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Bifocal treatment for peri-articular femoral nonunions

A retrospective case series review

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Abstract

Aim: This is a retrospective review of complex periarticular femoral nonunions where bone loss from comminution at original fracture, subsequent infection or lysis was identified and treated by radical excision, internal fixation, and concurrent femoral lengthening from a different level.

Material and Method: Sixteen patients with a mean age of 41 years were treated. There were 6 infected nonunions. Ten nonunions were located in the distal femur and the remaining proximal. Case notes and radiograph review were used to determine fracture union, lengthening achieved, and complications. Patient outcome was assessed using the SF-12, Tegner–Lysholm Knee Score, and Oxford Hip Score.

Results: Fracture union was achieved in all patients. The mean lengthening performed was 51 mm (range 30–80) with a fixator time averaging 39 weeks (range 17–80). The bone healing index was 1.9 months/cm. All but 2 patients were restored to within 5 mm of opposite leg length; 1 patient subsequently underwent contralateral limb shortening. The SF-12 had a mean Physical Health Composite Score of 40.0 (22.4–52.9) and a mean Mental Health Composite Score of 49 (30.7–62.0). The Oxford Hip Score was scored at a mean of 39 (21–47) and the Tegner–Lysholm score had a mean of 71 (36–94). There were 3 cases of fracture/deformity from the lengthened bone column (regenerate) and 2 patients required a quadricepsplasty for knee stiffness that was present prior to the treatment for the nonunion.

Conclusion: Bifocal treatment of complex periarticular femoral nonunions offers a single solution for dealing with bone loss, nonunion, and instability. The method is safe and reliable but has, as with all methods involving distraction osteogenesis, a significant complication rate. Despite this caution, the patients' outcomes were satisfactory.

Abbreviations: LRS = Limb Reconstruction System, MCS = Mental Health Composite Score, PCS = Physical Health Composite Score, PMMA = Poly(methyl methacrylate), SF-12 = 12-Item Short Form Survey, SPSS = Statistical Package for the Social Sciences.

Keywords: external fixator, femur, fracture, hip, Ilizarov, internal fixation, knee, limb lengthening, nonunion, trauma

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1. Introduction

Subtrochanteric and distal nonunions of the femur are recognized as difficult to treat. The objectives of treatment are to restore bony continuity, align and restore limb length without compromise to nearby joint function. Removal of the nonunion site allows an alteration of fracture biology and biomechanics; healthy bone surfaces can be opposed with a reduction of shear through the change in the shape of the fracture line. Stable internal fixation allows for healing but the excision introduces a limb length reduction which is greater if it is of a segment of bone.

Massive autologous cancellous bone grafting or a fibular strut graft has been used to restore limb lengths as well as address union. The complication rate is reportedly low but 15% of patients had residual shortening of >2 cm.[1] Bone transport using circular external fixation has been described but carries the morbidity of a prolonged time in external fixation and a risk of quadriceps muscle tethering and knee stiffness.

A different strategy has been used in this unit since 2000; stable internal fixation after alteration of the local biology and biomechanics by nonunion excision coupled to restoration of leg length equality by limb lengthening from an osteotomy at a site distant to the nonunion but within the same femur. The

Figure 1. Anterior-posterior radiograph of proximal femoral nonunion following open reduction and internal fixation and distal lengthening.

authors report a consecutive series of patients with peri-articular femoral nonunions treated with this method.

2. Patients and methods

There were 16 adult patients (15 men, 1 woman) with distal or proximal femoral nonunions associated with bone loss treated from 2000 to 2013 by this method; others with less significant bone loss were either not lengthened or the slight residual leg length discrepancy was accepted and not included in this series. This is a retrospective review of our case series and as such was deemed exempt from Institutional Review Board. The mean age was 41 years (23–60). In 10 patients, the fracture had been sustained in a motor vehicle accident (5 were motorcyclists) and in 6 patients from a fall. The femoral fracture was an isolated injury in 6 patients, one had another associated long bone fracture, and the other 9 had multiple injuries. The mean injury severity score (ISS) was 18 (9 to 32). Nine fractures were closed and the 7 open fractures were all Gustillo-Anderson Grade IIIA. All patients had a minimum of 1 previous failed attempt at operative management of the fracture at the original place of treatment. Of these 14 had one of more attempts at treating the ensuing non-union prior to referral. If infection was considered as a contributing cause, or if equivocal, a white-cell labeled or positron emission tomography-computed tomography scan was performed.[2,3] This revealed 6 probable infected and 10 aseptic nonunions.

Aseptic nonunions were fixed in one stage. The nonunion was exposed using a lateral approach for the subtrochanteric nonunions and, commonly, a combination of a lateral and a medial incision for distal femoral nonunions. Viability of bone was assessed visually and nonviable bone excised. Ends were also excised if this permitted a transverse configuration across the nonunion thereby altering the shape of the fracture and improving biomechanics. The method of definitive fixation was dependent on the treating surgeon's preference, with emphasis placed on achieving end-to-end contact and stability. Plate fixation was used in 14 cases, a retrograde nail in 1, and a combination of a plate and nail in 1. Where end-to-end contact was found to be suboptimal or incomplete despite excision, autogenous iliac crest bone graft was used (10 patients). A typical subtrochanteric nonunion would be fixed with a lateral plate (Fig. 1) and sometimes, an additional anterior plate. Distal femoral nonunions were fixed with a lateral and a medial plate (Fig. 2) with care taken to contour the plates to allow normalisation of the anatomical axis (Fig. 3). One patient who had a previous short retrograde nail was treated by revision retrograde nailing and supplemental plating.

Probable infected cases were treated in a staged manner. At the first operation, the existing metalwork was removed, a full

Figure 2. Anterior-posterior radiograph of distal femoral nonunion following open reduction and internal fixation with double plating.

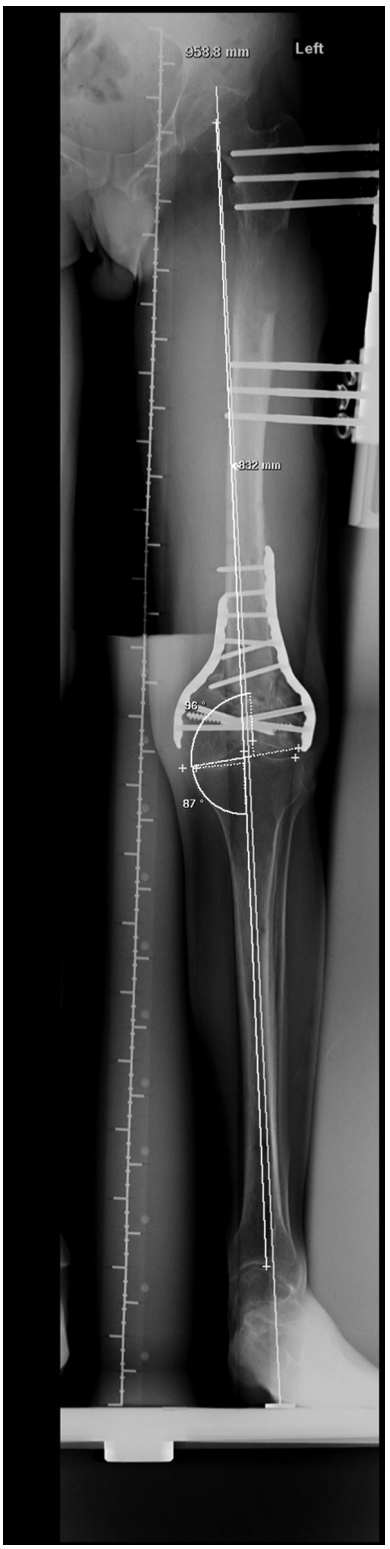

Figure 3. Anterior-posterior long leg alignment radiograph of postoperative distal femoral nonunion showing restoration of mechanical axis and proximal lengthening.

debridement carried out and multiple samples taken for microbiological analysis. The debrided nonunion site was stabilised initially with a temporary spanning external fixator with across-the-knee configurations for distal femoral nonunions

Figure 4. Anterior-posterior radiograph of first stage of treatment of infected distal femoral nonunion following debridement and application of spanning external fixator.

(Fig. 4). Local antibiotic delivery was used with gentamicin impregnated PMMA beads (Septopal, Biomet, Warsaw, Indiana)[4] or calcium sulfate (Stimulan, Biocomposites, Keele, England)[5] mixed with gentamicin.[6] Extended intravenous or enteral antibiotic treatment was given for 6 weeks after bacterial identification and antibiotic sensitivities were reported; this was decided upon in collaboration with medical microbiologists.

In the second stage, typically 6 to 8 weeks after the first, treatment similar to that for an aseptic nonunion was undertaken. The first 3 patients underwent application of a LRS rail external fixator (Limb Reconstruction System, Orthofix SRL, Verona, Italy) and femoral osteotomy for lengthening at a third stage 1 to 2 months after the second stage had been performed. With experience, this third stage was incorporated into the second and the remaining 13 underwent limb lengthening at the same time as definitive fixation of the nonunion. The LRS rail was used for lengthening and the osteotomy performed using published methods.[7]

Distal femoral and supracondylar nonunions had the lengthening osteotomy performed in the subtrochanteric area (Fig. 5). Proximal femoral and subtrochanteric nonunions had, conversely, osteotomies in the supracondylar area.

Patients were mobilised postoperatively partial weight-bearing advancing to greater loads after 6 weeks. Pin site care was performed according to a technique previously published by the unit[8] and in accordance with the British consensus method.[9]

A latency period of 7 days was followed by distraction in accordance with the Ilizarov method of limb lengthening. Monitoring of progress in lengthening and physiotherapy was continued on an out-patient basis. At completion of treatment, the external fixator was removed either in clinic or under anaesthetic. Some patients underwent a substitution of the

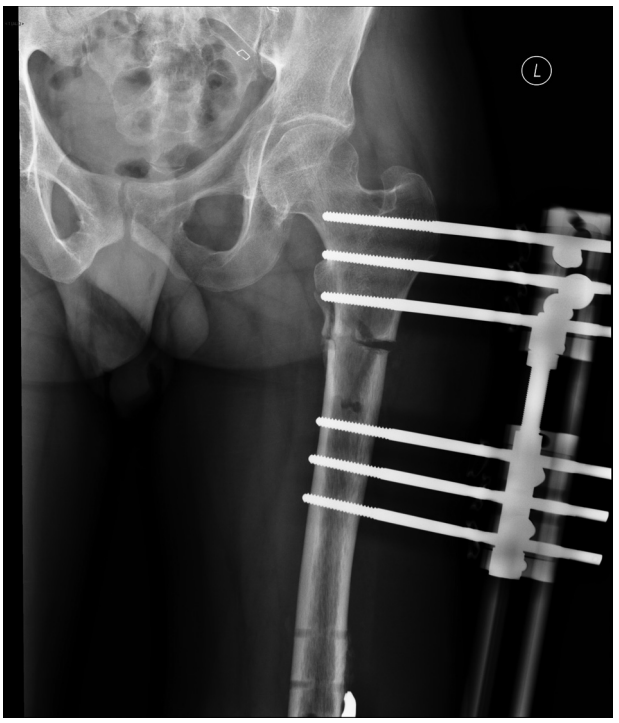

Figure 5. Immediate postoperative anterior-posterior radiograph of proximal corticotomy and lengthening for distal nonunion.

external fixator by a submuscular plate[10] as a planned procedure to reduce the time in external fixation.

Union across the fracture was determined both clinically and radiologically. Classic signs of clinical union (the ability to bear weight fully without discomfort and the absence of pain when stressing the area) were obscured by the presence of stable internal fixation. Radiological means were used principally; callus bridging or blurring of the fracture lines were sought on plain x-rays and, in several cases, computed tomography scanning was used to confirm.[11] Maturity of the lengthening column of bone was assessed on plain x-rays; a radiologically homogenous column (and the absence of the fibrous interzone) with early corticalisation of the edges was sought.

Five outcome areas were assessed: healing of the nonunion, consolidation of regenerate, complications of treatment, functional recovery, and general health status. The potential influence of patient comorbidities and characteristics of the nonunion on the time to union were investigated. The patient's age, ISS, nature of the initial injury (open or closed), and confirmed infection were also considered. The complications of treatment were assessed by the type and number of unscheduled operations. Pin-site infection, which is common with the use of external fixators, was documented but only listed as a complication if intervention greater than the administration of antibiotics was necessary.

The functional recovery was recorded at the final review using the Tegner–Lysholm knee score,[12] the Oxford Hip Score,[13] and general health status was measured by the short-form (SF-)12 version 2 questionnaire.[14,15,16] The Tegner–Lysholm knee score is a questionnaire-based evaluation of the function of the knee and evaluates the patient's ability to manage everyday life. We picked the Tegner–Lysholm score as it is regarded as the gold-standard for ligamentous and osteochondral injury to the knee. There is currently no validated, reliable and reproducible outcome measure for fractures around the knee.[17] The Oxford Hip Score is a

Figure 6. Anterior-posterior radiograph of healed proximal regenerate.

questionnaire-based assessment of pain, gait and activities of daily living, is well validated and widely used in the context of hip arthritis but the scoring areas were felt to be applicable to our patient group also. The SF-12 is a 12-item questionnaire which provides a general measurement of health that can be compared to population norms and has been shown to give comparable results to the more detailed SF-36.[18,19] It has been validated for use in Europe, United States, and Australia, has been studied extensively in trauma subgroups and has been recommended for use in trauma registries.[20] Statistical analysis was performed using Statistical Package for the Social Sciences (IBM, Version 20).

3. Results

The case notes and radiographs were available for all patients. Clinical review with functional and general health assessment was achieved in 13 patients, 3 patients could not be contacted despite multiple attempts. The mean follow-up was 2.7 years (1.0–9.2 years).

3.1. Fracture healing

Union was achieved in all cases at a mean of 22 weeks and median of 18 weeks (range 11–40). Previously closed fractures achieved

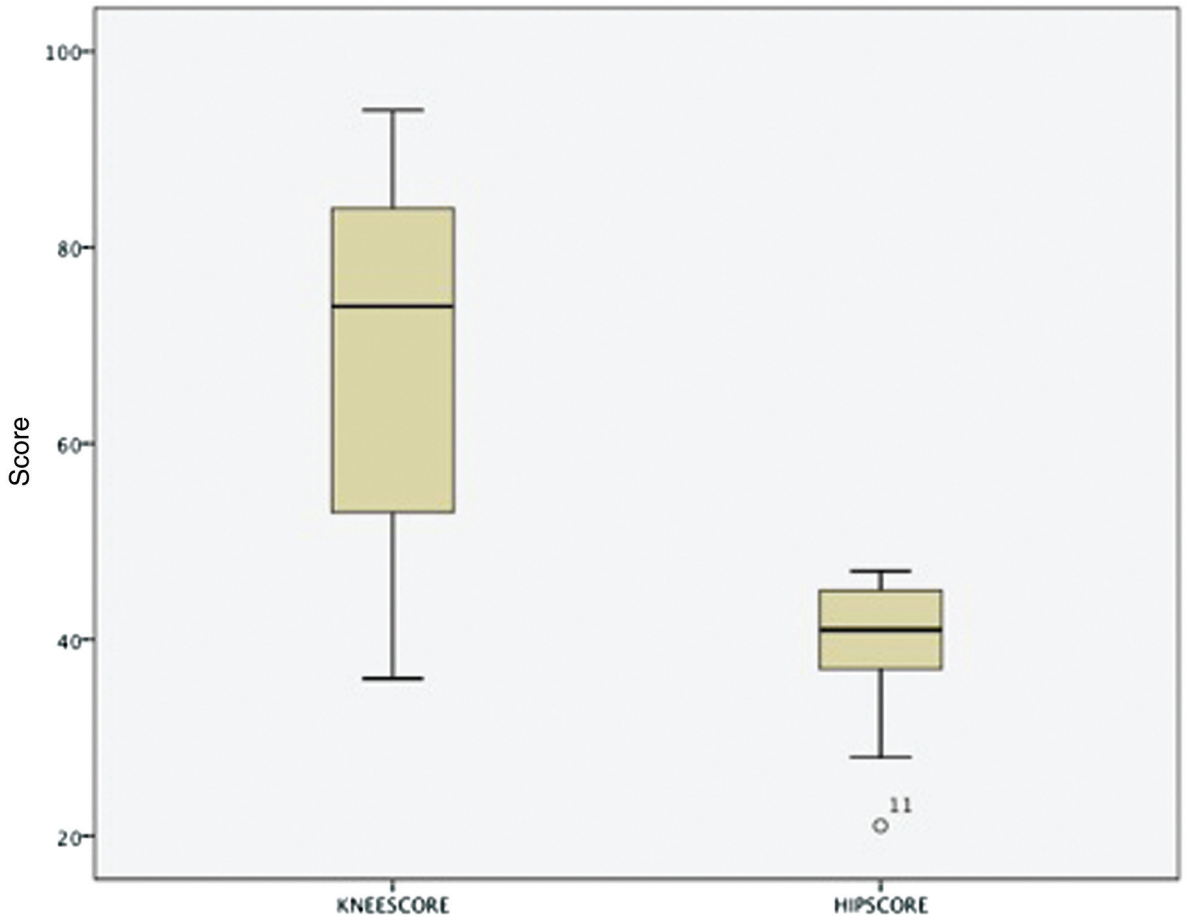

Figure 7. Oxford Hip Scores and Tegner–Lysholm knee scores box and whisker plot.

union in a mean of 19 weeks compared to 26 weeks in open fractures ($P = .313$, Pearson chi square test). Infected cases took 23 weeks to unite whereas aseptic ones took 22 weeks ($P = .452$, Pearson chi square test).

3.2. Regenerate consolidation

This occurred at a mean of 39 weeks (17–80 weeks) after osteotomy for lengthening (Fig. 6). The mean and median length obtained was 50 mm (30–80 mm). The mean lengthening index was 1.9 months/cm, with a mean fixator time of 39 weeks (17–80 weeks).

All but 2 patients were restored to within 5 mm of the opposite limb. One patient underwent contra-lateral shortening after being left with a residual leg length discrepancy and another was left with a residual leg length discrepancy of 20 mm without further intervention.

3.3. Complications

Three of the 16 patients required unplanned intervention at the site of the lengthening. One was treated by plating of the regenerate column for failure to progress to consolidation, another patient underwent half-pin exchange for loosening, and another patient developed fixator instability secondary to fracture through a pin which was revised. None of the 16 patients underwent reoperations at the nonunion site.

3.4. Functional recovery

The Oxford Hip Scores are grouped into satisfactory joint function (40 to 48), mild to moderate impairment of function (30–39), moderate to severe impairment (20 to 29), and severe (0 to 19). The Tegner–Lysholm knee scores are grouped into excellent (>90), good (84 to 90), fair (65–83), and poor (<65) categories. Two patients underwent a Judet quadriceplasty[21] (after completion of lengthening) for knee stiffness present at the time of referral for the nonunion. The mean knee score was 71 (36–94), while the mean hip score was 39 (21–47). This indicated that on average patients were left with fair knee function and mild to moderate impairment of hip function (Fig. 7).

The SF-12 scores were compared to the population norms for both physical component and mental component scores (Fig. 8). The results indicated that both physical and mental components were affected, with a mean Physical Health Composite Score of 40.0 (22.4–52.9) and Mental Health Composite Score of 49 (30.7–62.0) compared to UK mean scores of 50.9 for Physical Health Composite Score and 52.1 for Mental Health Composite Score, respectively.[22] We also compared the physical component scores of those patients with an ISS > 20 with those with a lower ISS and found no significant difference ($p = 0.802$ Pearson Chi Square).

4. Discussion

High-energy peri-articular fractures of the femur that evolve into established nonunions are difficult to treat. Even with modern

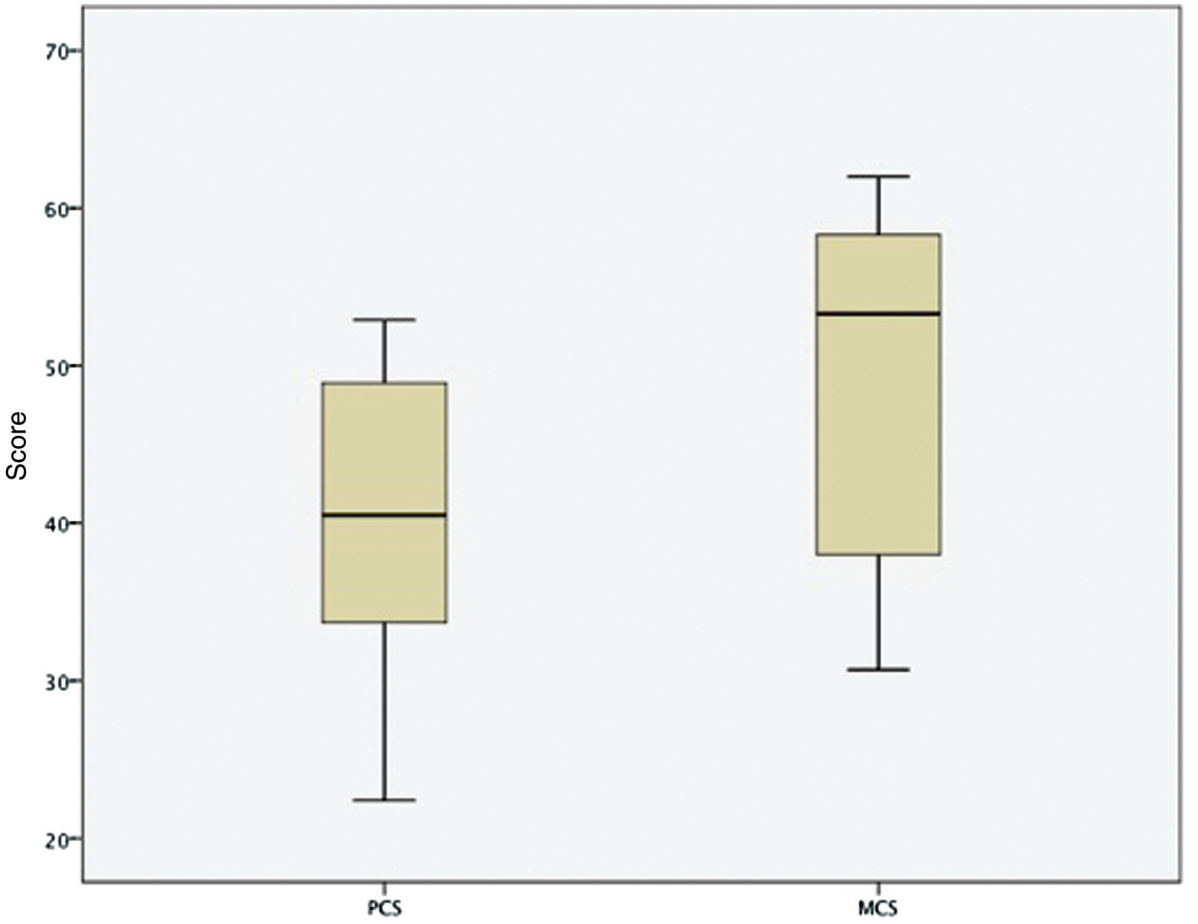

Figure 8. SF-12 scores box and whisker plot.

devices for internal fixation, a nonunion rate of about 20% for fresh fractures is acknowledged. Previous methods of treating such nonunions, for example using blade-plates and bone grafting, have a published union rate of up to 100%[23] taking on average between 16 and 32[24] weeks to unite but with no clear indication of restoration of length or overall limb alignment. This method of treatment is reliant on contact and compression across the nonunion and may produce some leg length loss from compression across comminuted areas. Alternatively, revision internal fixation with maintenance of femoral length may yield insufficient contact at the nonunion site and, unless made up through large cancellous grafts, lead yet again to failure.

Nonunions in the subtrochanteric area are less frequent than those in the distal femur and are seldom reported.[25] A recognized cause is the loss of contact from medial comminution leading to excessive bending stresses across the fixation implant and subsequent failure,[26] as is varus mal-reduction at initial fixation.[27] Both absent contact on the medial side or a varus alignment at fracture reduction produce increased bending moments on the implant, whether intramedullary or laterally sited. Unless specifically addressed, further revisions of internal fixation may fail.

Little has been published on the management of complex peri-articular femoral nonunions. Fourteen patients in this group had undergone one or more operations to address the non-union prior to referral. This was in addition the primary operative attempts at fracture treatment. Whilst a total joint replacement is an attractive option if pre-existing joint arthritis exists, the patients' age and the need for specialized arthroplasty implants may deter this solution for most except older patients. The age of our patients precluded this as a first line option.

External fixators are used treating complex femoral nonunions by either acute shortening at the nonunion site and with concomitant lengthening at the other end of the involved bone or by bone transport. Although union rates of up to 100%[28] have been published, there is a recognition that external fixators in the thigh carry a risk of knee stiffness, notwithstanding issues over patient compliance.

Metaphyseal fractures have a good intrinsic healing capacity because the region carries a good blood supply.[29] Severe fractures in these areas produce compromises in this local biology and this is, sometimes, accentuated by the extent of surgical trauma introduced at the time of fracture reduction and stabilization. When established nonunions are evident here, excision offers a change in the local biology and, by changes in the contact between bone ends and orientation of the major fracture line, in biomechanics. Using internal fixation produces stability without hindrance to recovery of joint motion as compared with external fixation.

This strategy for dealing with such nonunions creates a leg length discrepancy. Allowing for restoration of length in another part of the femur by osteotomy and gradual distraction (thus a bifocal strategy) recovers lost bone and has the added benefit of increasing the blood supply to the rest of the same bone.[30]

Union following the index intervention at the nonunion site was achieved in 100% of our patients, which compares well to

published series.[31,32,33] The success needs to be considered in light of 14 of the 16 patients having had one or more attempts at treating the nonunion elsewhere. While 3 patients underwent unplanned intervention at the site of the lengthening, for 2 patients these were minor day-case procedures.

The Physical Component Summary and the Mental Component Summary scores, despite successful treatment, are below the population mean. This is not uncommon in complex trauma including nonunion surgery in general. Some of these patients had multiple injuries which may have skewed the results. Despite this finding, recovery of limb function through union, restoration of limb length and alignment, and recovery of joint stability and movement remains the principal objective of intervention.

The hip and knee scores were comparable to results published previously.[34] The requirement for a quadricepsplasty to recover knee flexion was lower than in other reported studies where the treatment method relied only on external fixation.[35]

The weakness of this study is the small sample and heterogeneous nature of cases. Statistical analysis, while performed, is unlikely to reveal significant differences. Despite the retrospective review, data collection was complete. The consistent feature throughout was the use of the same strategy of excision of nonunion, stabilization by internal fixation with emphasis on contact and alignment, and restoration of leg length from an osteotomy at a distant site.

5. Conclusion

The bifocal treatment of periarticular femoral nonunions uses a combination of the principles of stable internal fixation and that of the Ilizarov method. It offers an alternative to solving this problem through surgically changing the local biology and biomechanics of the nonunion site and replacing the ensuing bone loss through leg lengthening.

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