure was standardized, making it possible to operate a large number of patients improving their quality of life [2]. Initially the cups were cemented using poli-methyl-methacrilate, allowing immediate stability and good outcomes; however, these type of fixation had critical issues, such as radiolucency at the bone-metal interface, aseptic loosening and the need for cup revision [3]. Over time, a more conservative approach emerged, focused on bone and soft tissue preservation, implementation of minimally invasive techniques and cementless fixation of the acetabular component, determining the overall success of the procedure, which showed excellent mid- and long-term results [4].

Press-fit primary stability has been developed in the late 1970s and early 1980s [5] and proved to be safe and effective [6–9]. In acetabular implants, press-fit technique requires a mismatch between the cup and the bone, allowing them to engage and interlock [10] with the implant oversized compared to acetabular bone reamed; however, a certain integrity of the acetabular rim is required to achieve primary stability [10, 11]. Correct positioning of the acetabular component is of paramount importance [12, 13]: the goal of the implant is to recreate a physiological center of rotation (COR) [12] and the cup is easier to adjust compared to the stem. The surgeons removes residual cartilage by exposing the subchondral bone to obtain a hemispherical cavity to host the cup [14], without excessive medialization of the implant [15].

Traditionally, the cup should have an inclination of 40°±10° and an anteversion of 15°±10° according to the parameters given by Lewinnek [16]. However, in recent literature the reliability of Lewinnek safe zones has been questioned [17]. For instance, in patients with stiffness and deformity of the lumbar spine, the suggested values of anteversion should be increased to 25–30° to reduce the risk of anterior impingement while sitting (Fig. 1) [18–20].

In more surgical complex patients, primary stability may not be achieved as expected. These situations may be represented by dysplastic hips, acetabular fractures, revision and re-revision surgery with acetabular bone loss, or when an oval or otherwise non-continent acetabular cavity

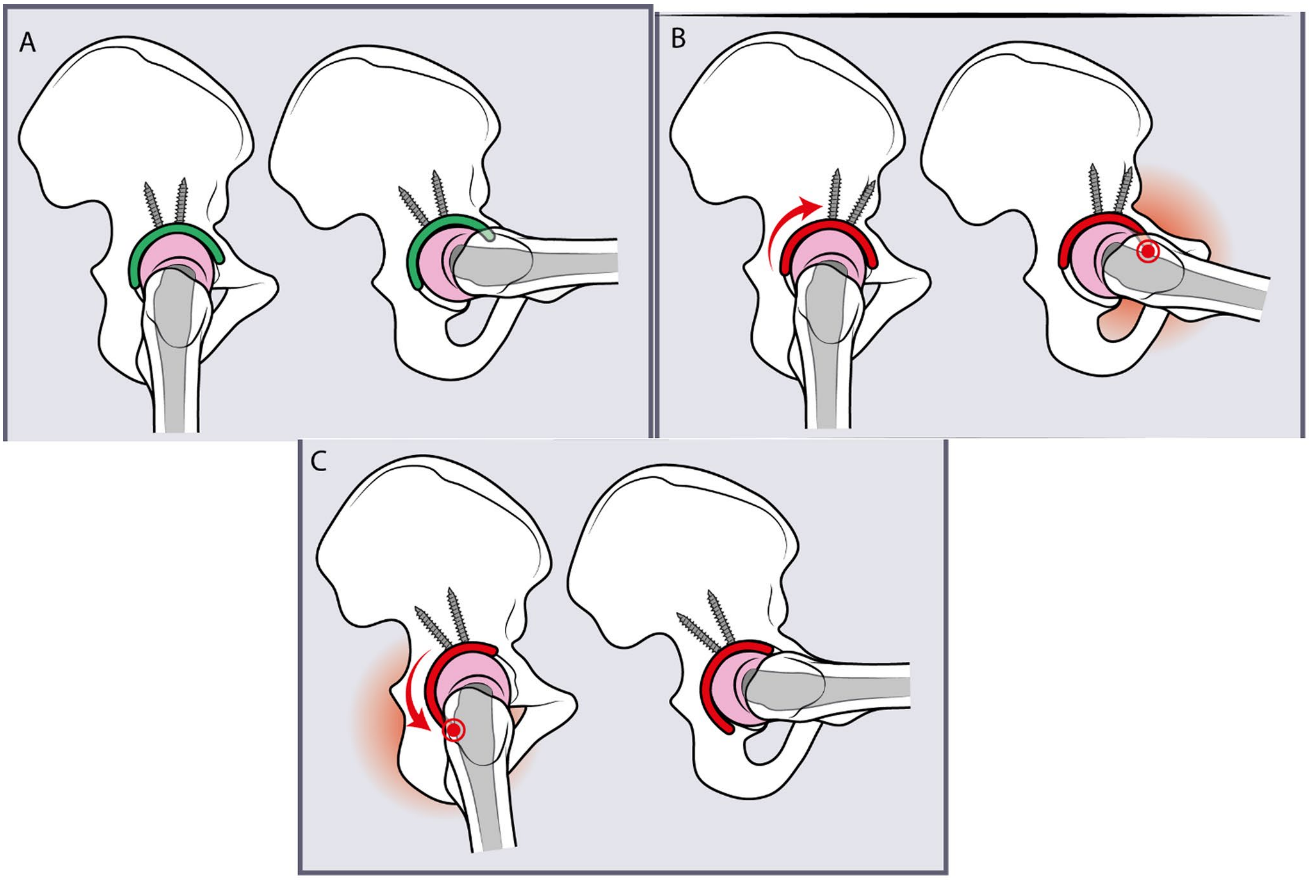

Fig. 1 **A** A correctly placed acetabular cup, with screws; **B** An excessive retroverted cup would lead to anterior impingement while the patient is sitting; **C** An excessive anteverted cup would lead to posterior impingement while the patient is standing

is obtained after eccentric reaming, leaving an acetabular bone defect [21]. In such situations, acetabular screws may be applied to improve stability [22]. The number and positioning of screws are both critical factors for ensuring the long-term stability of the implant. Acetabular cups fixed by only 1 screw results in greater migration compared with cups fixed with 2 screws [23]. When single screw fixation is used, the cup could pivot around the screw axis, generating micromotion even under small torque loading. Inserting a second screw enhances cup torque stability, and contrasts rotation. Further screw insertion could increase torque stability, but its effect is not as significant as the insertion of the second screw [24].

Screws can be inserted in any of the pelvis bones, contributing to primary stability while the process of osteointegration occurs [7, 10, 25]. However, positioning acetabular screws increases the surgical complexity and carries a risk of complications, particularly neuro-vascular lesions [26]. Anatomic studies established safety quadrants at the pelvis bone to insert screws for acetabular fixation, which can be applied in both regular and high hip COR, outlining the risks of screws misplacements for intrapelvic structures [27–29].

Intrapelvic vascular injury can be a dramatic complication that can occur intra and postoperatively after acetabular screws insertion in THA [26]. Managing bleeding in cases of intrapelvic vascular injury is extremely demanding, generally requiring intrapelvic extension of the surgical approach [30]. Moreover, bleeding is most often delayed, potentially leading to retroperitoneal blood collections and eventually death [26]. Meticulous execution of the surgical technique for screw placement and appropriate knowledge of pelvic bone and vascular anatomy is required to minimize risks [31].

The "*safe zone concept*" for acetabular screw placement was introduced in literature by Wasielewski et al. in the early 1990s [27, 28]. Acetabulum is divided into four quadrants by 2 perpendicular line crossing at the center of the acetabulum, with the first originated at the antero-superior iliac spine. This division makes it possible to distinguish: a postero-superior quadrant (target zone), a postero-inferior quadrant (caution zone), an antero-inferior quadrant (danger zone) and an antero-superior quadrant (referred to as "death zone") (Fig. 2).

Even though acetabular bone division into quadrants provides the surgeon with a valuable tool to identify target zones for screw drilling, there are no recognized three-dimensional referral points for acetabular screws placement.

Aim of this paper is to describe the ideal orientation for cementless acetabular component placement and screw perforations during THA. Literature is reviewed looking for manuscripts addressing the use of screws for the fixation of cementless acetabular components. Moreover, different type of cups and/or surgical techniques and strategies for severe bone loss are presented.

Pelvis and cup orientation

Screw placement technique is analyzed considering the three bones that make up the hemipelvis: ilium, pubis, and ischium. The entry point is described in a clock-wise system, in which 12 o'clock is represented by the head of the patient; the orientation is clockwise at the right hip and counterclockwise at the left hip. For description purposes, in the current review only right side implants, with clockwise orientation, will be considered. The inclination of the perforator and the tolerability angles are described in the two orthogonal coronal and sagittal planes (Fig. 3). Given bone stock availability and structures at risk, the tolerance to error progressively decreases from the iliac bone to the ischium, ending with the pubic bone. Results are presented both textually and graphically to facilitate learning and three-dimensional orientation on the operating field.

Iliac screws

The iliac bone is the largest of the three pelvis bones, and it can be divided into two parts: the body, which forms the upper wall or "rooftop" of the acetabulum, and the wing, the largest portion, which develops superiorly. The wing provides an abundant volume of trabecular bone in which the screws can be inserted, and iliac screws are the most commonly used to contribute to primary cups stability [32].

Drilling for iliac screws should be performed targeting the sacro-iliac joint and the posterior superior iliac spine. Specifically, drilling should be performed between 10 and 1 o'clock, with an approximately 30° range of tolerability. Given the abundance of bone stock, the length of the screws can reach up to 70 mm, if required (Fig. 4) [33].

Ischial screws

The ischium, located posteriorly to the pubis and caudal to the ileum, consists of a body that forms the posteroinferior wall of the acetabulum, and an L-shaped branch, first descending with the ischial tuberosity, and then ascending to connect with the pubis forming the ischio-pubic branch; it demarcates the obturator foramen at the inferior aspect.

Drilling for ischial screws should be performed toward the ischial tuberosity at an interval between 7 and 8 o'clock, and approximately 25° range tolerability. The placement area is narrow, and the length of the screws reaches 25 mm to rarely 40 mm (Fig. 5) [34].

There is a significant anatomical difference between male and female pelvis to favor pregnancy and delivery, which

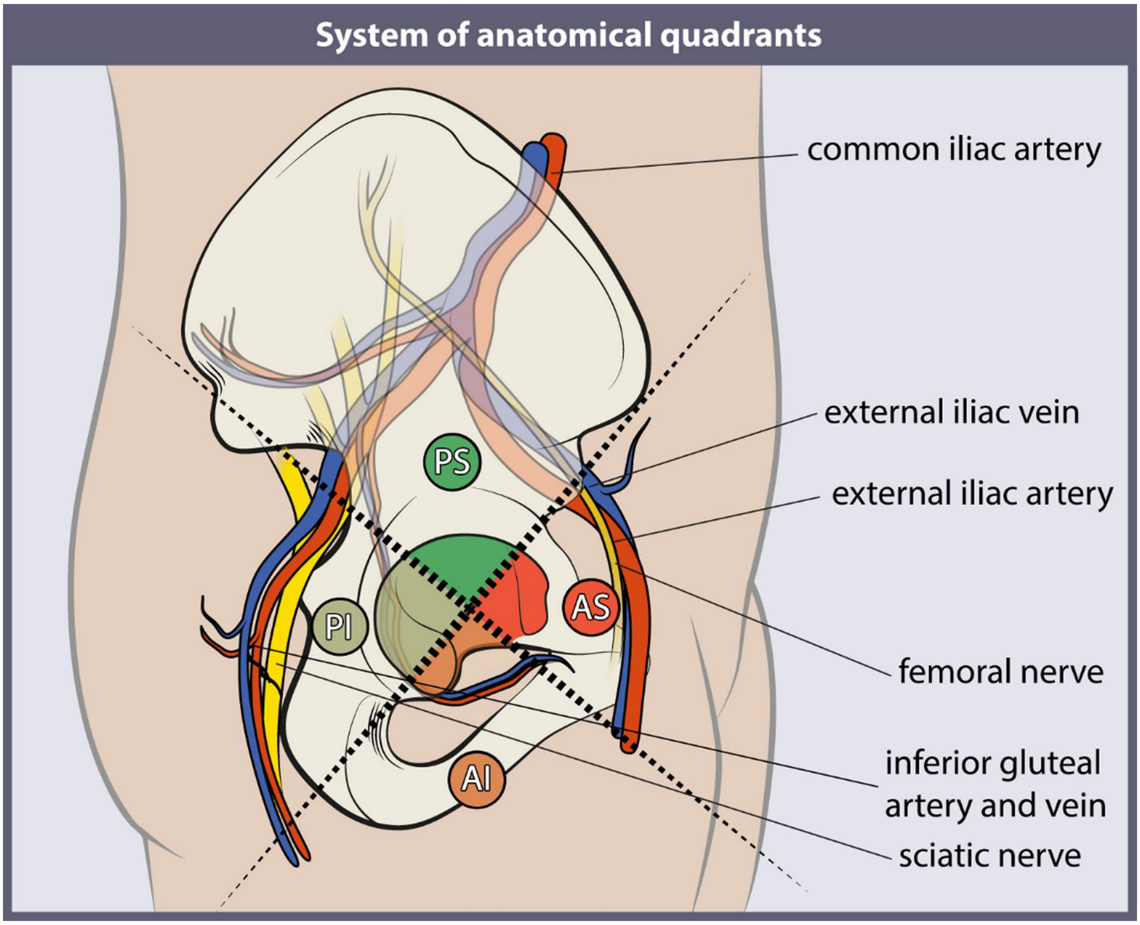

Fig. 2 Graphical representation of the right pelvis, showing the anatomical relationships with the main vascular and nervous structures at risk. PS (postero-superior) quadrant is the "safe zone"; structures at risk (sciatic nerve, superior gluteal nerve and vessels) are quite distant and there is a wide bone stock to insert screws; PI (postero-inferior) quadrant is a caution zone, safe if screws are <20 mm in length: the risks include sciatic nerve, inferior gluteal nerve and vessels, internal pudendal nerve and vessels; AI (antero-inferior) quadrant is a danger zone, with obturator nerve, artery, and vein at risk; AS (antero-superior) quadrant is a "death zone", and the risk is determined by the presence of external iliac artery and vein

requires a more lateral direction of the drill bit when aiming for ischial screws in women [34].

Pubic screws

The pubis, located anterior and superior to the ischium and inferior to the ileum, is formed by the body, medially, which faces the contralateral pubis at the symphysis, and by two branches, one directed towards the ileum (ileo-pubic branch) which represents the anteroinferior wall of the acetabulum, and the other towards the ischium (ischio-pubic branch), delimiting the obturator foramen.

Drilling for pubic screws should be performed towards the ileo-pubic branch and the pubic symphysis.

The direction of the drilling should be approximately at 4 o'clock with an approximately 15° range tolerability. The safety interval is small and the available bone volume is limited; crossing the arcuate line or pectineal crest should be avoided because of proximity to intrapelvic vascular structures, particularly the internal iliac artery and corona mortis artery. The length of the screws only rarely reaches 40 mm, with an average length of 25–30 mm (Fig. 6) [35].

Type of cups

Given the great variability of bone loss and the deformity that can be treated, numerous cup designs are available. Type of cups can be generally divided in relation with the number of screw holes: No-hole, Two/Three-holes and Multi-hole (Fig. 7).

No-hole cups are used exclusively when there is certainty of press-fit fixation; the other types of cups allow, through rotation of the component before placement and impaction, to direct the holes in the range of interest [36]. Two/three holes cups are those most commonly used in primary arthroplasty or revisions with bone stock preservation because

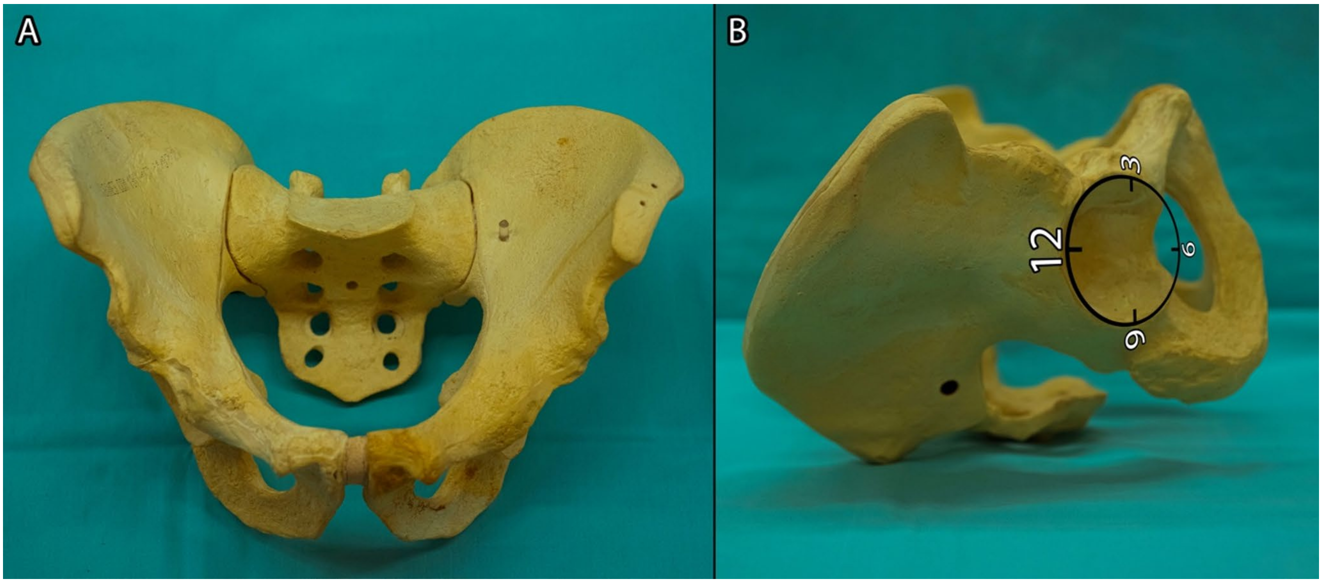

Fig. 3 Photographs of a pelvic sawbone for representation of reference points for screw positioning graphical indications. **A** coronal plane; **B** sagittal plane, clockwise system on the right side of the pelvis

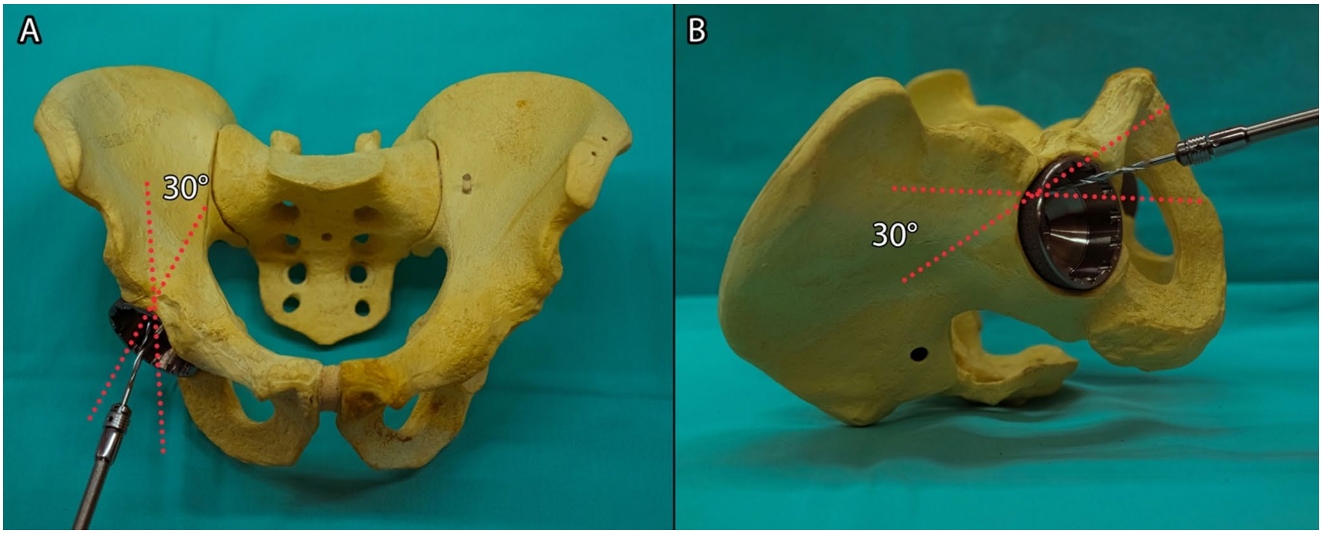

Fig. 4 Photographs of a pelvic sawbone with an implanted prosthetic cup and a drill tip for representation of iliac screw drilling: iliac screws are placed in the safe postero-superior quadrant; the target-zone, which allows for the greatest tolerance range of approximately 30° from the ideal point, lies between 10 and 1 o'clock

they are designed to facilitate screw positioning at the posterosuperior quadrant [37], which represents a good backup in case of unsatisfactory intraoperative primary stability.

Multi-hole cups allow circumferential screw placement [38], useful in the case of complex reconstructions, pelvis discontinuity fixation, and extremely poor bone quality and loss of one or both columns for cup fixation during THA [39, 40]. Before impacting the multi-hole cup in its final position, the rotation of the component should be checked to allow placement of a pubic or ischiatic screw, because the fixed distance between the holes might not encounter the narrow insertion point of iliac or pubic screws [41]. (Figures 8 and 9)

A sub-type of Multi-hole cup is the Rim-hole cup, which offers a more peripheral positioning of the screws that can be useful when peripheral bone stock is more reliable than medial bone stock.

Jumbo cups

The use of the term “Jumbo” is not standardized in literature, however many authors consider jumbo cups acetabular components with a diameter greater than 60–62 mm in

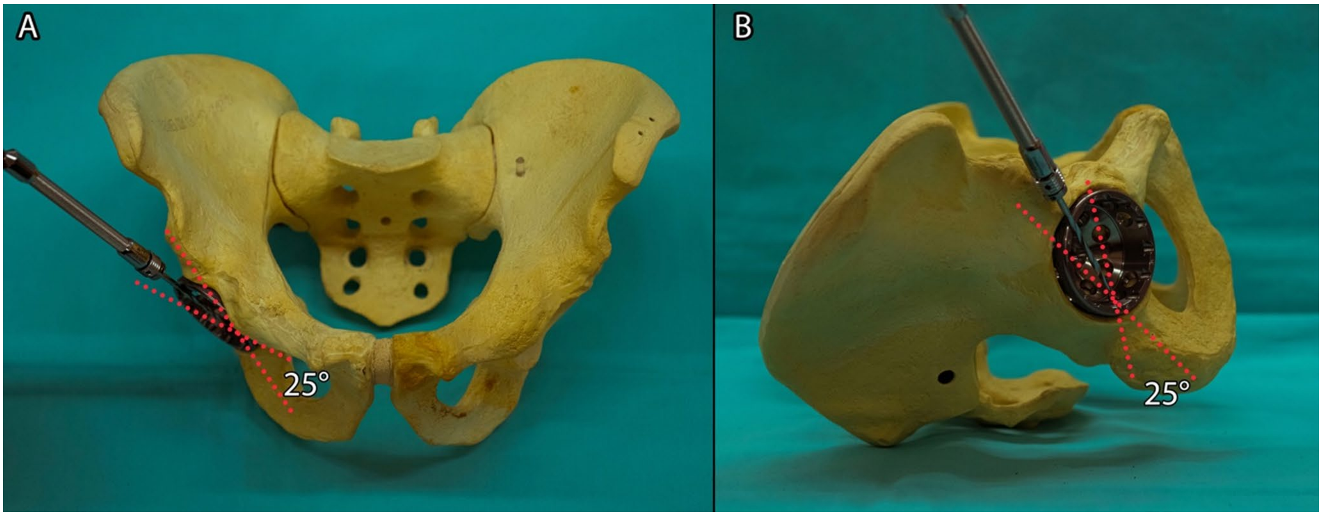

Fig. 5 Photographs of a pelvic sawbone with an implanted prosthetic cup and a drill tip for representation of ischial screws insertion: ischial screws are placed in the transition zone between the postero-inferior (caution zone) and antero-inferior (danger zone) quadrant, which allows for a reduced tolerance range of approximately 25° between 7 and 8 o'clock

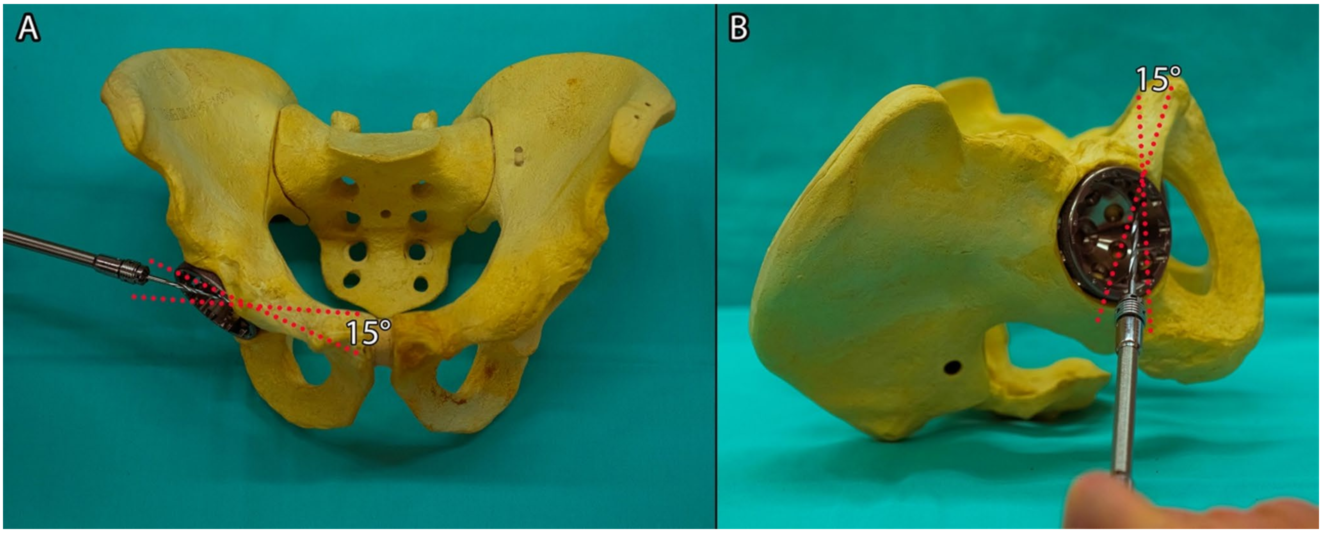

Fig. 6 Photographs of a pelvic sawbone with an implanted prosthetic cup and a drill tip for representation of pubic screws insertion: Pubic screws are placed in the antero-superior quadrant, the "death" zone, which allows the lowest tolerance range of approximately 15° from the ideal point at 4 o'clock

women and 64–66 mm in men [44]. Size augmentation has the advantage to maximize bone contact. If the jumbo cup is correctly placed, the direction of drilling of the screws does not change from that described above. However, it becomes more relevant when ischial screws are required in addition to iliac screws: ischial fixation opposes to the increased leverage arm that Jumbo cups exert compared to "regular" components. Moreover, the risk of proximalization of the COR must be kept in consideration, especially in patients with significant polar bone defects in DeLee and Charnley zone I [45] which further change the pattern of the safe zones for screw placement, as reported below.

Stemmed "iliac screw" cups

When bone loss is so severe that the use of standard hemispheric cup is not possible, stemmed cups were proposed to connect to the iliac isthmus, which often remain supportive [46]. It is a variant of iliac fixation and requires the use of a modified stemmed acetabular cup, called "ice cream cone"; alternatively, a unique large diameter screw is used instead of the stem, with positive outcomes [32, 47]; a second smaller screw is usually added to contrast implant rotation.

The reason for using a screw instead of a stem is to overcome the technical difficulties related to the monobloc design of stemmed cup prosthesis which can lead to

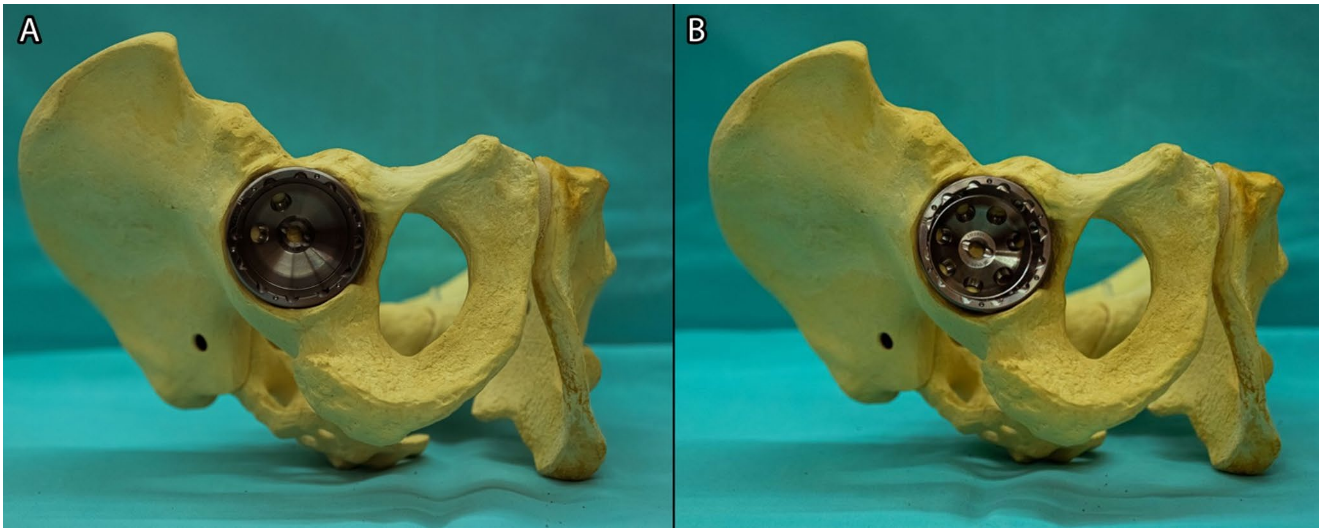

Fig. 7 Photographs of a pelvic sawbone with 2 different implanted prosthetic cups. **A**. 2 holes design-cup: oriented on the iliac bone, in the target zone of PS quadrant **B**. Multihole-design cup: holes are presented in two different levels approaching the center of the cup and allow screw placement on the whole surface of the cup with any kind of orientation

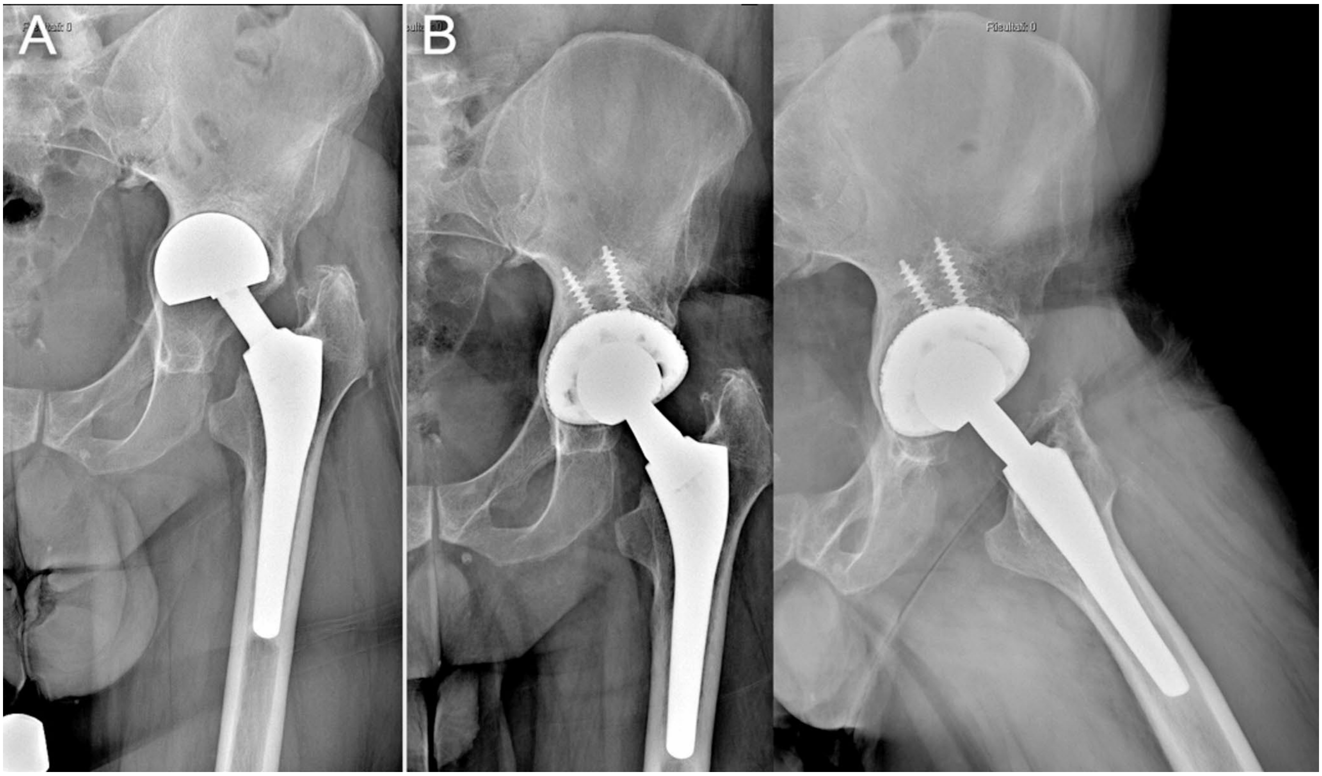

Fig. 8 Clinical Case. 48 year-old man, primarily treated with hemiarthroplasty for benign neoplastic lesion of the femoral head. **A**. Preoperative antero-posterior radiographs: cotyloiditis with proximal migration of the prosthetic head and consumption of the bone stock on the acetabular roof, Paprosky II-C defect [42, 43]. **B**. 2-years follow-up radiographs shows the good positioning of the revision cup stabilized by two screws in the postero-superior iliac quadrant and the integration of the superior bone grafting, allowing to restore a more natural centre of rotation

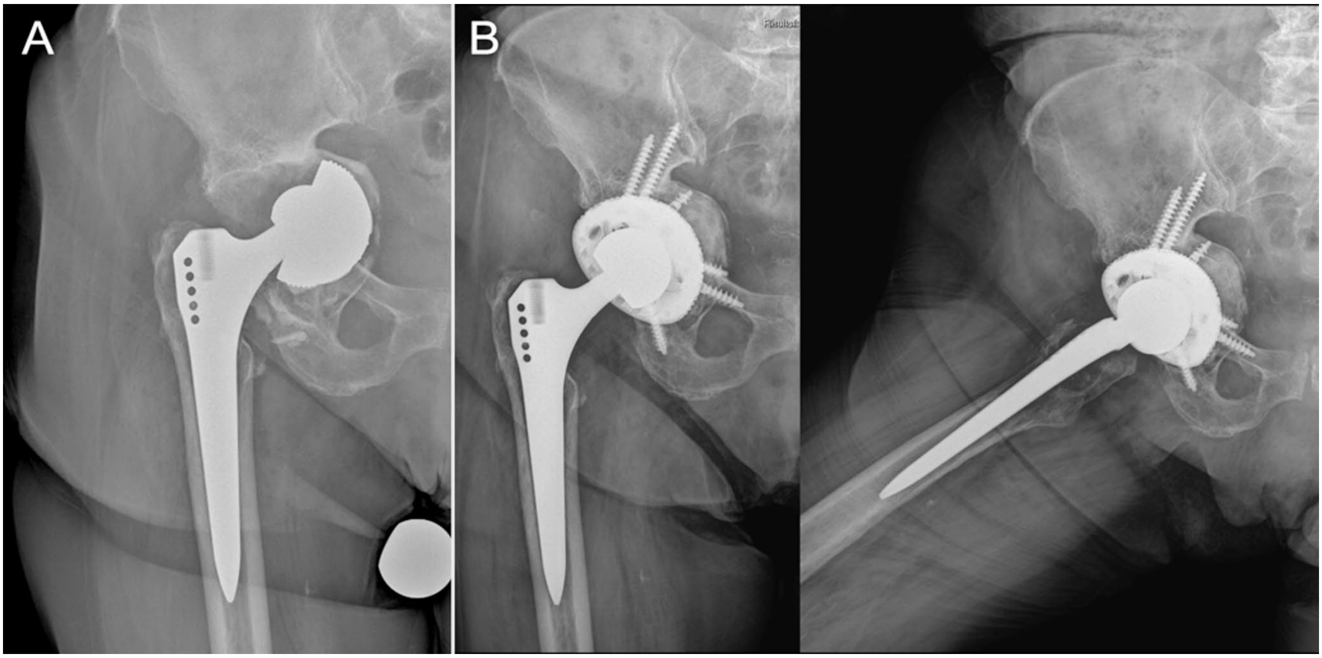

Fig. 9 Clinical Case. 81 year-old woman, primarily treated with total hip arthroplasty for hip arthritis. **A**. Preoperative antero-posterior radiographs: aseptic mobilization with severe medial bone loss and substantial intra-pelvic migration of the acetabular cup, Paprosky III-B defect [42, 43]. **B**. 18-months follow-up radiographs shows the good positioning of the multi-hole revision cup stabilized by screws in iliac, ischiatic and pubic bone, with the integration of the bone grafting and the reconstitution of the medial wall

inadequate cup version and/or inclination; moreover, it can be associated to placement of the stem outside the isthmus and/or with its perforation. In this case, the central iliac screw can be oriented following anatomical condition of the patient and independently to the inclination and orientation of the cup, to whom must be locked in the definitive implant [48]. In both cases, given the notable screw diameter and its typically abundant length, it is extremely important not to violate the intra- and extrapelvic bony plateau of the iliac bone, and not to reach the intra-articular sacroiliac joint, as this may cause residual postoperative pain [47].

Cup-cage implants and Kerbull type of fixation

When acetabular bone deficit exceeds 50% of the joint surface, surgery becomes more invasive and the use of even larger implants may be necessary, frequently involving reconstruction of the pelvic bone, potentially combined with bone grafts [49]. Cup-cage constructs consist of a trabecular metal acetabular cup with an anti-protrusion cage positioned above it [50]. These implants are generally provided with a hook placed between ischium and pubis enabling a distal grip which allows stability, without the need for ischial or pubic screws. Proximally, these constructs also include an iliac plate that allows the placement of transversal iliac screws, inserted with a more horizontal trajectory [51]. The direction of the drill uses the holes provided at the implant, which are typically positioned clockwise from 1 to 3 o'clock, with a coronal tilt of 90°-120° and a sagittal tilt of 90°-110°.

High hip COR

When the bone defect is substantial, the physiologic COR could not be restored and the surgeon may consider proximalizing the COR to achieve primary stability and improve the chance of osteointegration. The extent of proximalization determines the change in the relationship between the cup and the intrapelvic vascular structures. The safe targets described in literature lose validity, and more cautious drilling must be performed (Fig. 10).

The placement of pubic or ischial screws, especially if an acetabular bone deficit is present, will provide a traction effect that is medial and anterior in the case of a pubic screw, caudal in the case of an ischial screw. This movement, despite limited, could also be intentional. This is achieved by placing the iliac screws first without tightening them fully, which is done only after placement of the pubic and/or ischial screws. If final positioning has already been achieved prior to screw placement, iliac screws can be tightened first, allowing solidarization of the acetabular component with the pelvis, preventing cup displacement secondary to screw placement at the two other locations [52–54].

Previously reported indication for drilling may vary: iliac screws take on a more horizontal direction, maintaining the hourly interval but changing orientation with a coronal

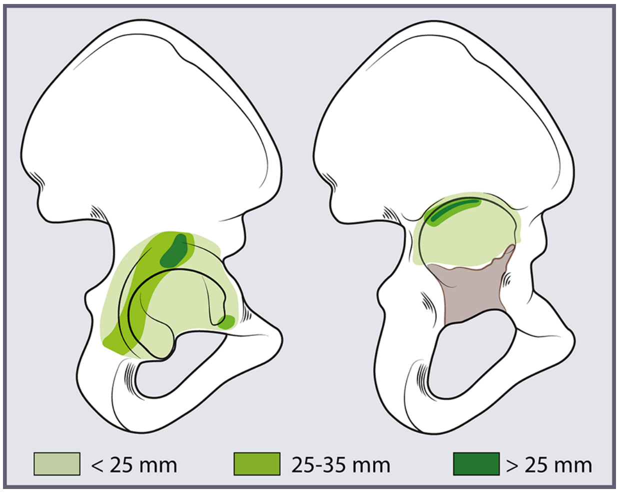

Fig. 10 Graphic representation of different bone stock in case of normal acetabulum (left) versus bone defect in the polar region, resulting in high COR (right): in the latter the availability of bone stock for screw placement is severely reduced

tilt up to 100°-120° and sagittal tilt up to 90°-110°, pubic screws assume a more distal tilt with a delayed 5 o'clock interval, a coronal tilt of 60°-70° and a sagittal tilt of 100°-110° and eventually ischial fixation may become unreliable in many patients because of the change of screws positioning compared to a physiological center of rotation. It is task of the surgeon, basing on his feelings and experience, to intraoperatively determine the extent of proximalization and the change in the inclination of the drill [33].

Technical considerations

In the placement of acetabular screws, surgeons' technical skills and expertise in tactile feedback during drilling are of paramount importance. The internal cortex represents the limit beyond which it is dangerous to proceed. However, particularly in elderly patients and in patients undergoing revisions surgery, bone quality is poor and tactile feedback may be inaccurate; in such cases, the surgeon should rely on the anatomical landmarks as outlined before. Drilling with an alternating rotation mode may results in less aggressive and more controllable deepening into the bone [55]. Bone drilling for screw placement may require the use of a drill with a flexible body, which may compromise precise centering of the tip; therefore, the use of a scope, controlled by the other hand, is recommended for this purpose.

The positioning of the patient on the surgical table also affects acetabular screw placement. The two most used patient setting for THA are the supine decubitus and the lateral decubitus.

In the supine position, the spine keeps more natural lumbosacral lordosis; therefore, the pelvis and acetabulum can be approached with a more straightforward point of view and a better spatial orientation, making easier to identify the posterosuperior quadrant.

On the contrary, in lateral decubitus, the physiological lumbosacral lordosis is lost due to the constrain applied to keep the body stable. Therefore, the pelvis is tilted backward, with the acetabulum in increased anteversion, leading to a higher risk of screw positioning at the antero-superior quadrant. The lateral decubitus requires careful positioning and patient stabilization because pelvis orientation and acetabular anteversion and inclination are strictly dependent from patient placement on the surgical table (Fig. 11).

The main limitation of the use of anatomical landmark for screw placement during cup fixation is the anatomical variability inherent to humans, and reproducibility rely on surgeons' experience. The use of navigation systems might further reduce the risk of neurovascular damage related with acetabular screw placement; however, knowledge of the anatomy of the district and technical mastery remain fundamental prerequisites that no surgeon can deprive of.

Conclusions

The technical ability to implant screws in uncemented fixation of the acetabular component in THA is extremely important for reconstructive orthopedic surgeons in both primary and revision THA. Knowledge of the bony and vascular anatomy of the pelvic district and the "quadrant system" minimizes the risks associated with screw placement, even though the risk of neurovascular damage cannot be erased. Surgeons should be aware of the variability in the design of implant components, ranging from standard 2-hole to multi-hole reconstruction rings, which should be applied after careful study of the clinical cases through second- and third-level diagnostics, in the direction of a patient-tailored surgery. The graphical presentation provided in the current review may help the surgeon in three-dimensional orientation of cup and screw placement, to improve the chance to achieve primary stability and eventual osteointegration.

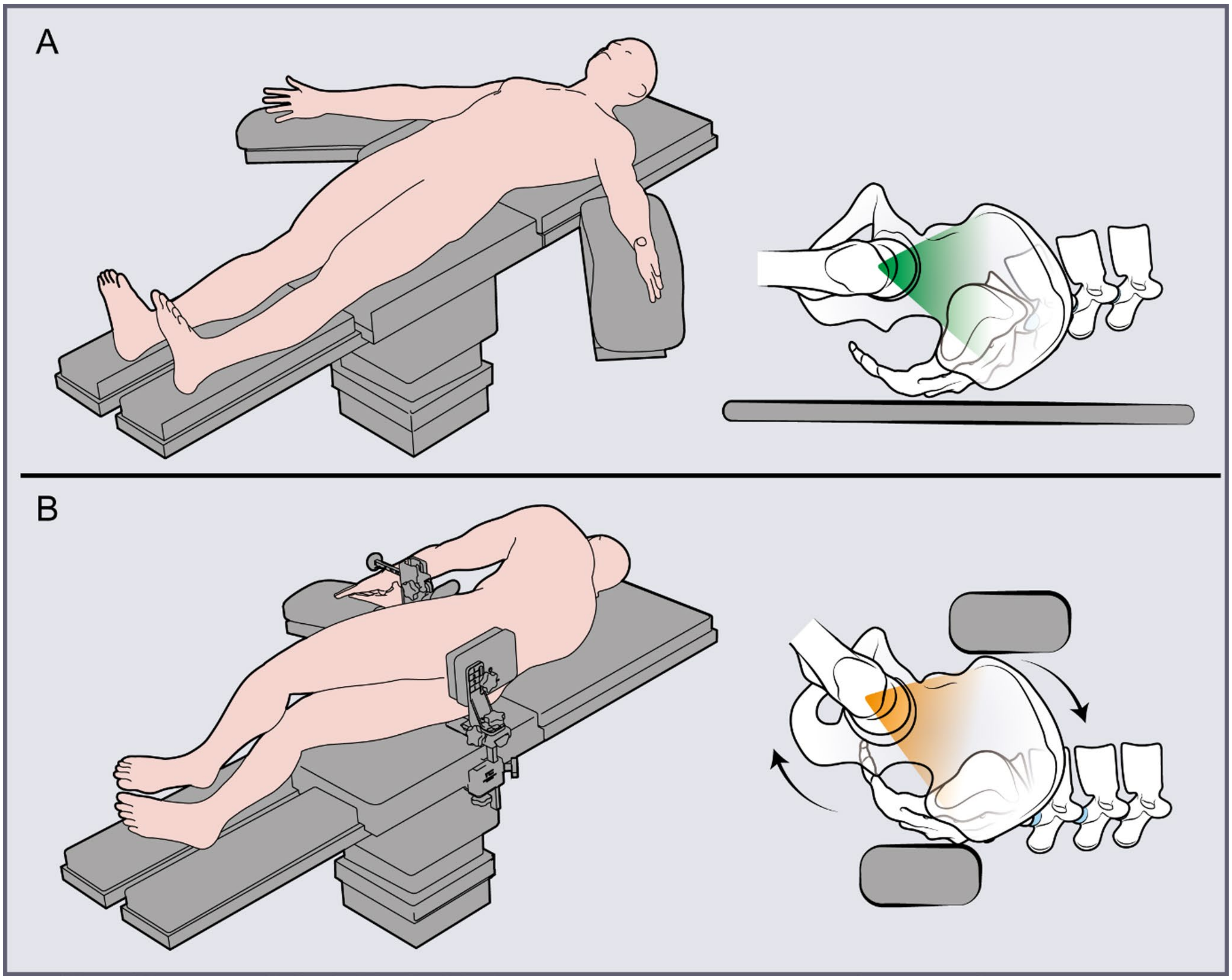

Fig. 11 Different orientation of the pelvis and the acetabulum depending on position on the surgical table. **A**: In supine decubitus, pelvis is more naturally tilted, leading to an easier spatial orientation. **B**: In lateral decubitus, spine is fixed with loss of lumbar lordosis, thus leading to more retroverted pelvis and more anteverted acetabulum; the spatial orientation to place screws in the postero-superior quadrant is more challenging

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Author contributions N.S. and D.P. contributed to ideation of the manuscript, examination the selected papers, identification and preparation of the figures, and wrote the main manuscript.M.B. contributed in selection process of the papers and in preparation of the figures.G.G. contributed in examination of the selected papers, preparation of the figures and writing of the main manuscript.F.P. contributed in ideation and preparation of the figures, mainly selection of the clinical cases; was consulted as second thought on selection of the papers and examination of the papers.E.C. contributed in selection process of the papers and examination of the selected papers, selection of the clinical cases.A.D.M. contributed in ideation of the manuscript, examination of the selected paper, approval of the figures and correction and improvement of the final manuscript.C.F., Head of the department, approved the ideation of the manuscript, the figures and the clinical case. He was consulted as final opinion on dispute regarding examination of the selected paper and gave final approval to the definitive manuscript. All Authors reviewed the final manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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