Kinematic Alignment Technique for Total Hip Arthroplasty

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Key Points

- Kinematically aligning hip components consists of restoring the native hip anatomy, plus or minus adjusting cup orientation and design to account for an abnormal spine–hip relationship.
- By restoring close-to-physiological hip biomechanics and preventing poor dynamic component interaction, the KA technique may be advantageous by improving prosthetic function, patient satisfaction and reducing the risk of revision surgery.
- The individual spine–hip relationship, which is radio-clinically defined, is now becoming a new parameter to consider when planning a hip replacement.
- Defining the spine–hip relationship of each patient is more informative than

just assessing their sagittal lumbo-pelvic kinematics, and is likely to result in more refined surgical planning.

- The kinematic implantation may be performed freehand, and therefore at low cost, by relying on intra-articular anatomical landmarks.

11.1 Introduction

11.1.1 The Concept

The concept was developed as a consequence of the increasing awareness that dynamic function is, in addition to improved arthroplasty materials and component positioning, a significant factor in total hip arthroplasty stability and lifespan [1–4].

The kinematic alignment (KA) technique for hip replacement consists of restoring the native hip anatomy, plus or minus adjusting the cup orientation and design to account for an abnormal spine–hip relationship (SHR) [1, 5, 6] (Fig. 11.1). In other words, it is a combination of both an anatomical hip reconstruction (proximal femur, acetabular anteversion and hip centre of rotation) and a kinematic cup alignment technique [7]. While the former enables a close-to-physiological peri-prosthetic soft tissue balance for optimum prosthetic function and patient satisfaction, the latter could reduce the risk of poor dynamic

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Fig. 11.1 Figure illustrating the restoration of the native anatomy (right) when kinematically aligning (KA) total hip components (left). *COR* centre of rotation, *TAL* transverse acetabular ligament, *SHR* spine–hip relationship

component interaction during activities of daily living (ADLs) for optimal implant lifespan. By generating a component interaction that is the best compromise between the standing and sitting positions, kinematically aligned hip components hopefully prevent the occurrence of an aberrant component interaction during ADLs, which may be clinically advantageous. This personalized technique applies to both stemmed (THR) and resurfacing (HR) implants, and is even more pertinent at a time when arthroplasty patients are becoming younger, with higher demands and expectations, in addition to a longer life expectancy [8].

The KA concept takes the individual SHR into consideration in order to determine a targeted adjustment of an anatomical cup positioning [6]

(Fig. 11.2). The subsequent plan can be well executed without the need for costly technology. Several reported strategies exist for taking the individual lumbo-pelvic sagittal kinematics into consideration when implanting hip components [9, 10], however they differ slightly from the reported KA concept presented here [1, 5, 6]. With other strategies, following radiographic estimation of the individual lumbo-pelvic kinematics, a targeted cup orientation is defined and then executed with the use of intraoperative technological tools [9, 10]. The radio-clinical definition of the individual SHR provides information on the patient's lumbo-pelvic kinematics, the presence of a spine–hip and/or hip–spine syndrome [11], the spinal sagittal balance status and, lastly, the constitutional biomechanical spine

Fig. 11.2 Simplified Bordeaux classification of spine-hip relationship (SHR) with types 2A, 1, B, C and D. The risks of poor functional component interaction and the

need for cup adjustment (design and orientation) are likely to increase from left (yellow colour) to right (red colour)

profile (this depends on the pelvic incidence value and whether the patient is a spine or hip user) [1]. Kinematically aligning hip components is therefore a sophisticated concept that leads to more refined THR planning.

11.1.2 The Rationale

Gold-standard techniques for implanting hip components have generated good long-term outcomes, but have failed to solve the common residual complications affecting modern prosthetic hip patients [8]. Those conventional techniques are designed to be biomechanically sound, do not aim to accurately reproduce the native hip anatomy [12], and traditionally involve either systematic [12] or combined component orientation [13] approaches. Despite successful reports, complications related to poor component interaction such as edge loading [14], articular impingement [15–17] and prosthetic instability [18] remain. Interestingly, the higher surgical precision achieved by means of technological assistance (computer navigation and robotics) has failed to significantly improve clinical outcomes of conventional THA [19]. Another interesting finding is the poor correlation observed between the static standing/supine radiographic cup orientation and the risk of conventional THA

instability [20–22]. Those last observations challenge the accuracy of such conventional implantation philosophies.

Alternative anatomic alignment techniques for implanting hip prostheses have successfully been promoted over the past few decades, but they have also failed to lessen the burden of residual complications from which prosthetic hip patients suffer [23–25]. These techniques aim to restore the native hip anatomy (with the exception of the acetabular inclination), and are best characterised through the following examples: use of the transverse acetabular ligament (TAL) for aligning the cup [23], hip resurfacing [26] and neck-sparing total hip replacement (neck anchor-age short femoral stem designs) [27]. The rationale for anatomical implantation lies in the following:

1. The limited ability to calculate an ideal cup orientation from preoperative images due to the multiple acetabular functional orientations and femoro-acetabular interplay combinations that individuals display during ADLs [28, 29].
2. Most hip pathologies causing degeneration (e.g. cam impingement, most pincer impingements, low-grade dysplasia, avascular necrosis, genetic, protrusio, all causes of hip arthritis, synovial diseases) are automatically corrected when modern high-tolerance (high

Fig. 11.3 Classification of abnormal lumbo-pelvic sagittal kinematics. *PI* Pelvic incidence

head-neck ratio) hip components are anatomically positioned.

3. The fact that restoring the native hip anatomy improves prosthetic hip function and patient satisfaction through the generation of a more physiological peri-prosthetic soft tissue balance and prosthetic hip kinematics [16, 30, 31].

Similar to conventional techniques, despite having been reported as safe and suitable for the majority of patients, several complications remain with anatomically implanted hip prostheses, primarily related to poor dynamic interaction of components [23, 27, 32]. Many of these may be explained by a lack of consideration for the functional aspect of the acetabular orientation, or in other words, through neglecting the individual lumbo-pelvic sagittal kinematics/SHR [32].

The presented kinematic alignment technique takes into consideration the functional acetabular orientation to allow more refined THA planning, and hopefully improved clinical outcomes of prosthetic hip patients [1, 5, 6]. Neglecting the sitting component interaction, along with the fact

that many complications occur when sitting, probably partly explains the poor correlation observed between the static standing/supine radiographic cup orientation and the risk of conventional THA instability [20–22].

The classification of abnormal lumbo-pelvic kinematics (Fig. 11.3) and SHRs (Table 11.1) [1], along with methods for defining the individual SHR (Fig. 11.4) and for determining the amount of cup adjustment needed (design [1] and orientation [6]) (Table 11.2) has previously been published. There are primarily two abnormal lumbo-pelvic kinematics (Fig. 11.3), the first being related to individuals who sit without sufficiently retroverting their pelvis (type 1 abnormal lumbo-pelvic kinematics – SHR B), and the second is the result of an ageing process with a stiff degenerated spine, locking the pelvis in a chronic retroverted position when the patient stands (type 2 abnormal lumbo-pelvic kinematics – SHR C/D) [1]. Both abnormal lumbo-pelvic kinematics (type 1 [32, 33] and type 2 [34–37]) adversely affect prosthetic hip patient outcomes (spine–hip syndrome), as they alter the sitting (type 1) or standing (type 2) acetabular orientation

Table 11.1 Simplified Bordeaux classification of spine-hip relationship and their diagnostic criteria

LPC	Simplified Bordeaux classification of SHR					
	Flexible LPC	Stiff LPC				
SHR	A	I	B	C	D	Fused spine
Diagnosis	PI >30° No standing PI-LL mismatch > 10° delta SS from standing to sitting	PI <30°	No standing PI-LL mismatch < 10° delta SS from standing to sitting	Standing PI-LL mismatch Normal SVA	Standing PI-LL mismatch Abnormal SVA	Instrumented or biologically fused spine

SHR Spine–Hip Relationship, LPC Lumbo–Pelvic Complex, PI Pelvic Incidence, LL Lumbo–Lordosis, SS Sacral Slope, SVA Sagittal Vertical Axis distance

Fig. 11.4 Algorithm for defining the individual spine–hip relationship (SHR). *PI* pelvic incidence, *LL* lumbar lordosis, *SS* sacral slope

and component interaction. When implanting such patients, it is important to adjust the cup (orientation and design) in order to compensate for the abnormal functional acetabular orientation. The appreciation and understanding of the individual SHR is therefore critical for the next stage of improvements in hip arthroplasty.

11.1.3 Intended Benefits

Compared to conventional techniques for replacing a hip, kinematically aligned hip components may potentially *improve prosthetic hip function and lifespan* because of the potential for improved anatomical reconstruction and interaction of

Table 11.2 Algorithm for adjusting the cup orientation to account for the individual spine-hip relationship (SHR)

	Simplified Bordeaux classification of SHR					
SHR	A	1	B	C	D	Fused spine
Cup anteversion adjustment	None (cup parallel to TAL)	Increased cup anteversion by 3.5° (relative to TAL) for every 10° of lack of pelvic retroversion when sitting (normal pelvic retroversion when sitting = 20°)		Reduced cup anteversion by 3.5° (relative to TAL) for every 10° of excessive standing pelvic retroversion (normal standing SS = 75% of PI)		Idem B or C, depending on position of fusion and residual flexibility
Cup inclination adjustment	None (radiographic target: 40°)	Don't change your freehand technique for cup inclination as the additional cup anteversion will increase the radiographic cup inclination (radiographic target: 40° to 50°)				

TAL Transverse Acetabular Ligament, APP Anterior Pelvic Plane

components during ADLs, respectively. The anatomic reconstruction should generate a close-to-physiological peri-prosthetic soft-tissue balance and hip biomechanics, which may be clinically advantageous, and hopefully result in improved prosthetic hip function and patient satisfaction [16, 30, 31, 38]. The better interaction of components during ADLs may decrease the risk of complications related to articular impingement and edge loading (e.g. instability, liner breakage, accelerated wear, squeaking and cup loosening) in addition to reducing the risk of revision, thus benefiting both the patient and society [8]. The benefits are even more likely considering that kinematic implantation is reproducible due to the fact that articular anatomical landmarks (TAL, femoral length and offset measures) are used for setting the components' orientation [39]. The relevance of the KA technique is further accentuated by the fact that implanted patients are now becoming younger and therefore have higher demands and expectations, as well as a longer life expectancy.

11.1.4 Indications and Contraindications

The kinematic alignment technique for hip components is applicable to most patients, as anatomically reconstructed hips are known to be successful [23, 26], and the kinematic cup adjustment aims to compensate for clinically deleterious abnormal spine-hip relations (SHRs) [34, 35, 40]. A series of 41 unselected consecutive KA THA patients has shown acceptable radiographic supine cup orientation and excellent early-term

clinical outcomes (no complications, high function and satisfaction) [6].

Determining which hip anatomical variants should not be reproduced, due to biomechanical inferiority, remains unclear. It seems unreasonable to restore hip pathoanatomies resulting from a post-traumatic malunion, a poorly performed acetabular or femoral osteotomy, a protrusio acetabulum or severe developmental hip disease (high-grade dysplasia or Legg-Calvé-Perthes), as those anatomies are not the result of the development of a harmonious interaction between the acetabulum and the proximal femur. Should we anatomically restore the fraction ($\approx 15\%$) of osteoarthritic hip patients that have an atypical femoral neck and/or acetabular anatomical orientation [12, 41, 42]? The functionality of the acetabulum and femoral neck orientations [1, 12, 43], in addition to the complex femoro-acetabular interplay [44, 45], makes it difficult to predict which hip anatomies may or may not be suitable for anatomic implantation. The fact that good long-term clinical outcomes have been reported with anatomically reconstructed hip patients [23, 26], even in those with degeneration secondary to a low-grade dysplasia [46], indicates anatomical implantation is probably reliable in the vast majority of patients.

In patients with severely stiff, degenerated hip(s), accurate definition of the individual SHR may not be possible, thus compromising kinematic planning. In the former situation, a severely stiff hip is likely to dictate the spine motion (or lumbo-pelvic kinematics) required between standing and sitting positions, thus making post-implantation lumbo-pelvic kinematics difficult to predict [28, 47–49]. In the latter case, bilateral degenerated hips

make it difficult to discriminate clinically between true (resulting from severe spine degeneration) and false (caused by bilateral fixed flexion deformity hip–spine syndrome) spinal sagittal imbalance [11]. In these clinical situations, the pre- and post-operative SHR may significantly differ as a result of the correction of the hip–spine syndrome. Given that the post-implantation SHR is difficult to predict, kinematically aligning hip components in these scenarios should be done with caution.

11.2 Planning a Kinematic Implantation

Radio-clinical definition of the individual SHR: A thorough *clinical examination* is the first step in defining the individual status for spinal sagittal

balance and degenerated hip flexibility. As previously stated, patients with a severely stiff hip or bilateral degenerated hips may not be the best candidates for a kinematic implantation. The second step is *radiographic evaluation* based on the analysis of lateral lumbo-pelvic views in functional standing and sitting positions (Fig. 11.5). This enables the definition of the individual pelvic incidence (PI), the diagnosis of spine degeneration (standing PI–lumbar lordosis mismatch) and an estimation of the lumbo-pelvic kinematics (delta sacral slope and delta lumbar lordosis) (Fig. 11.5) [1]. Ideally, the imaging should be performed with EOS™ bi-dimensional images (Biospace, Paris, France), but, if not available, conventional radiographs are sufficient. The methods for defining the individual SHR and the subsequent cup adjustment (design and orientation) have previously

Fig. 11.5 Preoperative lateral lumbo-pelvic standing (left) and sitting (right) radiographs showing measurements of spino-pelvic parameters in both positions: *PI*

pelvic incidence, *SS* sacral slope, *LL* L1–L5 lumbar lordosis and *SFA* – sacro-femoral angle

been published [1, 6] and are illustrated in Fig. 11.4 and Table 11.2, respectively.

Why take the individual pelvic incidence into consideration when planning a KA THA? The PI is an anatomical and biomechanical pelvic parameter that determines the sagittal spine morphology and kinematics (Fig. 11.6), in addition to the timing and severity of developing a spine–hip syndrome in the case of severe spine degeneration [1]. As a result, the PI has been shown to influence the functional acetabular orientation

[42, 50] and the risk of prosthetic instability [34, 35]. There may be two explanations for this:

- Patients with an abnormally low PI ($<30^\circ$) have a constitutionally low lumbar lordosis, and they are likely to primarily flex their hips (constitutional hip users – SHR type 1) when switching between standing and sitting positions (Fig. 11.6). This use of a large hip cone of mobility is likely to adversely affect prosthetic hip outcomes as a result of the increased

Fig. 11.6 Role of the pelvic incidence on the spine morphology and kinematics. *PI* pelvic incidence, *LPC* lumbo-pelvic complex

risks of articular impingement- and edge-loading-related complications. In the event of spine degeneration, these patients will rapidly decompensate their sagittal spinal imbalance but only moderately modify their hip biomechanics (slight deterioration of the standing acetabular orientation and standing femoro-acetabular interaction, plus slight increase of hip use, causing a moderate spine-hip syndrome). In the event of a hip replacement, such patients (SHR 1) may benefit from a high-tolerance cup design, plus or minus a slight adjustment of the cup orientation to compensate for the poor functional acetabular orientation resulting from the abnormal lumbo-pelvic kinematics (constitutionally stiff spine).

- Patients with a normal PI are likely to display more spine motion, and therefore less hip movement, when switching from a standing to sitting position (constitutional spine users). The use of a low hip range of motion for ADLs is likely to be protective with regard to the risks of prosthetic impingement, edge loading and instability [1]. However, in the situation of severe spine ageing, the loss of spine flexibility may have a severe clinical adverse impact as it significantly modifies the hip biomechanics: there is dramatic deterioration in the standing acetabular orientation and standing femoro-acetabular interaction, plus a significant increase in hip use, causing a severe spine-hip syndrome. This hypothesis may partly explain the higher PI [34, 35] and more severe spine degeneration (SHR types 2C and 2D) [35–37] that characterise unstable prosthetic hip patients. In the event of a hip replacement, such SHR 2D patients may benefit from a high-tolerance cup design in addition to a moderate cup orientation adjustment to compensate for their aberrant standing acetabular orientation.

Defining the cup adjustment (design and orientation) (Table 11.2): Planning a radiographic cup inclination below 50° is important to prevent poor standing and walking component interaction (superior edge loading). In contrast, the kinematic cup anteversion relative to the anterior

pelvic plane cannot be planned as its value primarily depends on the TAL orientation, which cannot be estimated on simple preoperative radiographs. For this specific reason, the KA concept does not aim to plan cup orientation relative to the anterior pelvic plane, but rather the amount of cup orientation adjustment, relative to anatomical positioning (TAL), that is needed to compensate for an abnormal SHR [6]. The key points to understand the rationale supporting the adjustment are:

1. The adjustment should first target the cup orientation, as the restoration of the native proximal femur anatomy and hip centre of rotation is key to producing clinically advantageous, close-to-physiological prosthetic hip kinematics.
2. A cup orientation adjustment is made when, and in addition to, the use of a higher tolerance cup design (larger head [51, 52], dual mobility [53]) is likely to be insufficient in compensating for the poor functional acetabular orientation resulting from the abnormal lumbo-pelvic kinematics.
3. The cup orientation adjustment aims only to compensate for half of the functional acetabular orientation abnormality that results from the poor lumbo-pelvic kinematics (compromised orientation).
4. The algorithm for calculating the amount of cup adjustment needed (Table 11.2) was determined based on the following published observations: the average posterior pelvic tilt from standing to sitting for healthy patients is approximately 20° [54, 55], for every 10° of pelvic tilt there is a change of radiographic cup orientation by approximately 7° (anteversion) and 3° (inclination) [56], and the normal standing sacral slope angle approximates 75% of the PI angle [57].

11.3 Performing a Kinematic Implantation

Kinematically aligning hip components can be performed with or without technological assistance, the latter method having been shown to

Fig. 11.7 Intraoperative steps for performing kinematic implantation of total hip components with manual instrumentation. *TAL* transverse acetabular ligament

Fig. 11.8 Ruler technique for assisting restoration of femoral length and medial offset. The distances between the centre of the femoral head and the greater trochanter (GT – femoral neck offset – (a) and lesser trochanter (LT – femoral neck length – (b) are measured after dislocation,

before the femoral neck cut. This serves to assess the quality of the femoral reconstruction with the trial stem in place (d and e). After the neck cut, ensure you accurately define the centre of the femoral head (c)

be reliable [6]. The freehand KA technique relies on intraoperative anatomical landmarks (e.g. TAL, femoral neck cut) and measurements (e.g. femoral offset and length), whilst following a precise stepwise execution as shown in Fig. 11.7. The *femoral reconstruction* aims to be anatomic, following a modified calliper technique as described by Hill et al. [58], which helps to restore the original femur length and medial offset (Fig. 11.8). Restoration of the constitutional femoral neck anteversion is done by ensuring a cut perpendicular to the neck (Fig. 11.9a, b) and broaching perpendicular to the neck cut (Fig. 11.9c). Regarding the *acetabular reconstruction*, the medio-lateral positioning (or depth) of the cup is adjusted by reaming the acetabulum not excessively medially, but rather sufficiently to restore the native hip centre of rotation as templated before the operation

(Fig. 11.10). The cup inclination is adjusted with the use of the classic alignment rod, in addition to positioning the inferior and superior parts of the cup relative to the inner border of the TAL and the acetabular roof, respectively. The cup anteversion is set relative to the TAL orientation, which has been marked on the skin (Fig. 11.11), as previously described by Meftah et al. [59], and is impacted perpendicular to it (anatomic and kinematic cup positions are identical) unless slight adjustment is needed (anatomic and kinematic cup positions differ) (Fig. 11.11). Whilst freehand anatomic and kinematic implantations are unlikely to be technically demanding [39], it is probable that technology (3D planning, assistive devices for precise implantation and intraoperative quality control tools) would be of value in further improving its reliability.

Fig. 11.9 The femoral cut is made perpendicular to the femoral neck in the frontal and axial planes (a). Following the neck cut, check the cut was properly executed in the

axial plane (b). When broaching the femur and inserting the trial stem, ensure you are perpendicularly aligned to the femoral neck cut plane (c)

Fig. 11.10 Pelvic radiographs showing the planned (above) and performed (below) medio-lateral positioning of the cup

11.4 Clinical Evidence

A single clinical study [6], a matched case-control design on prospectively collected clinical data, concluded that KA-THAs were overall safe, efficacious and not inferior to the conventional

THAs in the short term. The authors compared 41 consecutive freehand KA-THAs with 41 conventional mechanically aligned THAs with 1 year of follow-up. The KA patients had a more anatomical restoration and a higher supine radiographic cup anteversion, but with a similar proportion of cup orientations within the Lewinnek safe zone. Both techniques of alignment had similar excellent clinical outcomes with high function (mean Oxford Hip Score at 43), no instability or other aseptic complications and an average patient outcome satisfaction score of 95.4/100 and 89.5/100 for KA and MA patients, respectively.

11.5 Future Developments

The concept of kinematically aligning hip components is only at its early stage, with many refinements yet to be made. There are a few limitations which currently affect the quality of the kinematic planning, and thus need to be investigated through further research: firstly, the difficulty in accurately defining the preoperative individual SHR. This is due to the existence of various lumbo-pelvic kinematics in an individual between and within (intra-individual variability) multiple ADLs [29, 55, 60], and due to a frequent concomitance with a stiff osteoarthritic hip that may dictate some spine motion [11]. Secondly, it

Fig. 11.11 Skin marking is made parallel to the transverse acetabular ligament (TAL) either through posterior (a) or direct anterior (b) approaches. The TAL skin mark

serves to assist the kinematic cup implantation (a and c). Using the TAL skin mark, the surgeon can adjust the cup anteversion around the TAL orientation (d)

is difficult to anticipate the post-implantation individual SHR that will occur after correction of the hip soft tissue contracture [12, 28, 47, 49]. Lastly, it is the difficulty in anticipating the age-related SHR changes that will occur over years.

11.6 Conclusion

Kinematically aligning hip components involves restoring the native hip anatomy, plus or minus adjusting the cup (orientation and design) to account for an abnormal spine-hip relationship. By restoring close-to-physiological hip biomechanics and preventing poor dynamic component interaction, the KA technique may be advanta-

geous by improving prosthetic function, patient satisfaction and reducing the risk of revision. The kinematic planning is based on the radio-clinically defined individual spine-hip relationship, and the implantation may be performed freehand by relying on intra-articular anatomical landmarks, incurring no additional technological costs. Further research is needed to refine the KA technique.

11.7 Case Illustration

Kinematic implantation on patients having SHR 2A, B and D are illustrated in Figs. 11.12, 11.13 and 11.14, respectively.

Fig. 11.12 A 58-year-old patient with a right osteoarthritic hip and a spine-hip relationship type 2A (normal pelvic incidence $\approx 56^\circ$, normal standing lumbar lordosis $\approx 55^\circ$, normal delta sacral slope $\approx 22^\circ$). The cup and stem (neck-sparing design for subsequent neck anchorage) were then kinematically implanted without the need for a cup orientation adjustment, and a 36 mm ceramic bearing was used. Pre-operative lateral lumbo-pelvic standing

(left) and sitting (right) radiographs with spino-pelvic parameter measurements (a). Preoperative standing pelvic (b) and lateral cross-leg osteoarthritic hip views (c). Total hip replacement planning using Traumacad™ software (d). Post-operative supine pelvic (e) and lateral Dunn (f) radiographs with the kinematically implanted prosthetic hip

Fig. 11.12 (continued)

Fig. 11.13 A 62-year-old patient with bilateral osteoarthritic hips secondary to protrusio and a spine-hip relationship type B (normal pelvic incidence $\approx 44^\circ$, high standing lumbar lordosis $\approx 69^\circ$, low 8° delta sacral slope). In the event of a replacement, anatomically aligning components would have been suboptimal considering the risk of complications (posterior edge loading and posterior instability) related to poor interaction between components when sitting. In order to reduce those risks, the patient received a KA-THA performed through a direct anterior approach, preserving the integrity of posterior hip soft tissue. The stem was anatomically implanted; the cup

orientation was slightly adjusted with an additional 4° of anteversion relative to the transverse acetabular ligament. On both hips, the centre of rotation was not lateralised and no medial acetabular bone grafting was performed; this is because the protrusion was slight and no significant bony overhang was observed at the periphery of the cups during trialing and after final implantation. Pre-operative lateral lumbo-pelvic radiographs (a) in standing (left) and sitting (right) positions. Pre-operative antero-posterior standing pelvic (b) and lateral left hip (c) radiographs. Digital KA-THA templating (d). Post-operative antero-posterior supine pelvic (e) and lateral hip (f) radiographs

Fig. 11.13 (continued)

Fig. 11.14 A 79-year-old patient with severe spine degeneration and a spine-hip relationship type D (decompensated sagittal spinal imbalance). There is a normal pelvic incidence $\approx 60^\circ$ and low standing lumbar lordosis $\approx 18^\circ$ for 42° mismatch, 41° standing pelvic version (normally 20% of PI, which is approximately 12°) suggesting the patient has 29° excessive pelvic retroversion when standing. In the event of a replacement, anatomically aligning components would have been suboptimal considering the risks of poor standing component interaction (antero-superior edge loading and posterior prosthetic

impingement) and anterior instability. In order to reduce those risks, the patient received a KA-THA performed through a mini-posterior approach, preserving the integrity of anterior hip soft tissue, and with an adjusted kinematically aligned dual mobility cup, 5° retroverted relative to the TAL. Pre-operative lateral lumbo-pelvic radiographs (a) in standing (left) and sitting (right) positions. Pre-operative antero-posterior standing pelvic (b) and lateral left hip (c) radiographs. Digital KA-THA templating (d). Post-operative antero-posterior supine pelvic (e) and lateral left hip (f) radiographs

Fig. 11.14 (continued)

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