Treatment of distal radius fractures with external fixation, limited open reduction and dorsal autologous cancellous onlay bone grafting

Distal radius kırıklarının eksternal fiksasyonla, sınırlı açık redüksiyonla ve dorsal otolog kanselöz onlay kemik greftleme tekniğiyle tedavisi

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Abstract

Objectives: Distal radius fractures with their high incidence, are commonly encountered and have many methods for treatment. External fixation with grafting supplementation is still utilized by many surgeons today achieving good subjective and objective outcomes. We have modified previously reported external fixation with supplementation techniques to decrease the amount of graft utilized and have evaluated the outcomes.

Methods: This retrospective study of 29 patients evaluates a treatment technique of a dorsal autologous cancellous iliac crest bone on-lay graft with external fixation and limited open reductions for distal radial fractures. Range of motion, grip strength and radiographic outcome were scored. The mean follow-up was 2.5 years.

Results: Supplemental fixation was utilized in 8 of the 29 cases, 6 with percutaneous Kirschner wires and 2 with internal fixation with screws but without plates. The overall complication rate was 6 out of 29, of which, only 3 patients had loss of reduction, 1 with 5 mm loss of radial height, and 2 with 2 mm loss of articular congruity, but all with good/excellent outcomes. There were 79% good/excellent results and 21% fair results, using the Green and O’Brien classification.

Conclusion: Compared to current published results of distal radial fractures treated with external fixation supplemented with packed intramedullary autologous cancellous iliac crest graft, our dorsal on-lay technique is as effective a treatment modality. Additionally, there are several advantages including less bone graft to be harvested and associated morbidity.

Key words: Autologous cancellous bone graft, distal radius fracture, dorsal on-lay graft, external fixation.
Introduction

Fractures of the distal radius have been estimated to account for approximately one sixth of all fractures treated, representing one of the most common injuries encountered by the hand surgeon,[1,2] yet there remains no clear consensus on the management of these fractures. Currently, there is a trend toward using other techniques, however, external fixation has been in use for over 50 years and remains a surgical option for distal radial fractures.[3]

In an effort to improve upon the functional and radiographic outcomes of these difficult fractures, Leung et al.[4] were the first to advocate external fixation supplemented with cancellous bone grafting as a treatment for comminuted distal radial fractures. The main advantages proposed by using autologous cancellous bone grafting as an adjunct to external fixation included minimizing the incidence of late collapse and loss of reduction in these fractures, enhanced healing via the osteogenic potential of the bone graft, and a reduction in the length of time spent with the external fixator.[4] We have modified the Leung technique by employing a dorsal bridging autologous cancellous iliac crest on-lay bone graft rather than packing the medullary canal with morsalized graft thereby reducing the amount of graft needed. Additionally we reviewed the literature to assess the rates of late (greater than 12 months) anatomical collapse while using the technique of external fixation augmented with intramedulary graft.

The present study comprises a retrospective review of our series of 29 patients with fractures of the distal radius treated with our modified Leung protocol of external fixation, limited open reduction, and autologous cancellous iliac crest on-lay bone grafting.

Patients and Methods

Patient demographics and inclusion criteria

Over a 4 year period, 29 patients treated with external fixation, limited open reduction, and dorsal autologous iliac crest bone grafting for a distal radial fracture were available for follow up and inclusion in the present study. The patients included were part of a large group of distal radial fractures managed by one surgeon. An additional eight patients (22%) met the inclusion criteria for the study, but were either unavailable for follow-up or excluded because of inadequate records. These patients were collected non-consecutively from the office visits from one of the authors as well as directly from the Emergency Room of one hospital. All patients were under the senior author’s care at one hospital.

The criteria for surgical treatment as well as an unacceptable fracture reduction were if there was shortening of radial length greater than or equal to 5 mm, 10° or greater of dorsal angulation, or greater than or equal to 2 mm of articular incongruity as assessed by comparison with contralateral normal wrist X-ray. Redisplacement seen on follow-up after an initially acceptable closed reduction and immobilization was also an indication for surgical intervention. If any one of the criteria was met, it was an indication for surgery. Fractures of the distal radius both with and without articular comminution were accepted, however, fractures not indicated for external fixation, such as volar tear-drop and Barton’s type fractures, were rejected for this study.

The average time from injury to surgery was 6.4 (range: 1 to 23) days.

The mean follow-up was 2.5 years (range: 385 days to 4.7 years). There were 16 females and 13 males. The average age at injury was 57 (range: 23 to 78) years. Fifteen of the fractures occurred on the dominant hand, 14 on the non-dominant.

The mechanism of injury was a fall in 27 patients. One patient was a driver in a motor vehicle accident and another was a pedestrian struck by a motor vehicle. One patient sustained an ipsilateral two-part proximal humerus fracture that was treated in a sling, while another patient sustained significant ipsilateral hematoma on the arm, which healed without consequence. The remaining 27 patients did not have any associated injuries. All fractures were closed injuries. There were no acute injuries to vital structures in the region of the injured distal radius which required repair.

Radiological assessment

Preoperative, postoperative, and most recent follow-up (at least one year) radiographs were evaluated by an independent observer. Posterioranterior, lateral, and oblique radiographs were assessed for each patient at these three intervals. Radial length, radial inclination, and palmar tilt were all measured on radiographs according to the method described by Van der Linden and Ericson.[5] Articular incongruity, if present (21 patients), was also measured. A CT scan was performed pre-operatively for patients with non-definitive radiographs, however, it was not used for all patients and its parameters were not utilized for this study.

All patients indicated for surgery had preoperative radiographs taken and were classified according to the AO[6] and Frykman[7] classification schemes. Using the AO classification, there was one type A2 fracture, 5 type A3, 5 type C1, 13 type C2, and 5 were type C3. According to the Frykman classification, there were 3 grade I fractures, 2 grade II, 3 grade III, 3 grade IV, 2 grade V, 2 grade VI, 6 grade VII and 8 grade VIII fractures.
Operative technique

Limited open incisions were used both proximally and distally in order to avoid damage to tendons and to the radial sensory and lateral antebrachial cutaneous nerves. The fracture was reduced using fluoroscopic guidance, after which, the Agee-WristJack external fixator (Hand Biomechanics Lab, Inc., Sacramento, California) was applied.

Morselized autologous cancellous iliac crest bone graft was obtained through a 2 cm incision over the ipsilateral iliac crest, 5 cm proximal to the anterior superior iliac spine. An estimated 5 cc of cancellous graft was harvested from between the inner and outer tables of the ilium, using the Acumed Bone Graft System (Acumed, Inc., Beaverton, Oregon, USA). Graft procedure added an estimated 5 minutes of additional surgical time with the majority being spent on the subcuticular closure of the 2 cm incision.

The distal radius was then approached through a 2 cm dorsal longitudinal extraarticular incision between the third and fourth dorsal compartments. This incision, was used to reduce dorsal fragments (with use of fluoroscopy), apply the bone graft, and if necessary, restore palmar tilt. The extensor pollicis longus (EPL) tendon was identified, and the septum between the third and fourth compartments was divided, in order to prevent late rupture of the EPL tendon. The EPL tendon was not transposed dorsal to the retinaculum. The dorsal cortical fragments were reduced and morselized bone graft spread dorsally along the dorsal radial cortex and deep to the dorsal wrist extensor tendons, bridging the comminuted segment. Differing from Leung et al. [4,8] the graft was not impacted into the fracture or medullary canal. Rather, careful attention was paid to the reduction of the cortical fragments.

Supplemental fixation was employed in eight of the 29 patients, when it was deemed necessary to maintain articular congruence or to provide additional stabilization not achieved employing the external fixator and on-lay bone graft alone. Percutaneous Kirschner wires were employed in six patients, while internal fixation with screws without plates was used in two patients.

Immediately postoperative, range of motion exercises were instituted and patients were seen as outpatients within 48 hours of the operation to insure they achieved full finger motion. Length of external fixation averaged 32.3 (range: 21 to 47) days. Fixators were removed in the office without the use of anesthesia when there was radiographic evidence of dorsal cortical healing and incorporation of the dorsal bridging bone graft. Radiographic evidence was the presence of bridging bony trabecula. No form of immobilization was employed after removal of the fixator. Iliac crest bone graft donor areas were inspected one week post-operatively.

Figs. 1-7 depicts a clinical example with final radiological outcome at 4.7 years.
Final evaluation

At the most recent follow-up, all patients were examined and evaluated by an independent observer. Radiographs were taken and analyzed for radial length, radial inclination, and palmar angulation as described previously in the Radiographic Assessment section. Flexion, extension, supination and pronation of the involved and uninjured wrists were measured and expressed as a percentage of that of the uninjured side. Grip strengths of the injured and uninjured sides were measured in kilograms using a Jamar adjustable dynamometer (Asimow Engineering, Los Angeles, California). Two measurements were recorded and averaged for each side, and the result was expressed as a percentage of the uninjured limb. Patients were assessed for pain status by choosing: no pain, mild occasional pain, mild constant pain, moderate pain not requiring medical treatment or analgesics, or severe pain requiring medical treatment.

Clinical results were graded according to the modified system of Green and O’ Brien.\(^9,10\) This is a scoring system that employs subjective and objective parameters to determine a clinical outcome rating.

Statistical analysis

Statistical analysis was performed to show significance in the measurements between post-op and present results for the four radiographic variables measured. Paired t-tests were used to assess significance for all variables. Confidence intervals of 95% were also assessed for these variables. The alpha level for all significance tests was set at \(p=0.05\).
Results

Radiographic

Radial length
Preoperative radial length averaged 5.8 (range: 0-12) mm, which was improved to a radial length average of 12 (range: 7-14) mm postoperatively. On most recent follow-up, radial length averaged 11.2 (range: 5-14) mm. Radiographs taken immediately postoperatively improved the mean radial length of 6.2 (range: 2 to 11) mm, as compared to the average preoperative radial length. The mean loss from immediate postoperative to most recent follow-up was 0.8 (range: 0 to 5) mm.

Radial inclination
Preoperative radial inclination averaged 14° (range: 4° to 23°). This parameter was improved to an immediate postoperative mean of 22° (range: 16° to 28°), and at most recent follow-up averaged 21° (range: 14° to 26°) with a mean loss from immediate postoperative to most recent follow-up of 2° (range: 0° to 7°).

Palmar tilt
The mean preoperative palmar tilt measured 14° dorsal (range: 8° palmar to 34° dorsal). This was improved to a postoperative average of 4° palmar (range: 2° dorsal to 14° palmar), remaining stable at recent evaluation with a mean loss of 1° (range: 0° to 4°).

Articular incongruity
Twenty-one of the 29 patients included in the study had an intra-articular component to their fracture (73%). The mean preoperative articular stepoff measured 2 (range: 0 to 6) mm, which improved to an average of 0.4 (range: 0 to 1) mm of incongruity immediately postoperative. On the most recent radiographs, mean articular stepoff measured 1 (range: 0 to 3) mm, with only 2 of the 21 patients with an intra-articular component to their fracture having evidence of residual articular incongruence greater than 2 mm.

Motion and strength at most recent follow-up

Flexion-extension
Average wrist flexion and extension measured 69° (range: 34° to 85°) and 63° (range: 34° to 85°), respectively. This represents a mean flexion-extension arc of 90% of the uninjured side.

Supination-pronation
Mean forearm supination measured 79° (range: 60° to 90°), while pronation averaged 82° (range: 70° to 90°). The mean supination-pronation arc was calculated to be 98% of the uninvolved limb.

Grip strength
The mean grip strength was measured to be 28.8 (range: 9 to 49.5) kg, representing an average strength of 97% of the unaffected side.

Subjective parameters
All of the patients who were employed prior to their injury returned to their pre-injury employment status without limitations. Nineteen of the 29 patients denied any pain in the injured wrist at the most recent follow-up. Seven patients had mild occasional pain, three had moderate but tolerable pain and none had severe to intolerable pain.

Outcome scores
According to the modified scoring system of Green and O’Brien, 79% of the patients had a good or excellent functional outcome. None of the patients had a poor rating, while 6 of 29 (21%) had a fair outcome.

Complications
No intraoperative complications were reported. There were no symptoms consistent with carpal tunnel syndrome, reflex sympathetic dystrophy, or injury to the radial sensory or lateral antebrachial cutaneous nerves. There were no iatrogenic fractures, donor site complications, or tendon injuries. The only complaint at the iliac crest bone graft site was minor soreness. There were no long-term problems, complications or pain associated with the donor site.

Six out of the 29 patients developed complications (21%). Three (10%) patients had superficial infections of the fixated pin tracts, none requiring early removal of the fixator. Of the three patients sustaining a Frykman grade VIII, AO type C3, two resulted in a fair outcome and the other excellent on the most recent follow up according to the modified system of Green and O’Brien.

In addition to these six complications, three patients, who all had good or excellent clinical outcomes, had radiographic evidence of loss of fracture reduction at the most recent follow-up. One patient had a 5 mm loss of radial length and two patients had evidence of 3 mm of residual articular incongruity, however, neither of these patients had radiographic evidence of radiocarpal arthritis on their most recent follow-up.

Statistical
The radiographic variables radial length, radial inclination, palmar tilt and articular incongruency were all statistically significant (p<.05) in comparison of post-operative measurements to the most recent follow up (Table 1).
Discussion

Historically, the results of treating complex distal radial fracture with external fixation alone, when examined critically, are discouraging.\textsuperscript{[8,21-24]} Variables including outcomes for palmar tilt,\textsuperscript{[17]} late radiographic collapse\textsuperscript{[18]} and, displacement of previously reduced fractures\textsuperscript{[2,19]} have been reported as some of the hurdles facing external fixation. Proposed hypothetical reasons for such complications include the viscoelastic relaxation of the ligaments with time,\textsuperscript{[20]} and/or due to the late resorption of comminuted bone.\textsuperscript{[20]} Furthermore, significant dorsal cortical and cancellous comminution, inherent in displaced and unstable distal radial fractures, had not been reliably addressed by external fixation alone, leading to the rationale of augmenting external fixation with dorsal bone grafting, first advocated by Leung et al.\textsuperscript{[48]}

Our onlay technique of the bone graft is new and differs from Leung et al.\textsuperscript{[48]} by exposing and reducing the fracture and subsequently spreading the graft over the reduced dorsal cortical surface rather than packing a “substantial volume” into the fracture void. The graft is no longer used as an intraosseous buttress but as a dorsal bridge over the accurately reduced dorsal cortical fragments to the cortex.

We have demonstrated the dorsally reinforced cortex, which handles most of the mechanical load, is able to maintain radiographic alignment and fulfill the theoretical rapid osteogenic potential of the autologous bone graft established by the presence of bridging bony trabeculae at three weeks. This rapid healing minimizes the potential for late fracture collapse\textsuperscript{[8,20]} and allows for a diminution of the distraction forces across the radiocarpal joint. Thus permitting an earlier removal of the fixator without risking loss of reduction as corroborated by our findings of a low incidence of radiographic collapse (10%) with a similar earlier fixator removal time of (32 days) than external fixation alone (6-8 weeks)\textsuperscript{[22-24]} or external fixation with supplementation 3-8 weeks.\textsuperscript{[8,21,23]} Our 10% late anatomic radiographic loss is similarly, within range of current rates found in the literature (9-13%) utilizing the Leung intramedulary graft technique with external fixations although casting post-fixator was utilized by Widman and Isacson,\textsuperscript{[25]} and Tylissanakis et al.\textsuperscript{[21]} only included AO classification type C compared to only 80% type C from our data. Meta-analysis\textsuperscript{[23]} of 28 external fixation studies both with and without graft augmentation and with follow up time at least 1 year, reported a similar radial inclination, 20.1° (19.2-21.2) to our finding of 21°, however our palmar tilt results demonstrated a better restoration of 4° to the reported palmar tilt of 0.5° (-2.1-3.2; 95% CI).

An advantage to our dorsal onlay technique is that only a small amount of graft is required while having comparable outcomes to current intramedulary techniques. Percutaneous harvesting with low associated graft-site morbidity is possible with a minimal addition of an estimated 5 minutes to surgery time and, in most instances, the can be performed as outpatient surgery. We have reported no serious complications of the donor site at one-week postoperative or at the most recent follow up which is far below the 35% complication rate (severe pain or requiring medical treatment) of the donor site post-op and 26% after 1 year reported in a recent prospective randomized study looking at morbidity associated with autologous grafting for comminuted distal radial fractures by Rajan et al.\textsuperscript{[27]}

Three of our patients had radiographic evidence of loss of fracture reduction at the first visit after hardware removal and may have benefited from a longer period of external fixation. Despite these radiographic findings, these patients ultimately had good to excellent functional outcomes, which agrees with the observation that clinical results do not always correspond with radiographic parameters.\textsuperscript{[20]} An additional three patients experienced superficial infections of the fixated pin tracts, however, it was felt that these three patients were not fully compliant with the pin care protocol of twice daily pin site cleaning with diluted hydrogen peroxide. The two patients described in the results section that experienced protracted postoperative wrist pain and stiffness without signs of complex regional pain syndrome both did not benefit from intensive physiotherapy. The etiology of the suboptimal results of these two patients is unclear, particularly because the latter of the two (Frykman grade VIII, AO type C3) had a stable anatomic reduction of the fracture, and had initially achieved excellent motion after each of the arthroscopic releases. It should be noted that both of these patients were involved in litigation with respect to their injuries. The impact that this had upon their outcomes is unclear.

Table 1. Statistical analysis of radiographic variables

| Variable               | Post-op mean (95% CI) | Present mean (95% CI) | Paired t-test p-value |
|------------------------|-----------------------|-----------------------|-----------------------|
| Radial Length (mm)     | 14 (13.3-14.7)        | 13 (12.2-14.1)        | 0.0043                |
| Radial inclination (degrees) | 22 (20.87-23.26)  | 21 (19.3-21.7)        | 0.0003                |
| Palmar tilt (degrees)  | 4 (2.3-6.4)           | 4 (1.4-5.6)           | 0.0019                |
| Articular incongruency (mm) | 0.4 (0.2-0.7)      | 0.7 (0.3-1.1)         | 0.0481                |
While our results of are promising, a limitation of the study is a sample size of 29 patients. Further evaluation of this technique should be undertaken to enhance its external validity. Although supplemental fixation was utilized in our paper, it does not necessarily prevent late collapse when used with external fixation.

Given current trends and alternative options for the treatment of distal radial fractures, external fixation with bone graft supplementation is probably not the first choice of treatment in 2009. However, if employed, we hypothesize that our onlay bone graft technique should be utilized by fractures with primarily dorsal comminution with minimal articular comminution and should not be used in a volar tear-drop or a Barton’s type fracture. We are not advocating this as the best treatment option, but using it as a model to report the efficacy and advantages of cortical onlay graft given it is still a popular treatment.

In conclusion, we report 79% good to excellent functional outcomes and have shown acceptable radiographic outcomes with few serious complications (10%) or loss of reduction (10%). We have shown that external fixation supplemented with dorsal on-lay autologous morsellized cancellous iliac crest bone graft has a lower morbidity associated with the donor site and has been shown to promote cortical healing as effectively as the current treatment modality for distal radial fractures of external fixation supplemented with packed intramedullary autologous cancellous iliac crest grafting.

Conflicts of Interest: No conflicts declared.

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