Low-Dose Irradiation and Constrained Revision For Severe, Idiopathic, Arthrofibrosis Following Total Knee Arthroplasty

Abstract

Treatment options for arthrofibrosis following total knee arthroplasty include manipulation under anesthesia, open or arthroscopic arthrolysis, and revision surgery to correct identifiable problems. We propose preoperative low-dose irradiation and Constrained Condylar or Rotating-hinge revision for severe, idiopathic arthrofibrosis. Irradiation may decrease fibro-osseous proliferation while constrained implants allow femoral shortening and release of contracted collateral ligaments. Fourteen patients underwent fifteen procedures for a mean overall motion of 46 degrees and flexion contracture of 30 degrees. One patient had worsening range of motion while thirteen patients had 57 degrees mean gain in range of motion (range 5-90 degrees). Flexion contractures decreased by a mean of 28 degrees. There were no significant complications at a mean follow up of 34 months (range 24 to 74 months).

Introduction

Arthrofibrosis following total knee arthroplasty is a frustrating complication for the patient and the surgeon. Although arthrofibrosis may result from operative technical errors, infection, instability, or other complications [1,2], idiopathic arthrofibrosis is not uncommon [3]. The overall incidence of arthrofibrosis is difficult to determine owing to controversy regarding the range of motion at which the knee is considered stiff and whether flexion contracture represents a significant limitation independent of the arc of motion [3,4,5,6]. In one report, 1.3% of posterior stabilized implants developed postoperative stiffness and almost one half of these cases were considered idiopathic by the authors [2]. The patient's perception of functional limitations imposed by the stiff knee is also variable. It is influenced by individual and cultural needs and is therefore, difficult to quantify. Some authors proposed utilizing gait analysis and activities of daily living to diagnose stiffness and recommend intervention [1,7].

Preoperative limitation of motion is a strong predictor of stiffness following total knee arthroplasty [3,8], and the degree of stiffness allowed to develop before arthrofibrosis is treated may influence the final outcome [7]. Despite the tendency to perceive the degree of stiffness as the principle prognostic factor, the duration of stiffness, the maturity of the scar tissue, the presence of

heterotropic ossification, and the patient's biologic response to surgical trauma may play significant roles [9,10,11].

Arthrofibrosis may be treated with manipulation under anesthesia, arthroscopic arthrolysis, open arthrolysis with or without exchange of the polyethylene insert, and revision surgery to correct a technical error, replace loose or unstable components, or even revise well-fixed, well-aligned implants [3,4,6,8,9,12,13,14,15,16,17,18,19,20]. There are two strategies for treatment of arthrofibrosis. One strategy aims at increasing the capacity of capsular and periarticular soft tissues to accommodate the retained components through closed manipulation [9,13,20], or arthrolysis [15,16]. The other strategy involves insert exchange or revision arthroplasty to alter the flexion and/or the extension gap and increase the range of motion [3,4,6,7]. When revision corrects a complication or addresses an identifiable positional, or sizing error, the surgical rational is clear and the outcome is favorable [6,8]. A challenging situation however, is idiopathic arthrofibrosis particularly when it is longstanding and resistant to treatment. Furthermore, some patients may have an inherent tendency to develop significant scarring and/or heterotropic ossification [9,10] representing an important biological component of arthrofibrosis.

We performed preoperative irradiation and revision arthroplasty with femoral shortening and Constrained Condylar or Rotating-

hinge implants for severe, idiopathic, longstanding arthrofibrosis. Low-dose irradiation of 800 rads was utilized, similar to prophylactic irradiation for heterotropic ossification of the hip at our institution. The goal was to suppress fibroblastic proliferation similar to treatment of skin keloids [21], and prophylaxis of heterotropic ossification in high-risk patients undergoing total hip arthroplasy [22]. We hypothesized that avoidance of radical arthrolysis may minimize postoperative scarring in predisposed patients. Therefore, we attempted to surgically improve the arc of motion within the confines of the contracted capsular and periarticular tissues by implant revision associated with femoral shortening and without extensive arthrolysis. However, release or recession of severely contracted collateral ligaments was necessary and revision with a constrained implant was required to restore knee stability.

Materials and methods:

This is a retrospective chart review aiming to determine the outcome of preoperative low-dose irradiation of 800 rads and revision arthroplasty with femoral shortening and Constrained Condylar or Rotating-hinge prostheses for severe, longstanding, idiopathic arthrofibrosis following total knee arthroplasty. Institutional review board approval was obtained then, the computerized database maintained at our department was queried

to identify all patients who had severe limitation of motion defined as flexion contracture of 30 degrees or more and/or an overall motion arc of 70 degrees or less, had a minimum of 4 months delay between total knee arthroplasty and presentation, and have a minimum follow up of two years. Exclusion criteria were: mild or early stiffness typically treated by manipulation under anesthesia, infected stiff arthroplasties in which the treatment of infection prevailed, and the presence of loosening, instability, or mal-alignment that provided an explanation for stiffness and therefore, potential guidelines for treatment. Twenty patients who met the surgical inclusion criteria were identified. Six patients were excluded due to short follow-up. The remaining 14 patients (table 1) underwent 15 procedures utilizing the proposed technique between November 2003 and November 2009 for severe, idiopathic arthrofibrosis and were included in this report.

There were 11 females and 3 males with a mean age of 60.2 years at the time of revision (range 48-69 years). One patient had index knee replacement at our institution while the remaining 13 patients were referred following total knee arthroplasty performed elsewhere. Eighteen unsuccessful procedures to improve range of motion were performed prior to referral: Eight patients had one manipulation under anesthesia each, and two patients had two manipulations each, 3 patients had one arthroscopic arthrolysis

each, while 3 patients had open arthrolysis that was combined with patellar component removal in one.

All patients were disabled by severe limitation of range of motion. The mean arc of motion at presentation was 46 degrees (ranging from complete stiffness to 80 degrees motion arc). Two patients had arc of motion of 80 degrees each and were still offered the procedure due to severe flexion contractures of 30 and 40 degrees. Twelve of fourteen patients had a mean flexion contracture at presentation of 30 degrees (range 10 to 45 degrees). The mean flexion in all patients was 71 degrees (range 35-120 degrees). None of the patients had an extension lag.

Routine preoperative radiographic evaluation included standing weight-bearing anterior-posterior, lateral, skyline, and long alignment views. These views were obtained in all patients to confirm proper alignment and fixation of implants and to determine the mechanical axis. All components were well fixed and well aligned with proper level of joint line and all knees were clinically stable. Radiographic evaluation revealed significant heterotropic ossification of the quadriceps, the posterior capsule, and/or the collateral ligaments in three patients.

All patients included in this report had serologic testing and knee aspiration to exclude infection prior to surgery. None of the

patients had history of contact allergy to metals and therefore, routine testing was not performed. Revision was performed at an average of 20 months (range 4 to 67 months) following total knee arthroplasty. The revised implants included 6 Cruciate Retaining, 8 Posterior Stabilized, and one Constrained Condylar implants.

Technique:

All patients received 800 rads of external beam irradiation to their knees immediately before surgery. Under general anesthesia and muscle relaxation, all knees were re-examined to confirm stability then, cautiously manipulated to confirm the severity of stiffness. Surgical exposure involved a midline skin incision unless otherwise dictated by unusual preexisting scars. A generous medial parapatellar arthrotomy allowed the development of the suprapatellar pouch and gutters. Dissection in the region of the distal femur remained extraperiosteal without intentional resection of synovium in order to minimize postoperative fibrosis. The goal was to achieve implant removal with the least surgical trauma. Proper alignment, rotation, and fixation of prosthetic components were verified prior to implant removal. The fibrotic retropatellar fat pad was excised to allow lateral patellar subluxation and exposure of the tibial polyethylene insert that was removed as soon as exposure allowed. Exposure of the tibia was enhanced by dissection of the posterior medial corner in flexion and external

rotation. In preparation for femoral component removal, the collateral ligaments were protected behind retractors to expose the posterior condyles and disrupt the fixation interface. However, the collateral ligaments were frequently hypertrophic or occasionally, ossified and their release was necessary to obtain range of motion. No extensile measures as quadriceps snip or tibial tubercle osteotomy were required for exposure despite severe stiffness. The tibial component was removed utilizing standard techniques. The flexion and extension gaps were subsequently examined and the quality of the collateral ligaments and their bony attachments, the hypertrophy and ossification of the posterior capsule, and the extent of femoral shortening required to correct the flexion contracture were evaluated.

Severe capsular and collateral ligament scarring and/or heterotropic ossification was encountered in 9 procedures. This required collateral ligament resection and significant distal femoral shortening to improve range of motion. In addition, hypertrophy of the posterior capsule produced impingement on the posterior tibia in deep flexion resulting in forward dislocation of a constrained condylar trial in some cases. A rotating-hinge implant (OSS, Biomet Inc., Warsaw, Indiana) was therefore, required for reconstruction in all 9 procedures. A reduced size femoral component was preferred to enhance motion, improve

patellofemoral kinematics, and allow tension-free arthrotomy repair (Figure 1 a,b). In the remaining six procedures, sufficient femoral shortening was achieved while the distal femoral cut remained below the epicondyles. Therefore, the collateral ligaments could be preserved and a constrained condylar implant (SSK, Biomet Inc., Warsaw, Indiana) could be utilized. This implant has a deeper femoral box and a larger tibial polyethylene post than standard designs allowing restoration of varus/valgus, rotational, and flexion stability (Figure 2 a,b). We utilized cement for fixation in the femoral and tibial metaphyseal segments and press fit, nonporous, titanium stems to engage the isthmus. The patellar component was resected to increase the flexion range unless the remaining bone was considered too thin that the fracture risk was high. Lateral retinacular release combined with medial plication and distal advancement of the vastus medialis at the time of arthrotomy repair was performed when necessary to ensure adequate patellar tracking and improve the range of flexion. Deep suction drains were utilized in all cases.

Postoperatively, aggressive rehabilitation in addition to night extension splinting in patients with flexion contracture was initiated to maintain range of motion. Follow-up clinical and radiographic examination allowed documentation of surgical outcome particularly postoperative complications, need for

manipulation under anesthesia, range of motion, functional outcome, patient satisfaction, and implant survival. Restoration of functional range of motion, and correction of flexion contractures were the primary outcome measures in evaluation of the proposed technique.

Results

The mean follow up was 34 months (range 24 to 74 months). All except one patient were compliant with prescribed postoperative physical therapy and splinting. Manipulation under anesthesia was performed in seven patients, once in four patients and twice in three patients within 4 to 6 weeks following revision. Table 2 shows range of motion outcomes and complications in all patients. Table 3 shows overall gain in range of motion and deformity correction at last follow up.

Range of motion:

One patient presented with 40 degrees flexion contracture and flexion to 85 degrees at 10 months following index total knee arthroplasty performed at an outside facility. He had the proposed treatment along with Constrained Condylar revision and was subsequently dissatisfied at 15 months of follow up due to a residual 20 degrees flexion contracture despite a 110 degrees flexion range. A second revision utilizing a Rotating-hinge implant

was performed to allow further femoral shortening and sacrifice of the collateral ligaments. This resulted in a 5 to 120 degrees range of motion at 24 months of follow up. Another patient presented with 15 to 80 degrees range of motion and had full correction of the 15 degrees flexion contracture at 29 months of follow up following Rotating-hinge revision yet, lost 30 degrees of flexion (overall loss of 15 degrees) and was the only patient who lost motion. The remaining patients had 57 degrees mean gain in overall range of motion (range 5-90 degrees). When all 14 patients at last follow up were evaluated, the mean gain in range of motion was 52 degrees resulting in a mean arc of 98 degrees (range 50-130 degrees).

Range of flexion:

Twelve of fourteen patients had less than 90 degrees flexion range at presentation. Postoperatively, increased flexion with mean improvement of 35 degrees (range 5-85 degrees) was identified at last follow up. The mean flexion in all 14 patients at last follow up was 100 degrees (range 50-130 degrees).

Flexion contracture:

Twelve of fourteen patients presented with flexion contractures and required 13 revision procedures to obtain a mean correction of

28 degrees. Only 4 patients retained some degree of flexion contracture at last follow-up; mean 8 degrees (range 5-15 degrees).

Extension lag:

All patients developed an early postoperative extension lag that was particularly manifest in cases with significant emphasis on improving the range of flexion. The extension lag was temporary and full recovery was achieved at last follow-up except in two patients who were still satisfied with their outcomes despite 5 and 10 degrees residual extension lags.

Functional outcome:

All except one patient perceived improved functional capacity attributed to increased range of motion and less pain at the time of last follow up. Upon direct questioning, nine patients were highly satisfied with their results, one patient was satisfied, and one patient was dissatisfied at last follow up. Satisfaction was not reported in three patients. Complete preoperative and final knee society scores at last follow up including both clinical and functional components were available in 7 patients who were followed for an average of 31 months. Their mean preoperative knee society clinical score was 44 (range 25-62). This score improved at last follow up to a mean of 85 (range 74-94). Their mean preoperative knee society function score was 36 (range 5-

70). This score improved at last follow up to a mean of 71 (range 50-90).

Complications:

Postoperative complications occurred in three patients. These included an intraarticular hematoma that required surgical evacuation in one patient, incisional cellulitis that required I.V antibiotics in one patient, and asymptomatic pulmonary embolism following re-revision in one patient. All complications were treated uneventfully. There were no postoperative instability, aseptic loosening, deep prosthetic infection, or implant failure at the time of last follow-up. However, one Constrained Condylar Knee implant required re-revision to correct residual flexion deformity by further femoral shortening and conversion into a Rotating-hinge implant. All remaining implants were retained at the time of last follow up. There were no complications related to the use of night extension splints in patients with preoperative flexion deformity.

Discussion

Arthrofibrosis following primary total knee arthroplasty varies in severity from mild early stiffness amenable to closed manipulation, to severe ankylosis that may be more disabling than the arthritic knee. The condition may result from technical errors, surgical complications, poor patients' compliance with rehabilitation, or

may develop without an identifiable cause [1,2,3]. Patients may be disabled by stiffness [1,7,23], or only by flexion contractures despite functional range of motion. As flexion contractures increase from 15 to 30 degrees, the quadriceps is required to increase its maximum contraction force during ambulation from 22% to 51% [24]. Satisfactory functional results have been reported when flexion contractures were corrected even if the overall arc of motion remained unchanged [7].

One study defined stiffness as arc of motion below 45 degrees and flexion contracture more than 20 degrees [6]. Another study defined stiffness as motion less than 75 degrees of flexion or more than 15 degrees of flexion contracture [3]. Other authors defined arthrofibrosis without consideration for flexion contracture [4,5]. In our study, a mean flexion contracture of 30 degrees and a mean arc of motion of only 46 degrees were treated at an average 20 months following index arthroplasty. This severe longstanding arthrofibrosis was further compounded by lack of surgically correctable problems in all patients.

Several techniques have been described for the treatment of knee arthrofibrosis [3,4,6,8,9,12,13,14,15,16,17,18,19,20]. Manipulation under anesthesia has been more effective when performed earlier than 3 to 4 months following arthroplasty [9,13,20]. Arthroscopy has been described for arthrolysis [15,16], or release of tight

posterior cruciate ligaments [8,18,19]. Open arthrolysis with downsizing of tibial inserts to improve extension [12], or upsizing to correct arthrolysis-induced instability [17] have produced either poor outcomes [12] or satisfactory results only in mild to moderate stiffness [17]. The literature on revision arthroplasty for arthrofibrosis is scarce and in most reports, the authors could identify and therefore, correct technical errors by implant revision [4,6,7], a finding that was found to correlate with favorable outcomes [6]. Revision surgery corrected loosening, instability, or oversized components in 8 of 11 knees by Christensen, Crawford et al. [4], 11 of 16 knees by Haidukewych, Jacofsky et al. [7], and 8 of 13 knees by Nicholls and Dorr [6]. We are only aware of one study that specifically reported the outcome of revision arthroplasty for idiopathic arthrofibrosis [25]. This report included only six patients in whom the severity of arthrofibrosis and the rational of revision surgery were unclear, and constrained implants were not required, raising doubts regarding the severity of stiffness treated. All patients in our series had severe, longstanding, idiopathic arthrofibrosis. All knees were clinically stable and thorough analysis of preoperative radiographs confirmed that all components were well positioned, well fixed, and appropriately sized. With preoperative irradiation and constrained revision, a mean gain of 52 degrees in arc of motion and 28 degrees correction

of flexion contractures in our patients compares favorably with other reports on revision arthroplasty for arthrofibrosis and the outcome may be even more satisfactory when the severity of arthrofibrosis and its idiopathic nature in our patients is considered [4,6,7]. The role of proper rehabilitation and the frequent need for postoperative manipulations under anesthesia constituted a significant component of preoperative patient education and counseling. All except one patient had clinically significant improvement in range of motion. This patient was considered to have failed treatment. She was reportedly, noncompliant with postoperative rehabilitation and the treating surgeon's recommendation to undergo manipulation under anesthesia.

The degree of stiffness before treatment is an important prognostic factor in arthrofibrosis [7]. However, knees with similar degrees of stiffness may have dissimilar outcomes probably owing to variability in postoperative compliance with rehabilitation, as well as some patients' specific propensity to form dense scar tissue and/or heterotropic ossification. One clinical-pathological study showed that newly formed fibrous tissue matures during the first 6 months after surgery therefore, restricting the outcome of delayed intervention [11]. Heterotropic ossification represents one stage in a systematic deposition of fibrous and fibroosseous tissues [10]. The incidence of heterotropic ossification following total knee

arthroplasty reached 28% in some reports [9,10]. However, minor calcifications on plain radiographs could be overlooked if not specifically sought and consequently, the true incidence of heterotropic ossification may be underestimated [10]. We report significant radiographic heterotropic ossification in 3 of 14 patients involving the quadriceps, posterior capsule, and collateral ligaments.

In severe, idiopathic arthrofibrosis, we hypothesized that both the biological and mechanical causality should be addressed. Our utilization of preoperative irradiation in attempt to suppress the fibroblastic and fibroosseous proliferation was derived from well-established applications in plastic and orthopedic surgery. Freund first reported the restoration of hypertrophic scars to normal skin by Roentgen treatment in 1898; only three years after Wilhelm Conrad Rontgen detected x-rays. Harris subsequently reported preoperative roentgen exposure for the treatment of keloids in 1901. The first combination of surgery and postoperative Roentgen treatment of keloids was described by Freund in 1909 [21]. Currently, surgery combined with irradiation is an effective treatment for keloids [26]. In orthopedics, low-dose irradiation is an established prophylactic modality against heterotropic ossification following total hip arthroplasty in high-risk patients [22]. We are unaware of other reports on the utility of preoperative

irradiation in the treatment of arthrofibrosis following total knee arthroplasty. In addition, we assumed that further attempts to improve motion by scar excision is unlikely to succeed and should probably be avoided owing to the suspected patients' propensity to form exuberant scar in response to surgical trauma. As opposed to open arthrolysis techniques, we limited surgical dissection to the exposure needed for implant removal and femoral shortening.

Some degree of femoral shortening was necessary in all patients to allow correction of flexion contractures as well as increase the range of flexion. Retrospectively, it is our impression that differences were not clinically significant between patients who had Constrained Condylar and Rotating-hinge implants as regards to range of motion and flexion deformities at presentation as well as at last follow up (table 4). The decision regarding implant selection was made intraoperatively according to the quality of the soft tissues and the degree of femoral shortening required. In patients with severe arthrofibrosis, we frequently observed marked thickening and occasional heterotropic ossification within the collateral ligaments, which limited their elastic properties and excursion. Knee flexion was only achievable after complete release of the collateral ligaments in some cases and a Rotating-hinge implant was therefore, necessary to maintain knee stability. In some cases, a severely thickened and occasionally ossified

posterior capsule impinged on the posterior tibia in deep flexion resulting in forward dislocation of the otherwise robust tibial post during constrained condylar trialing. This finding was also considered an indication for femoral shortening, release of the posterior capsule, and the use of a Rotating-hinge implant, which we utilized in 9 procedures while a Constrained Condylar implant was appropriate in 6 procedures.

Limitations of the current study include first, its retrospective, non-randomized nature and the small number of patients reported. Second, the proposed technique combined biological and mechanical remedies to the problem of arthrofibrosis but the study design did not allow identification of the relative contribution of each hypothesis to the reported outcomes. Third, the undetermined long-term durability of highly constrained implants may stimulate legitimate concerns.

Despite the limited number of patients, the current study is larger than most reports on surgical revision for knee arthrofibrosis [4,6,7,25]. In addition, we are unaware of reports on the utility of a single strategy in the management of severe idiopathic arthrofibrosis. Although the authors believe non-constrained implants are preferable whenever possible, the implantation of constrained knee prostheses was mandatory to restore stability in all patients in this study. Excellent long-term results have been

reported with Rotating-hinge knee implants in 72% of non-neoplastic limb-salvage procedures in one report [27]. The functional benefits are generally considered the primary goals of surgical intervention in such non-oncologic limb-salvage situations in which patients present with a distressing complication and frequently have low functional expectations and demands. We report no failures as a result of infection, aseptic loosening, or instability and no major complications related to the surgical procedure or prosthetic constraints, regardless of implant design at a minimum 2 years and an average of 34 months of follow-up.

Our current experience with preoperative low-dose irradiation, femoral shortening, and constrained revision in severe idiopathic arthrofibrosis following total knee arthroplasty is encouraging. However, longer follow up is necessary to determine long-term durability of the hyposthesis. A larger, prospective, randomized study is required to reveal the relative contribution of low-dose prophylactic irradiation to the prevention of recurrent stiffness in severe, idiopathic arthrofibrosis.

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