Should patients be weightbearing when obtaining preoperative radiographs of the hip and the knee?

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Response/Recommendation: Current literature supports the use of weightbearing radiographs in the preoperative evaluation of patients undergoing hip and knee arthroplasty. This approach not only provides a more accurate representation of anatomical considerations such the degree of joint space narrowing, lower extremity alignment and other radiographic parameters, but also provides additional information on the affected joint in functional positions. This allows the formulation of a comprehensive preoperative plan, potentially leading to better surgical outcomes.

Level of Evidence: Moderate

Rationale:

Knee

Determination of joint width is an important part of the evaluation of degenerative joint disease as it constitutes the basis for surgical decision-making. In the context of knee osteoarthritis, it is well-established that arthritis does not uniformly involve each of the three compartments of the knee. When disease is limited to one compartment, surgical options include unicompartmental knee arthroplasty (UKA) or high tibial osteotomy (HTO) as opposed to total knee arthroplasty (TKA). As the choice between these procedures and their surgical outcomes depend on the status of the unaffected compartment(s), it is imperative that surgeons thoroughly evaluate the extent of disease in each compartment preoperatively. Although magnetic resonance imaging (MRI) has been shown to be the most sensitive tool for assessing articular cartilage [1,2], plain radiography remains the most widely available and least costly modality [1,2]. Standing knee radiographs are now the standard imaging tool for evaluating of presence and degree of joint space narrowing and bone attrition in knee arthrosis, offering higher precision compared to ultrasonography and MRI [3]. Optimizing the information from radiographs could therefore decrease the need for more costly alternative imaging techniques.

Variations in radiographic measurements may occur based on the weightbearing status of the patient [4,5]. The knee osteoarthritis severity scale initially proposed by Kellgren and Lawrence was widely criticized because it was derived from non-weightbearing projections and overemphasized the presence of osteophytes, which some argue are a natural occurrence with aging and not always pathologic [6]. In contrast, joint space narrowing is only a gross descriptor in the Kellgren-Lawrence grading system. Blackburn et al. attempted to correlate the radiographic Kellgren-Lawrence scale with arthroscopic findings; not surprisingly, the authors found that the scale underestimated the articular cartilage damage [7].

It is important to note that conventional weightbearing radiography may still underestimate the extent of cartilage wear. In an analysis of 34 patients with knee osteoarthritis, Wiedow et al. found that the degree of underestimation in patients with medial arthrosis was small and acceptable.

However, in patients with lateral arthrosis, more pronounced discrepancies were found [8]. The flexion view knee radiograph first described by Holmblad [9] and Resnick et al. [10] showed that a standard tunnel view was more sensitive to joint space narrowing than standing anteroposterior (AP) projections. This assertion was subsequently supported by biomechanical data demonstrating that peak articular stresses at the femorotibial articulation occurred at 28° flexion because of diminished contact area [11]. Rosenberg et al. investigated the accuracy of the 45° posteroanterior (PA) weightbearing projection in a consecutive series of 53 patients who underwent arthroscopy [12]. Using a minimum difference of 2 mm in joint space width between the medial and lateral compartments as a criterion for predicting articular cartilage ulceration or erosion on arthroscopy, they found a greater sensitivity with the 45° PA projection (80–85%) compared to standing AP radiographs (25–30%) and there were no false positives for either the medial or lateral compartments in their study [12]. In line with the preceding studies, Dervin et al. found that the 45° PA was superior for detecting lateral compartment wear, but offered no advantage on the medial side [13]. Twelve patients were categorized as having severe lateral compartment articular chondropathy (Grade IV) at the time of arthroscopy. The lateral joint space height averaged 1 .0 ± 1.7 mm on the 45° PA radiograph compared to 2.7 ± 1.1 mm on the 3-foot standing AP view. Using a cut-point of 2 mm or less to predict Grade IV chondral changes, the 45° PA view was more sensitive than the standing AP view (83% versus 42%) at correctly detecting the most severe chondropathy. The authors hence proposed that the 45° PA view be the screening radiograph of choice in evaluating any patient for osteoarthritis of the knee.

It is important to qualify, however, that neither osteophytosis using the Kellgren-Lawrence grading nor joint space narrowing on weightbearing radiographs provides an accurate assessment of osteoarthritis in patients with relatively early disease, as radiographs in general are not sensitive enough for this purpose [14]. Brandt et al. confirmed the well-recognized insensitivity of the plain radiographs in early osteoarthritis, demonstrating that joint space narrowing in standing AP radiographs was not uncommon in the presence of normal tibiofemoral articular cartilage [14]. Specifically, 32 patients (35%) had grossly normal articular cartilage in both tibiofemoral compartments on arthroscopy; however, based on Kellgren-Lawrence grading as well as a separate criteria emphasizing joint space narrowing, a radiographic diagnosis of osteoarthritis was made in 26 (81%) of these individuals.

In addition, the mechanical axis angle measured on weightbearing radiographs can differ up to 2.0° from radiographs in the supine position [4,5]. Positioning a patient supine eliminates the ground reaction force on the knee, which can underestimate alignment deformity. The knee adduction moment, which forces the knee into varus during weightbearing, is not captured in the supine position. Brouwer et al. analyzed 20 patients with medial compartmental osteoarthritis and found that the mean difference between hip-knee-ankle (HKA) angles measured standing and supine was 2°(range 1–3°; SD 0.45, $p < 0.001$), with more varus deviation observed in the standing position compared to the supine position [4]. Specogna et al. measured HKA angles in 40 patients with varus knees and found that the mean difference was 1.59° (95% CI, 1.03-2.14) for single- versus double-limb standing, 1.63° (95% CI, 1.07-2.18) for double-limb standing versus supine, and 3.21° (95% CI, 2.49-3.94) for single-limb standing versus supine [5]. Wang et al. similarly showed that the mean HKA angle measured on single-leg stance radiographs was more varus (mean diff 2.1°, $P < 0.001$) than on double-leg stance radiographs, which was more varus (mean diff 1.4°, $P < 0.001$) than that on supine radiographs [15]. Mechanical axis measurements were also found to be different when comparing weightbearing radiographs to computer-assisted navigation data or MRI [16–19], which are non-weightbearing, three-dimensional imaging modalities that further negate the confounding effect of knee rotation or flexion. Consequently, full-length weightbearing AP radiographs are regarded as the gold standard for determining knee joint alignment [20].

Several factors may affect the extent of an alignment discrepancy between supine and standing radiographs, which include severe soft tissue laxity around the knee joint [5,21] as well as the difference in joint attrition [22,23]. In patients with increased ligamentous laxity, the difference in HKA measured on standing and supine whole-leg radiographs may be even more pronounced [24]. In contrast, when the soft tissues are balanced after TKA, the postoperative difference in HKA measured on weightbearing and non-weightbearing radiographs decreases [25].

An accurate preoperative weightbearing assessment provides valuable information on lower extremity alignment, accounting for the loss of cartilage and ligamentous imbalance of the knee, which has been termed "functional deformity". This will not be seen on a preoperative CT scan [26] or intraoperative radiography [19]. A greater awareness of the variation in alignment between preoperative assessment, intraoperative execution and post-operative review will allow surgeons to reliably achieve their alignment goals in knee reconstruction.

Hip

The goals of total hip arthroplasty (THA) not only include the elimination of a painful hip joint, but also the restoration of leg length, offset, and a mechanically stable ball-and-socket joint. To achieve these goals, component positioning needs to optimized. Specifically, the risk of femoral neck impingement on the acetabular rim, polyethylene liner or adjacent unresected bone needs to be minimized in order to avoid pain, edge loading, and accelerated component wear [27].

Historically, the preoperative evaluation of patients with hip arthritis relied on supine plain radiographs [28]. More recently, weightbearing presurgical THA planning has been proposed. This has been driven by the advent of modern imaging technology such as the digitization of traditional X-ray machines and full-body upright stereoradiography (EOS Imaging, Paris, France), as well as the newfound understanding that single-position static images of the pelvis cannot adequately inform the surgeon of optimal implant positioning. The hips and spine are dynamically interconnected through the pelvis, and it is now well established that the sagittal orientation of the pelvis changes in concert with a person's posture during activities of daily living [29]. This concept is best understood by observing two weightbearing radiographs: a lateral radiograph of the lumbopelvic region in the standing position, as well as the same radiograph in the seated position with the hips and knees flexed. Based on these projections, important sagittal spinopelvic alignment parameters have been described: lumbar lordosis (LL), pelvic incidence (PI), spinopelvic tilt (SPT), and sacral slope (SS) [30]. An in-depth analysis of the hip-spine relationship will be provided in a later section of this symposium (Section L).

Hip component positioning was traditionally guided by Lewinnek's "safe zone" in order to prevent component impingement and decrease the likelihood of prosthetic dislocation [31]. This "safe zone" was established based on the traditional technique of the patient supine on a flat X-ray plate. Recent literature, however, has demonstrated that concept of Lewinnek's "safe zone" is not necessarily protective of prosthetic dislocation, especially in patients with degenerative lumbar disease, spinal fusions, and spinal deformity [32–36]. It is now established that pathologically altered spinopelvic kinematics warrant a patient-specific acetabular component safe zone, which has been termed “functional anteversion” or “functional safe zone” based on the variation in acetabular orientation in relation to postural changes [37,38]. Importantly, the acetabular cup must be placed within a narrow range of patient-specific anteversion/inclination values, tailored specifically to one’s spinopelvic mobility and pelvic tilt in certain functional positions [39]. These values can only be determined using weightbearing images in a standing and sitting position to assess the stiffness of the lumbopelvic complex and the functional position of the acetabulum [40,41]. Spinal mobility is a quantifiable risk factor, with an increased risk for dislocation conferred with less than 20 degrees of flexibility in LL from the standing position to a flexed seated position [42]. The Hip-Spine Workgroup therefore advocates that four static radiographs be obtained for preoperative planning prior to THA: a supine AP pelvis, a standing AP pelvis, a standing lateral pelvis, and a seated lateral pelvis [29]. These images should be ideally obtained on 36-inch radiographic cassettes or by stereoradiography (EOS Imaging, Paris, France); however, in many cases, a smaller cassette can still be useful. By comparing the standing and seated lateral radiographs, the hip surgeon will be able to assess the change in pelvic tilt, as measured by the AP pelvic tilt, SPT, or SS. Changes to these values that are <20 degrees from standing to sitting implies a stiff spine that will be unable to tilt posteriorly in a sitting position, increasing the risk of femoroacetabular impingement and resultant instability or premature component wear. For these patients, the Hip- Spine Study Group made a recommendation for increasing acetabular anteversion to prevent a posterior dislocation [29]. Spinopelvic mobility data derived from functional weightbearing radiography not only influences alignment targets, but also influences the bearing choice at times, as some surgeons advocate for the use of a dual-mobility liners in at-risk patients in an effort to maximize stability [43]. The rationale of this practice will be dissected in a later section of the symposium (Section L).

It clear that the biomechanics of the spino-pelvic junction must be considered in the context of acetabular component orientation, and consequently, weightbearing imaging of the hip and pelvis should be obtained as they provide hip surgeons with vital information to determine the optimal surgical plan.

Limb length discrepancy (LLD) is the leading cause of litigation and occurs in up to 32% of patients following THA [44]. Accurate restoration of limb length in THA remains paramount, yet LLD is often a technical error due to insufficient preoperative planning and inaccurate surgical execution. LLD can be measured clinically or radiographically, but for the purpose of this review, only the radiographic methods will be evaluated.

The conventional method for assessing LLD on preoperative radiographs involves drawing a line through the inferior aspect of the teardrops on a weightbearing AP pelvic radiograph, followed by measuring the vertical distance of the most prominent point on each lesser trochanter to the inter-teardrop line [45–47]. This measurement normalizes pelvic obliquity in favor of determining anatomical differences at hips, such as acetabular cartilage degeneration and femoral head wear. Although this method fails to evaluate other sources of LLD apart from the pelvis and proximal femur and may be limited by rotation of the lesser trochanter and adduction or abduction contractures of the hip, it is still the most widely used method at present.

The variation in LLD between supine to standing has been previously examined using supine scanograms [48,49]. Sabharwal et al. included 79 children and 32 adults in whom LLD was secondary to trauma (55%), congenital shortening (18%), Blount disease (14%), or another cause (13%). The measurement of limb length obtained from standing AP radiographs was very similar to that obtained from a scanogram, especially in the absence of substantial mechanical axis deviation. The authors thus proposed the use of a standing AP radiograph of the lower extremities as the initial imaging study for patients with suspected LLD [48]. More recently, the variation between supine and standing radiographs was examined in AP pelvic radiographs, wherein Bhanushali et al. found that the median variation in LLD from supine to standing AP pelvis radiographs was -1.5 mm (range, 0.7 to 6.9), and no cases varied by >10 mm [50].

In patients with hip dysplasia, a supine AP pelvic radiograph may also overlook changes in acetabular version and coverage in weightbearing positions [51]. For patients undergoing hip preservation surgery, suboptimal correction can result in instability or femoroacetabular impingement [52]. Variation between measurements made on supine and standing radiographs may render a surgeon's intraoperative correction on the supine patient inadequate for a standing posture. As such, an appreciation of this variation remains crucial to reduce the risk of complications. Bhanushali et al. analyzed the anterior coverage (AC), posterior coverage (PC), lateral centre-edge angle (LCEA), acetabular inclination (AI), sharp angle (SA), pelvic tilt (PT), retroversion index (RI), femoroepiphyseal acetabular roof (FEAR) index, femoroepiphyseal horizontal angle (FEHA), leg length discrepancy (LLD), and pelvic obliquity (PO) and found that there was significant variation in AC and PT between supine and standing radiographs in patients undergoing PAO surgery for hip dysplasia. It is well established that PT decreases from supine to standing [51,53–58], with variations of between 3° to 5° reported in the literature [51,53,55,56]. A small decrease in AC was also found in several reports [51,53,59], although variations in LCEA and SA remain contentious [51,58,60,61]. Nonetheless, given the aforementioned variations in radiographic parameters on weightbearing versus supine radiographs, it is recommended that both views be routinely obtained prior to periacetabular osteotomy surgery, allowing surgeons to plan using a supine radiograph and adjust their correction by the variation observed between supine and standing radiographs of each individual patient.

Conclusion

Despite the limitations of conventional radiographs, they remain the most practical and readily available imaging tools for preoperative planning in patients with hip and knee arthritis. It is the consensus of this panel that weightbearing radiographs should be obtained whenever possible as they provide additional information on joint space narrowing, lower extremity alignment, the spinopelvic relationship, limb length discrepancy and other radiographic parameters. Technological advancements such as the EOS imaging system could enhance the accuracy and comprehensiveness of these assessments, supporting the use of weightbearing radiographs as standard practice.

MeSH Terms

1. Radiograph
2. X-ray

3. Weightbearing
4. Preoperative
5. Hip
6. Knee

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