Successful joint replacement surgery requires precise preoperative planning and intraoperative placement of implants such that the function of the joint is optimized biomechanically and biologically. The five-step “pelvic tilt algorithm” will enhance the outcome of hip replacement surgery as a result of improved acetabular component alignment. It will solve the problem of pelvic tilt as an unknown variable during hip replacement surgery, and will allow for more consistent and accurate acetabular component placement.
Joint replacement surgery is a well-accepted treatment for arthritic conditions of the hip. Successful surgery requires precise preoperative planning and intraoperative placement of implants such that the function of the joint is optimized biomechanically and biologically. By using the pelvic tilt algorithm, a technique outlined below, the surgeon can employ a stepwise method to guarantee accurate placement of the acetabular prosthesis within the bone to ensure optimum function of the joint following surgery. The pelvic tilt algorithm enables the surgeon to perform the necessary measurements critical to the preoperative planning process in a fast, precise, and cost-efficient manner.

**IMPORTANCE OF PREOPERATIVE PLANNING FOR TOTAL HIP ARTHROPLASTY**

In hip replacement surgery, successful reconstruction is predicated upon restoring the biomechanics of the hip back to "normal." The hip joint is often referred to as a "ball and socket" joint. The "socket," or acetabular component, is made out of metal and is placed within the existing bony socket, or acetabulum, of the pelvis. The "ball" is attached to a "shank," or femoral component, which is placed into the thigh bone. Precise placement of implants within the host bone is necessary to ensure proper function of the hip replacement to avoid intraoperative or postoperative complications and to ensure long-lasting function.

From a biomechanical standpoint, successful hip function depends on proper orientation of the center of rotation of the joint. Specifically, this refers to achieving anatomic placement of the acetabular component following surgery. Many patients with arthritic conditions of the hip have acetabular deformity. This is due to erosion or wearing away of the cartilage of the hip joint. Thus, one of the goals of surgery is to return the center of hip rotation to its original position, as this will restore the original biomechanics of the joint and thereby optimize function. Preoperatively determining the proper position of the acetabular component is necessary to correct it intraoperatively to achieve anatomic position of the acetabular component.

Femoral offset is the measurement of the distance from the center of the rotation of the hip joint to the longitudinal axis of the femoral shaft. This is an important measurement as it determines the moment arm of the abductor muscles. In other words, the amount of offset determines how hard the muscles have to work—the greater the offset, the greater the moment arm, given the same force applied. It is, therefore, important to restore offset appropriately in order for the hip to function properly. For example, if a hip prosthesis is placed with insufficient offset as a result of acetabular component malposition, the hip muscles will have to generate increased force, leading to discomfort and easy fatigability. The extra force applied to the joint can be harmful over the long term, leading to premature wear and loosening. Furthermore, insufficient offset can create laxity of the joint, leading to dislocation.

From a biological standpoint, a successful reconstruction must be long-lasting. In large part, this depends on successful fixation of the implant to the host bone. An implant that is malpositioned, for example, is susceptible to early loosening, as the component will not be well supported within the bone. Therefore, accurate placement of the acetabular prosthesis will optimize the long-term success of joint replacement surgery while minimizing the risk of complication, such as dislocation and loosening.

The biggest problem faced in hip replacement surgery today is acetabular component alignment. Insertion of the acetabular component is facilitated by alignment devices that attach to the insertion rod (Fig. 1). The alignment guide references the surgical table on which the patient rests. It is assumed that the patient’s pelvis is parallel to the table. This assumption is predicated on the expectation that the surgical table is parallel to the floor. The ideal position (in most patients) for the acetabular component is 45° of inclination and 20° of anteversion.

Despite the fact that the alignment guide (45°) is parallel to the floor during insertion of the prosthesis, the resultant inclination is often different than expected. It is not unusual to see a postoperative x-ray which depicts an acetabular component in less than an ideal position, with increased or decreased inclination or anteversion (Figs. 2a–d).

![Figure 1. Insertion of the acetabular component is facilitated by alignment devices that attach to the insertion rod. The alignment guide references the surgical table on which the patient rests.](image-url)
Acetabular component malposition is often caused by unrecognized tilting of the pelvis in the lateral decubitus position. For example, if the pelvis is tilted 10°, this will cause a 10° error in acetabular component inclination. Similarly, if the pelvis is leaning forward 20° while in the lateral decubitus position, and the insertion device is placed in 20° of anteversion, the actual anteversion of the acetabular component will be 0°. This discovery has led some surgeons to use intraoperative x-rays and navigation as a means of detecting pelvic tilt intraoperatively (Fig. 3).

Other surgeons routinely insert the acetabular component in 35° of inclination, even though the goal is 45°. Their rationale is that it is impossible to know whether the pelvis is tilted, so they would rather have a cup with less inclination rather than too much. A cup that is too vertical can result in dislocation and loosening, and it is considered suboptimal. For example, if the pelvis is tilted 10°, and the insertion angle is 45°, then the actual inclination angle would be 55°. In this setting, an insertion angle of 35° would result in an actual inclination angle of 45°.

Intraoperative x-ray is often time-consuming and can potentially increase the risk of infection due to the introduction of x-ray equipment into the operating theater. The image (shot through the anteroposterior pelvis) is invariably of poor quality; bony landmarks are often obscured. This hinders the surgeon’s ability to accurately measure pelvic tilt.
A pelvic tilt algorithm is important because the pelvis may be rotated or tilted during the operative procedure. Many landmarks can be used to determine the orientation of the pelvis, and the most identifiable bony landmark is the anterior superior iliac spine (ASIS), which is easily identified with gentle palpation on all patients, regardless of size. Using the pelvic tilt algorithm, the “pelvic axis” is defined as the line which connects the left ASIS to the right ASIS.

**THE PELVIC TILT ALGORITHM**

By using the pelvic tilt algorithm, the surgeon can increase the overall accuracy of acetabular component positioning, thereby reducing the potential for complications and increasing the survival of the joint replacement. The addition of the pelvic tilt algorithm used intraoperatively assures accurate execution of the preoperative plan. The following describes a step-by-step pelvic tilt algorithm for placement of the acetabular component in total hip replacement, using a 3D reference coordinate system (X, Y, and Z axes).

**Step one** determines the orientation of the pelvic axis. This is important because the pelvis may be rotated or tilted during the operative procedure. Many landmarks can be used to determine the orientation of the pelvis, including the anterior superior iliac spine, the acetabular teardrop, the ischial tuberosity, the obturator foramen, or the greater sciatic notch. The most commonly used landmark (when using conventional radiography) is the acetabular teardrop, which is commonly seen on the anteroposterior view of the pelvis. When connected by a line, the left and right acetabular teardrops serve as a reference for pelvic orientation. This line represents the pelvic axis, which is used to determine the appropriate abduction or inclination angle of the acetabular component so that the prosthesis may be placed in proper position in relation to the pelvis (Figs. 4a and b). Clinically, the most identifiable bony landmark is the anterior superior iliac spine (ASIS), which is easily identified with gentle palpation on all patients, regardless of size. Using the pelvic tilt algorithm, the “pelvic axis” is defined as the line which connects the left ASIS to the right ASIS.

**Step two** determines the X, Y, and Z axes. The X axis is defined as the ground. The Y axis is defined as the long axis (length) of the operating table. The Z axis is defined as the short axis (width) of the operating table.

**Step three**—Once the pelvic axis has been determined, an angular measurement is made between the pelvic axis and the Y axis. This angular measurement is known as the “inclination angle.” The inclination angle will be positive if the hip to be operated on is tilted cephalad, and it will be negative if tilted caudad. Since the patient is lying on their side on the operating table, neutral alignment of the operating table must be verified. Many institutions use a “peg board” or similar device to stabilize a patient. The peg board lies atop the operating table, and is secured with clamps. The operating table and peg board are aligned in parallel without angulation in any plane. The patient is then placed on his or her side on the peg board and secured in position by “pegs” which are inserted into the peg board at a perpendicular angle to the peg board. The pegs are placed in front of and behind the pelvis to prevent the pelvis from moving during the operation. The pegs may, therefore, be used as a fixed reference to the floor (X axis).

**Step four** determines the “pelvic tilt” of the acetabulum. This is accomplished by making an angular measurement between the “pelvic axis” and the Z axis. This measurement will be positive if the pelvis is tilted forward or negative if the pelvis is tilted backward.

**Step five** determines the insertional angle of the acetabular component. The surgeon determines the ideal position of the acetabular component (e.g., 45° of inclination and 20° of anteversion). This is based on a level pelvis. The pelvic tilt algorithm determines the preoperative alignment of the pelvis in terms of “acetabular inclination” and pelvic tilt. If the pelvis is level to the Y and Z axes, no adjustment in acetabular component insertional angle is required. However, if any degree of acetabular inclination or pelvic tilt is noted, a correction of such is recommended to the insertional angle of the acetabular component. The pelvic tilt algorithm determines the amount of correction needed to place the implants in “ideal position” and calculates an insertional angle which compensates for acetabular inclination and pelvic tilt. The result is that the acetabular...
component is inserted in the ideal position. At the conclusion of steps one through five, appropriate cup position will be accomplished.

CONCLUSION

The five-step pelvic tilt algorithm outlined above will enhance the outcome of hip replacement surgery as a result of improved acetabular component alignment. It will solve the problem of pelvic tilt as an unknown variable during hip replacement surgery, and it will allow for more consistent and accurate acetabular component placement.

AUTHORS’ DISCLOSURES

The authors have no conflicts of interest to disclose.

REFERENCES