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Flexion and Extension Gap Balancing in Revision Total Knee Arthroplasty

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Revision total knee arthroplasty presents a unique set of problems when attempting to balance flexion and extension gaps. Loss of soft tissue support and established deformity can make balancing difficult. One needs to balance the flexion and extension gap heights as well as medial and lateral symmetry, which may not always be attainable. We used a set of stepwise techniques to reestablish the joint line in extension using femoral augments, and then balanced the flexion gap using different sized femoral components. We retrospectively analyzed 45 patients who had revision total knee replacement with an average of 4 years followup. These patients had a mean flexion of 105° and none had signs of instability in flexion or extension or on clinical exam. Despite the complex nature of revision knee arthroplasty, cases utilizing an algorithm to balance the extension and flexion gaps, with increased implant constraint when necessary, can aid in obtaining a good outcome.

Level of Evidence: Therapeutic study, level IV (case series). See Guidelines for Authors for a complete description of levels of evidence.

The degree of difficulty a revision total knee arthroplasty (TKA) presents to a surgeon often supersedes that of a primary knee arthroplasty. Substantial osteolysis and loss of soft tissue support of the surrounding knee sleeve often leads to a severe imbalance of the flexion and extension gap heights (Fig 1). Handling these difficulties in a stepwise fashion before relying on a highly constrained implant or hinge replacement may lead to a reliably obtained clinical result and may increase the longevity of the revised implants.

Many authors have reported techniques for knee revision and balancing the flexion and extension gaps.[6,9,18,20,22] Most of these studies reported on the technique of establishing the joint line on the femoral side in extension with distal augments on the femoral component as one of the first steps.[9,21,22] In these studies balancing was accomplished by recognizing changes on the tibial side of the joint would affect both the flexion and extension gaps, while on the femoral side distal augments affect the extension gap, and femoral sizing with or without posterior augments affect the flexion gap. This technique leads to balancing the heights of the flexion gap by using a larger femoral implant. Once the heights of the gaps are equalized, the symmetry of the medial and lateral gaps in extension and flexion can then be addressed.

Gap balancing in revision total knee replacement (TKR) may be complicated by the presence of bone loss from osteolysis which may contribute to loss of soft tissue supporting structures. If soft tissue support has been compromised secondary to bone loss then it may be necessary to utilize an implant with more constraint. The symmetry may not always be an issue if deformity of the lower extremity is not present. However, deformity is often present when there is bone loss from osteolysis or bone erosion from a loose implant. When this occurs, primary total knee techniques may be used for obtaining gap symmetry. If soft tissue support has been lost secondary to bone loss it may necessitate using an implant with more constraint.

The goals of soft tissue and gap balancing in revision TKR should be to create a symmetric medial and lateral joint gap throughout a range of motion (ROM) with proper tibio-femoral alignment. Alignment is established with a neutral mechanical axis in the coronal plane and full extension in the sagittal plane. In the transverse plane, the tibia should remain perpendicular to the epicondylar axis throughout a ROM with the femoral component aligned to the epicondylar axis, if still present, or to the Whiteside anteroposterior (AP) axis.[23] This is often challenging in

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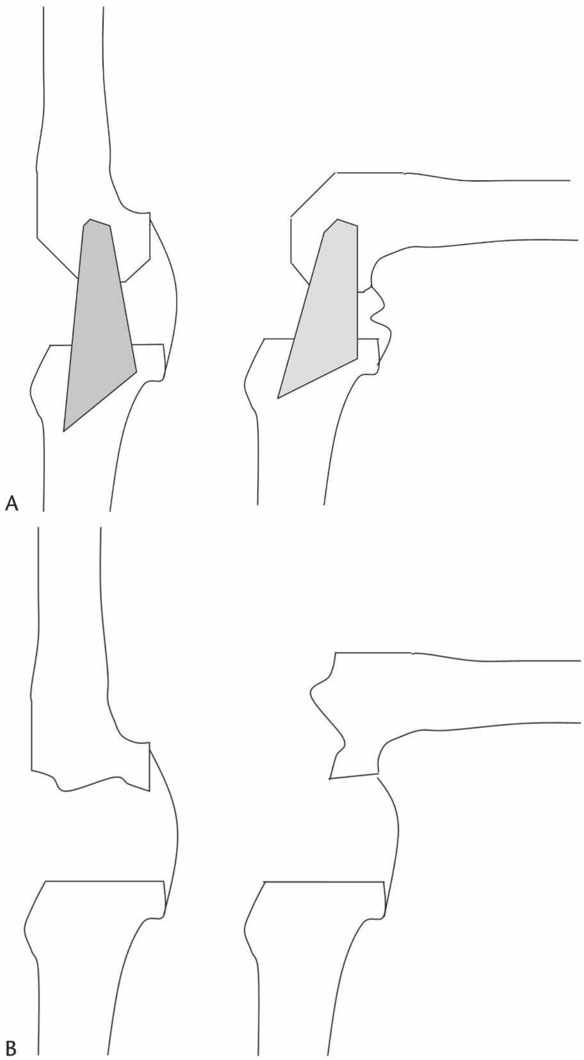

Fig 1A–B. (A) With collateral support (shaded area) the tibia is held to the femur in flexion and extension. (B) When the collateral origin on the epicondyle is compromised the tibia falls away from the femur in flexion until the posterior structures are allowed to support the tibia.

the revision total knee setting due to the issues discussed above.

Given the complexity of issues surrounding revision knee arthroplasty discussed above with the possible presence of soft tissue instability and bone loss which may result in severe asymmetry of the resulting flexion and extension gaps, we developed a stepwise assessment and surgical technique to adequately establish a stable knee revision. We describe that assessment and report a retrospective series using the technique

MATERIAL AND METHODS

We retrospectively reviewed 45 knee replacement revisions utilizing the techniques we describe below. All of the revisions were performed for aseptic or septic (8 patients) loosening of components. These involved selected cases for the senior author (KAK) that involved revisions of both components from 1995 to 2002 with a minimum followup of two years and consecutive cases for the coauthor (WMM) from 2001 to 2004. All cases were grouped to compare preoperative and postoperative ROM, stability exam and Knee Society scores. We included 34 females and 11 males with an average age of 73 years (range 49 to 84). Patients had confirmed knee aspirates for septic diagnosis and radiographic evidence of loosening for the aseptic group. Eight revisions were performed for septic loosening in a staged manner and the remainder were performed for aseptic loosening involving replacement of both components.

Clinical and radiographic data were collected in the office setting of both authors at 6 weeks, 3 months, 12 months, and then on a yearly basis where appropriate. Stability exams were recorded by each surgeon in full extension and flexion for comparison.

When discussing gap balancing in flexion and extension during revision TKA one must understand the implants available as well as their definitions. Most manufacturers offer a variety of implants with varying levels of constraint. These different types of implants may not be necessary for a revision TKA surgery if a stable, well aligned single implant on the femoral or tibial aspect of the joint is present. However, on the femoral side of the joint, this may necessitate the revision of a stable implant if a constrained intercondylar peg is necessary for stability after revising an unstable tibia component.

Some straightforward revisions may allow the use of a posterior stabilized (PS) or a primary joint replacement level of constraint. The PS pegs will not support varus or valgus deflection of the joint, but will prevent posterior translation of the tibia against the femur. As an alternative to a PS type of insert constraint some manufacturers have offered a tibial insert with an increased anterior lip (often described as ultra conforming or conforming plus) which in some cases has a greater jump height than a PS peg in flexion due to the anterior placement of the jump height which is a greater deterrent to subluxation of the joint and therefore limits the amount of posterior translation the tibia has on the femur (Profix, Smith & Nephew, Inc, Memphis, TN). These inserts allow no support to varus or valgus deflection, and use of either a PS or ultra conforming type of implant necessitates a stable gap kinematic profile (a symmetric medial and lateral joint gap in flexion and extension).

The next level of constraint is a constrained intercondylar or CCK type of prosthesis. This has a larger tibial post with a femoral housing that allows constraint in the coronal plane against varus or valgus deflection. In flexion there is still an associated jump height of the peg which is typically greater than a PS insert. With either a PS or CCK type of intercondylar peg if this jump height is exceeded it can cause dislocation of the peg from the femoral housing.[11] These implants are typically utilized when there is an extension and flexion gap mismatch or asymmetry that does not exceed the peg's jump height in flexion (Table 1).

The highest constrained implant is a hinged or linked prosthesis. A hinge type of implant allows support in the coronal

TABLE 1. Jump Height for Four Different Manufacturer Posterior Stabilized (PS) and Constrained Condyler (CCK) Knee Systems in 90 Degrees of Flexion

Manufacturer	PS (mm)	CCK (mm)
DePuy PFC Sigma	16.3	20.3
Smith & Nephew Genesis II	18.0	18.0
Stryker, Inc.		
Duracon	15.9	20.3
Scorpio	15.0	21.0
Zimmer NextGen	17.0	25.0

plane of the tibia throughout a full arc of flexion. These implants are utilized when all attempts of flexion and extension gap balancing have failed, and if there is an unstable or unsupported aspect of the joint gap that exceeds the jump height of a constrained condylar type of peg. The definitions and scenarios described above are applicable to the surgical methods section.[6,20]

The varying levels of constrained implants described above can aid the surgeon to establish a stable revision TKA, but one should realize a more constrained implant may be necessary when the gaps cannot be adequately balanced. Our stepwise technique for gap balancing to obtain a stable knee was utilized with the hope of maximizing implant longevity while minimizing constraint when appropriate.

For a knee revision with stable components but with existing coronal plane deformity and instability (which may result from inadequately aligned components at the time of the index surgery leading to the loss of soft tissue support on the convex side), anatomic alignment was first attained in full extension. The preoperative longstanding radiographic assessments were utilized to reveal any varus or valgus deformities on the femoral or tibial side of the joint. In these cases one should avoid utilizing soft tissue reconstructive procedures when there is a lower extremity deformity present in the face of stable implants, since this places mores strain on the reconstruction and may predispose the reconstruction to failure. Component revision with proper alignment and reassessment of the gaps can then result in a stable construct.

A knee revision with loose components but without substantial bone loss was managed with a similar approach. After the failed implants were removed, bony cuts of the distal femur and proximal tibia were performed to provide a solid foundation for stable fixation, after which the trial components were put in place. The distal aspect of the femoral component was placed to reapproximate the femoral joint line. The joint line was approximated from preoperative radiographs or by measuring from another landmark prior to removal of the component and débridement. When necessary, distal femoral augments were utilized to reestablish the proper joint line position (Fig 2). Once the joint line was established on the femoral side of the joint, the tibial trial inserts were then increased until neutral extension was obtained. The flexion gap was assessed after the trial components were in place. When bone loss did not compromise soft tissue

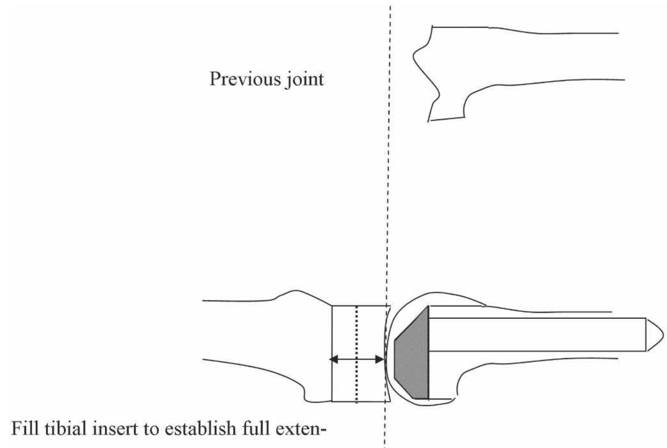

Fig 2. An illustration shows the reestablishment of the distal femoral joint line with augments, and the increase of the tibial insert height to obtain full extension.

support of the collaterals, equalizing the height of the flexion gap was usually obtained by increasing the size of the femoral component if necessary (Fig 3). If a larger femoral component was utilized to fill the flexion gap, the need for an offset stem was assessed to prevent the anterior buildup of the distal femur with the prosthesis which may cause excessive filling of the anterior compartment. One must be careful not to leave too large of a gap, allowing the jump height of the posterior stabilizing or CCK peg of the tibial insert to be exceeded (Table 1). The surgeon should not rely on the quadriceps mechanism to hold the tibia reduced against the femoral implant in flexion. This can be detrimental even in a more constrained condylar type of implant once flexion is obtained postoperatively and the extensor mechanism is elongated.[11]

When unstable components without lower extremity deformity are present, the previous technique may be enough to establish the flexion and extension gap heights, and medial and lateral gap symmetry. After full extension was obtained with an

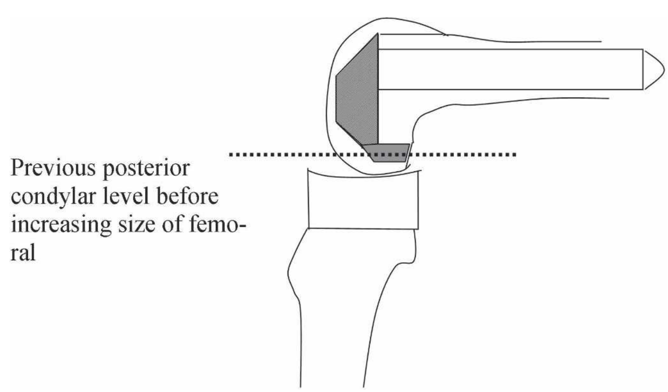

Fig 3. An illustration shows how the component size may be increased to fill the flexion gap.

equalized height of the flexion gap, then the medial and lateral gap stability and symmetry were assessed. The assessment was accomplished by either using trial components to fill the gaps with varus and valgus applied force, or using distraction to assess the symmetry of the gaps.[14] In the revision setting with bone loss or rotational instability of the femoral trial, using mechanical tensioners or an applied varus and valgus force with trial components in place may be difficult. In this case manual distraction of the joint in flexion and extension was often utilized. If the medial or lateral gaps were tight, then soft tissue releases were considered where no loss of supporting structures and a relatively normal medial and lateral soft tissue sleeve of the knee were present.

When substantial bone loss on the tibial side of the joint was present without femoral deficiencies there is often less disparity between the extension and flexion gap. This is usually because continuation of the support of the medial soft tissue sleeve with the periosteum of the upper tibia exists and replacing the void allows for continued support. On the femoral side of the joint this is not always the case. Loss of epicondylar bony support can have a major effect on the flexion space more than the extension space. This is because the more posterior capsular support in full extension may allow for adequate support, but in flexion this side of the soft tissue sleeve is elongated with loss of collateral origins on the epicondyles, which then allows the tibia to fall away from the femur (Fig 1).[9,10,15] In this situation it is necessary to increase the constraint of the implant to a constrained intercondylar or CCK type. If there was a question as to whether the increase in the flexion gap on this side of the joint was excessive enough to allow instability of the intercondylar peg, then a hinged prosthesis was considered.[9,11] As stated previously, the surgeon should not presume the extensor mechanism can lend support of the joint in flexion by holding the tibia against the femur. Once flexion is obtained during the postoperative period it can then lead to stretching and loss of support with eventual instability and intercondylar peg dislocation in flexion.[11]

Once the flexion and extension gap heights were addressed, the symmetry of the medial and lateral aspects of the gaps were assessed and the need for medial or lateral soft tissue sleeve releases considered. Medial releases are most commonly performed on the tibial side of the joint, and lateral releases on the femoral side. Engh and Ammeen described a medial epicondylar osteotomy for exposure and balancing varus deformity.[5] Elkus et al described a pie crusting technique of lateral structures for valgus deformity, which are some of the exceptions.[4] Understanding the differential effects of these soft tissue releases is paramount. Many cadaveric and clinical studies have documented the effects releases have on flexion and extension.[4,8,10,13,15,17,19,24] The extension space is mainly governed by support of the collaterals and posterior soft tissue sleeves. Whiteside et al described the effects of the anterior and posterior medial collateral ligament.[24] He stated the posterior aspect and posterior oblique ligament have more effect on the extension space, and the anterior aspect of the superficial medial collateral ligament has more effect on the flexion gap.[24] The flexion space is mainly governed by the collaterals and the posterior cruciate ligament.[16] When extensive lateral soft tissue release is necessary to balance the extension gap it often leads to a much larger increase in the lateral soft tissue gap in flexion, which can substantially affect stability.[8,15] This happens to a lesser effect on the medial side of the soft tissue sleeve when an extensive release is necessary.[10,19,24]

RESULTS

The average preoperative Knee Society function score was 36 and knee score was 37 for the patient group. At an average 4 year followup period (range 1 year to 7 years), the average ROM was 5° of flexion to a maximum flexion of 105° (range, recurvatum of 4° to a flexion value of 125°) with a Knee Society function score of 57 (range, 35–100) and a knee score of 71 points (range, 50–94 points). There were no complaints of instability in any of the patients. All patients had an increase in their Knee Society knee and function scores at last followup.

No patient had a stability exam recorded over 5° in full extension or 90° of flexion. There were no patients who needed another procedure for instability during this followup period, nor were any peg dislocations reported.

One patient had a structural tibial allograft (Fig 4) placed for support of a deficient cavitary medial condylar defect. Despite the bone loss on both sides of the joint, the knee was stable in flexion and a constrained condylar type of implant was utilized with cemented stems. The patients had an average of 105° ROM and no pain at 18 months postoperatively.

DISCUSSION

Preoperative planning for revision TKR procedures is paramount. Adequate radiographs including longstanding views are necessary to assess weightbearing deformity. The amount of osteolysis and the regions of bone that may allow a substantial loss of soft tissue support (ie, epicondyles) may aid in the operative process. Examination of the joint prior to exposure, with tension and varus and valgus applied stress, can alert the surgeon to the need for a medial or lateral soft tissue release. By predicting the need for a lateral soft tissue release, the surgeon may be less aggressive during medial soft tissue exposure. For the multiple variables that can contribute to difficulties in revision TKA the authors utilize the stepwise approach described for this case series. The methods utilized in the revision cases reported in this series appear to have provided a stable outcome.

As with any retrospective case series, this report is limited by the number of patients and the lack of a comparative control group. We therefore compared our patients to those in previous reports in the literature to interpret the data and provide conclusions.

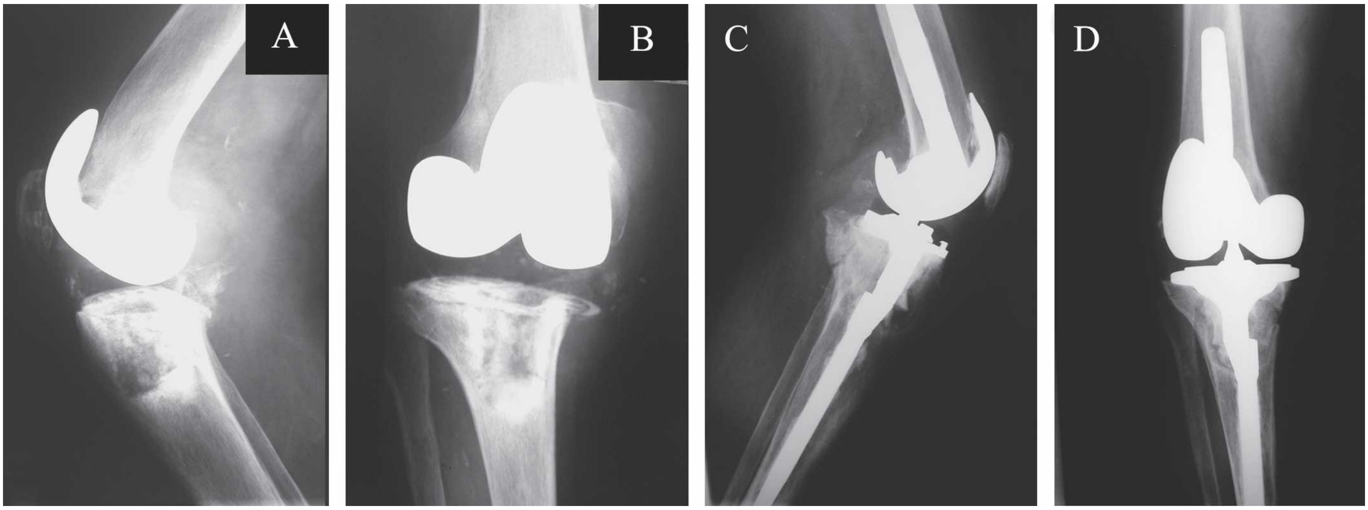

Fig 4A–C. (A) Anteroposterior and (B) lateral radiographs from an outside institution show a failed primary total knee replacement with an all polyethylene tibial component. (C) Anteroposterior and (D) lateral postoperative radiographs from the same patient with a structural femoral head allograft for support from the bone loss of the medial tibial metaphysis.

We reported any medial lateral gap imbalance we deemed substantial and in which we used a CCK type of implant. Soft tissue advancement procedures to aid in balancing are often difficult to perform due to the presence of intramedullary stems, inadequate bone stock, or inadequate soft tissue structures that do not allow support or fixation of the tissues once they are advanced.[12] There may be simple revision scenarios where bone and soft tissue quality are not an issue, where soft tissue advancement procedures may play a role and be helpful once a full medial or lateral release does not allow balancing of the soft tissue gaps. For these situations, surgeons might be helped by reviews of soft tissue support structural advancement techniques.[12]

Our results compared favorably with revision knee replacement studies reported in the literature.[1–3,7,22] Clatworthy et al[3] prospectively reviewed 50 patients who underwent 52 revision knee replacements with structural grafts from three different institutions. Twenty-nine knees in 27 patients were then evaluated at an average of about 8 years postoperatively.[3] Using a modified Hospital for Special Surgery (HSS) knee score, they found an improvement from 32.5 points preoperatively to 75.6 points at their last evaluation.[3] Maximum flexion obtained in these patients increased from 60.5° preoperatively to 88.6° after revision surgery. Thirteen of the revisions failed, resulting in a 75% success rate. They reported 72% of the allograft survived.[3] Despite using substantial structural allograft, this series had a relatively high success rate.[3]

Barrack et al[1] reported on 14 revision knee replacements using a rotating hinge implant with 2–6 years followup. They compared the results to a series of 87 patients who underwent revision with a constrained condylar implant. Their results were comparable to other reports in the literature for knee scores and ROM despite the fact their series had more complicated revisions cases that required linked types of implants.

Whiteside[22] reported on 89 revision knee replacements using a standard condylar implant with ligament balancing techniques. All knees were balanced by the filling effect of the implants and the tibial insert.[22] Patients had no symptomatic laxity with an average of 3° of laxity measured at 5 years followup, and less than 5° at 10 years followup.

Haas et al[7] reported on 67 revision TKRs with up to an 8-year followup. Using a condylar revision system with uncemented stems, their postoperative knee score averaged 76. At last followup, 84% of patients had good or excellent results and 7% had fair or poor results. The remaining six patients had revision failure and necessitated another operation.

Despite the complex variables affecting total knee revision surgery, good results can be obtained by using sound principles and surgical technique. Our report offers information to aid surgeons in reliably obtaining successful results.

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