A Prospective Study on the Initial Results of a Low Profile Ulna Shortening Osteotomy System

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Abstract Extra-articular ulna shortening osteotomy, in principle, is an accepted treatment option for symptomatic degenerative and traumatic triangular fibrocartilage complex (TFCC) tears. Despite the benefits of this surgical approach, potential disadvantages include risk of nonunion, soft tissue irritation, and the need for future hardware removal. A recently introduced low profile ulna shortening system was designed to decrease these potential complications. A single-surgeon prospective study was performed to evaluate this system. Ten consecutive patients undergoing ulna shortening for ulnar-sided wrist pain compatible with TFCC pathology participated in the study. Subjective, objective, and radiographic assessments were performed preoperatively and up to 24 weeks postoperatively. Based on visual analog scale (VOS) ratings (0 to 10), pain scores significantly improved ($p < 0.05$) and average patient satisfaction was 8.7. DASH and PRWE scores improved at three month follow-up ($p < 0.05$). Osteotomy healing time averaged 10.3 weeks, and there were no nonunions. Average discomfort associated with palpation of the plate at final

follow-up was 3.3 (using VOS), and one patient requested removal of the hardware. In this short-term follow-up study, the assessed ulna shortening system appears effective and, in general, well tolerated.

Keywords Ulna shortening osteotomy · Ulnar abutment · Triangular fibrocartilage complex tears

Introduction

Linscheid [11], Chen and Wolfe [3], Mizuseki et al. [18], Feldon et al. [8], Wehbe and Cautilli [24], Rayhack et al. [21], and Chennagiri and Burge [4] are a few of the authors who have described their own techniques and/or instrumentation to perform ulna shortening osteotomies. This implies two things. First, that ulna shortening is a widely accepted principle for the treatment of certain types of ulnar sided wrist pain. Second, that the current strategies to accomplish this are imperfect.

Multiple authors have noted the utility of extra-articular ulna shortening osteotomies in treating both degenerative and traumatic tears of the triangular fibrocartilage complex (TFCC) in patients with ulnar positive and neutral variants [1–3, 5, 6, 9, 12, 17, 18, 21, 23, 24]. Several authors while not disputing the clinical benefits of this surgical procedure noted high rates of complications including nonunion and hardware irritation [2, 6, 12, 18, 21, 24]. Noting this dichotomy, Trumble recently developed a unique ulna shortening system (TriMed, Inc., Valencia, CA) designed to decrease these complications [13]. This prospective study evaluates the cutting accuracy, bone healing potential, patient satisfaction and pain relief, and complications (including plate irritation and need for plate removal) associated with this new system.

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Materials and Methods

Ten consecutive patients who formed the senior author's practice planning to undergo ulna shortening osteotomy for TFCC-related complaints between February 2006 and November 2007, voluntarily agreed to participate in this study. Institutional review board approval and informed consent were obtained. Inclusion criteria consisted of ulnar-sided wrist pain compatible with TFCC pathology and an ulnar neutral or positive variance as demonstrated by pronated/stressed wrist posteroanterior radiographic imaging. There were two male and eight female patients with ages ranging from 21 to 69 years (mean, 47 years). All patients had pain with activities requiring loaded ulnar deviation of the affected wrist such as lifting, using a screwdriver, and chopping. Seven out of ten patients experienced tenderness to palpation at the end of the ulna (ulna fovea). All ten had a positive ulnar grind test, and nine had pain with pronation and supination. While all patients demonstrated a stable distal radioulna joint (DRUJ) as demonstrated by shear testing in full supination, neutral, and full pronation, half of the patients had pain with this maneuver. Magnetic resonance imaging was performed on six wrists and demonstrated TFCC pathology ranging from thinning to full-thickness tears. Eight patients received and responded temporarily to an ulna–carpal injection of cortisone and local anesthetic. Ulnar variance averaged from neutral to 3 mm ulnar positive. Arthroscopy, performed in all patients to confirm suspected TFCC tears prior to ulna shortening, demonstrated one traumatic tear, eight full-thickness degenerative tears, and one partial-thickness degenerative tear. None of the tears were deemed repairable and all were debrided arthroscopically. One patient had undergone previous wrist arthroscopy and TFCC debridement.

Ulna shortening was performed as described by the manufacturer. An incision was made along the subcutaneous border of the ulna starting about 1 cm proximal to the ulna head and extending approximately 15 cm proximally. The ulna was approached between the extensor carpi ulnaris and the flexor carpi ulnaris. Soft tissue stripping was minimized, but the volar and ulnar aspects of the ulna were cleared for plate placement and osteotomy. The plate was placed on the volar surface of the ulna and secured with three bicortical screws on one side of the planned osteotomy and with one screw in an oblong screw hole (to allow sliding) on the other side (Fig. 1a). Two k-wires were placed in slots through the plate to control rotation during compression (Fig. 1b). Two sequential cutting jigs were secured to the plate depending on the planned shortening, and two parallel cuts were performed while copiously irrigating the bone and saw blade to prevent thermal damage (Fig. 1c, d). A sliver of bone was removed

(Fig. 1e). A compression clamp was applied (attached to the plate and to a k-wire drilled opposite the osteotomy; Fig. 1f) and, after partially loosening the “sliding” screw, the osteotomy was compressed (Fig. 1g). A lag screw was placed across the osteotomy before further securing the plate with two final bicortical screws (Fig. 1h). The remaining k-wires and jigs were removed before closing the wound in layers (Fig. 1i, j). A volar splint was applied primarily for comfort across the wrist for 2 weeks until the first postoperative visit, and then, a removable wrist splint was applied until clinical or radiographic evidence of bony healing. Patients were instructed by a certified hand therapist in a supervised home therapy program which included range of motion, scar massage, strengthening, and edema control.

Outcomes Measurements

Patients were evaluated preoperatively by the senior author and a certified hand therapist at 6 weeks (ten patients), 12 weeks (ten patients), and 24 weeks (five patients) postoperatively. Visual analog scales (VAS, 0 to 10) were used to assess average, lowest, and highest subjective pain levels as well as patient satisfaction. Range of motion, grip strength, ulnar grind test, and point tenderness assessments were performed at all visits. Patients completed functional impairment questionnaires, Disability of the Arm, Shoulder, and Hand (DASH) and patient-rated wrist evaluation (PRWE), preoperatively and at 12 and 24 weeks postoperatively. Higher DASH and PRWE scores indicate more impairment. Lowered scores indicate improvement. Finally, radiographic examinations were performed at all follow-up visits (and at 2-week intervals following the 6-week visit if bony healing was not demonstrated by bridging trabeculae or callus formation; Fig. 2).

Results

Average preoperative pain levels rated on the VAS (10 highest) ranged from 3 to 7 (4.9 ± 1.2). Highest subjective pain levels (subjective report of the most pain associated with the ulnar side of the wrist) ranged from 7 to 10 (8.1 ± 1.2), and lowest subjective pain levels (estimate of least pain the wrist experienced) ranged from 0 to 4 (1.8 ± 1.3). At 12 weeks follow-up, average wrist pain ranged from 1 to 7 (2.3 ± 1.9 ; statistically significant improvement from preoperative values using Student's *t* test, $p < 0.001$); highest pain levels ranged from 2 to 9 (5.2 ± 2.3 ; statistically significant, $p < 0.002$); and lowest levels ranged from 0 to 5 (0.9 ± 1.6 ; $p > 0.05$). At 24 weeks follow-up, average pain ranged from 0 to 7 (2.7 ± 2.6 ; $p < 0.05$); highest pain levels ranged from 1 to 10 (5 ± 3.7 ; statistically significant,

Figure 1 Ulna osteotomy technique. **a** Plate clamped to volar aspect of ulna. Three screws secure the plate to the bone on one side of the osteotomy and an additional screw is placed in an oblong “sliding” hole on the other side. **b** Two k-wires are placed in antirotation slots to prevent bone shifting during osteotomy and compression. **c** The first cutting guide is clamped to the plate and while copiously irrigating, the first osteotomy is performed. **d** The first guide is removed, and a second jig guides the second cut. **e** A precise sliver of bone is removed. **f** A compression clamp is secured to the plate, and the bone opposite the osteotomy using a bicortical k-wire. **g** The “sliding screw” is loosened (minimally) and compression applied. **h** The new bone position is secured by tightening the “sliding screw”, placing a lag screw across the osteotomy and placing two final screws in the plate. **i, j** showing final plate position and tight approximation of compressed osteotomy.

Figure 2 Radiographs of forearm demonstrating plate position and osteotomy alignment.

$p < 0.05$), and lowest pain levels ranged from 0 to 6 (1.7 ± 2.7 ; statistically significant, $p < 0.05$; Fig. 3). At 12 weeks, four out of ten had persistent pain with ulnar grind test though this dropped to one out of five at 24 weeks.

Patient satisfaction using a VAS at final follow-up (12 or 24 weeks) ranged from four to ten (8.7 ± 1.9 ; Fig. 4). Preoperative DASH scores ranged from 15 to 68.36 (36.9 ± 17.69), and preoperative PRWE scores ranged from 37.5 to 76 (56.68 ± 12.63). At 3 months follow-up, DASH scores ranged from five to 81.03 (28.58 ± 26.88) ($p < 0.05$) and PRWE scores ranged from four to 82 (29.2 ± 24.27 ; $p < 0.005$; Fig. 5).

Preoperative total active motion (TAM) for extension and flexion ranged from 50° to 135° ($103 \pm 31^\circ$); for radial–ulnar deviation, ranged from 25° to 60° ($39 \pm 14^\circ$); for supination–pronation, ranged from 125° to 180° ($143 \pm 19^\circ$). At 12 weeks follow-up, TAM for flexion–extension ranged from 75° to 165° ($114 \pm 29^\circ$); for radial–ulnar deviation, ranged from 33° to 70° ($49.3 \pm 11^\circ$); and for supination–pronation, ranged from 120° to 170° ($146 \pm 16^\circ$). At 24 weeks, TAM for flexion–extension ranged from 105° to 150° ($126 \pm 18^\circ$); for radial–ulnar deviation, ranged

Figure 3 Mean subjective pain ratings using a 10-point visual analog scale.

from 40° to 65° ($56 \pm 10^\circ$); and for supination–pronation, ranged from 130° to 165° ($150 \pm 14^\circ$). These measurements were statistically improved for radial–ulnar deviation both at 12 and 24 weeks compared with preoperative values ($p < 0.05$), but no statistical difference was noted between preoperative and postoperative values for flexion–extension or supination–pronation values (Fig. 6).

Preoperative grip strength ranged from 3 to 34 kg (15 ± 10), and though there was a slight trend towards improvement at 12 weeks (5 to 34 kg, average 18 ± 10) and at 24 weeks (16 to 34 kg, average 27 ± 8), there was no statistical difference between these measurements (Fig. 7).

Planned shortening ranged from 2 to 4 mm, and actual shortening as measured at 12 weeks follow-up (all in pronated/clenched fist views) ranged from 1.5 to 4 mm. For three wrists, the actual shortening was 1 mm less than

Figure 4 Subjective patient satisfaction using visual analog scale.

Figure 5 Mean DASH and PRWE scores at 12 weeks follow-up. Decreasing scores indicate improvement.

planned; for two wrists, shortening was 0.5 mm less than intended, and for one wrist, shortening was 0.5 mm more than intended. Osteotomy healing time ranged from 6 to 22 weeks ($10.3 \text{ weeks} \pm 5.5 \text{ weeks}$). There were no nonunions. At 12 weeks, VAS ratings of pain to palpation over the plate itself ranged from 0 to 8 (average 3.3 ± 2.1 ; Fig. 8). One patient had the plate electively removed at eight months postoperatively, though the patient reported only intermittent discomfort.

Discussion

Milche is given credit as the first to describe ulna shortening osteotomy for traumatic ulnar abutment [15]. Since then, numerous authors have reported the utility of this surgical approach (with or without TFCC debridement) for degenerative TFCC tears, ulnar abutment syndrome, and traumatic TFCC tears [1–3, 5, 6, 9, 12, 17, 18, 21, 23, 24]. Although these pathologies are more prevalent in

Figure 6 Mean total arcs of motion for supination/pronation, radial/ulnar deviation, and flexion/extension as measured preoperatively, at 12 weeks postoperatively, and at 24 weeks postoperatively.

Figure 7 Mean grip strengths as measured preoperatively, at 12 weeks postoperatively, and at 24 weeks postoperatively.

patients with ulnar positive and neutral wrists [2, 7, 19], the successful use of ulna shortening has been described even in case of ulnar negative variance [9, 22]. Based on the principles outlined by Palmer's study in 1981 [20], shortening the ulna significantly reduces forces transmitted through the ulnar side of the wrist (from 18% to 4%). Since ulnar abutment and degenerative TFCC tears are most likely a result of excessive load bearing through the ulnocarpal joint, shortening the ulna as part of the treatment strategy for these disorders makes empiric sense. Likewise, while an acute TFCC tear may not be related to chronic stresses, per se, unloading the damaged side of the joint, theoretically, should help. Menon et al. [14] and Minami et al. [16] have reported poor results of debridement without ulna shortening while several other authors reported 90% to 100% excellent and good results following ulna shortening for both degenerative and traumatic TFCC tears [2, 5, 16, 22–24]. Hulsizer et al. [9] even reported successful pain relief following ulna shortening in 12 out of 13 patients who had persistent symptoms despite previous arthroscopic debridement.

Despite these benefits, ulna shortening osteotomies are historically not without complications and challenges including technical difficulty, risk of nonunion, and painful

Figure 8 Subjective pain at plate with palpation at 12 weeks postoperatively.

hardware (and even fractures associated with premature hardware removal) [2, 3, 6, 8, 12, 18, 21, 24]. In rationalizing the need for an improved ulna shortening system, Rayhack et al. noted excessive healing times and risk of nonunion, imprecise cuts, and “struggles with fixing the osteotomy” as all problems with free-hand techniques [21]. Even using a compression jig, his group reported an average healing time of 21 weeks and one nonunion in 23 osteotomies (which improved to 11 weeks for 17 osteotomies once he switched from a transverse to an oblique cutting angle) [21]. Mizuseki et al. [18] introduced their own osteotomy system noting their own previous experience with nonunion, angulation, and imprecise shortening. Constantine et al. [6] reported a 3-month mean time to union in patients having undergone ulna shortening osteotomy. Of the reported complications, painful hardware seems to be the most predominant. Complaints of plate irritation have been found in multiple studies—60% [2], 68% [12], and 100% [24]—often lowering patient satisfaction rates and necessitating a second surgery to remove the plate [3, 12] which occasionally resulted in fracture through the osteotomy site [18, 24]. This particular problem has led some surgeons to favor the wafer procedure (excision of the distal 2–4 mm of ulna) over extra-articular ulna shortening [6, 8].

Noting the utility of the ulna shortening osteotomy but citing some of the problems above, Trumble developed an ulna shortening system [10]. Utilizing a low-profile plate placed on the volar surface of the distal ulna shaft, it is designed to decrease complications. Ulnarly or dorsally positioned plates tend to cause symptoms due to their subcutaneous placement or tend to irritate the extensor carpi ulnaris tendon [18]. The cutting guides of the Trumble plate temporarily attach to the plate itself allowing for precise shortening without loss of rotational control. The use of an oblique osteotomy provides a larger healing surface and allows for placement of a lag screw which, when combined with the compression clamp, should ensure high union rates.

This prospective study, specifically aimed at evaluating our results in using this system, in general, supported the proposed benefits. Ulna shortening, for properly selected patients, is beneficial. As a group, our patients achieved marked pain relief, reported high levels of satisfaction, and showed improvements in PRWE and DASH scores. Though there was a slight increase in subjective pain ratings between the 12 week postoperative visit and the 24 week postoperative visit, this, as well as the high final dropout rate (50%) may be explained by the fact that only patients with ongoing discomfort returned for this final follow-up. The authors' impression (though not collected as formal data) was that patients doing well had no incentive to return. At final follow-up, either at 12 weeks or 24 weeks,

only one out of ten patients was dissatisfied and had no real improvement in pain ratings. It should be noted that this patient had had multiple surgeries and was involved in litigation (though we did not include these factors as independent variables in interpreting the data). This patient showed worsening of PRWE scores, and two patients (including this patient) had worsening of DASH scores as well. Range of motion only improved in a radial–ulnar plane, which was probably related to decrease in ulnar wrist pain. As a group, the study patients did not have a large ROM deficit to improve upon; however, it should be noted that this surgical procedure did not result in loss of wrist motion. Grip strength did not improve when looking at the whole group, which was surprising when noting the improvements in pain levels. No patients had marked loss of strength, and a few did show definite improvements. We did not record the normal side though it would have been interesting to note “percentage of the normal side” strength.

The ulna shortening system was generally accurate, achieved reliable bone healing, and the plate was well tolerated by patients. The “achieved” shortening was within 1 mm of the “intended” shortening for all wrists. Slight variations in X-ray beam angle and wrist position as well as observer measurement error could account for these deviations. However, even slight overloosening of the screw in the slotted/sliding hole allowed overcompression with overlapping of the osteotomy and overshooting. This needs to be kept in mind when performing the surgery. Union times at an average of 10.3 weeks were comparable to some studies [6] though a little longer than the 7.3 weeks was reported by Trumble's group for this same system [13]. Again, slight changes in forearm rotation or X-ray beam direction make exact replication of an image difficult. We discontinued protection of the osteotomy when no well-defined osteotomy line could be visualized on radiographic imaging and the patient was nontender at the osteotomy site. Plate discomfort was not felt to be a significant problem but was not entirely avoided. Several patients had some discomfort associated with pressure over the plate. One patient had significant discomfort though did not want it removed. The one patient that had the plate removed had relatively modest complaints. In conclusion, we have found this ulna shortening system to be predictable, reliable, and well tolerated.

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