Percutaneous volar locked plate fixation in metaphyseal fractures of distal radius

Technical description and preliminary results

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Abstract

Objective: To evaluate objective and subjective outcomes after closed reduction and minimally invasive volar locked T-plate osteosynthesis for distal radius fractures with metaphyseal involvement.

Methods: We retrospectively evaluated six patients treated with minimally invasive volar locked T-plate osteosynthesis for unstable extra-articular or partial articular distal radius fractures with metaphyseal involvement, between 2007 and 2012. Average age: 40.17 years. According to the AO/OTA classification, all patients had 23A3 type fractures. Indirect reduction was performed. Two volar small incisions were made; a volar locked compression T-plate was introduced in the sub-muscular plane, under radioscopic guidance. Analysis included radiological parameters, range of motion and strength. Subjective results were assessed using DASH score and the Visual Analogue Scale.

Results: All fractures healed within 2.4 months. Radiographic outcomes showed no differences between the first postoperative control and the last one at one-year follow-up. Average flexion and extension 70° and 60°, pronation and supination: 79° and 80°. Grip strength: 78.4%. DASH score 19.82 and visual analogue scale: 1.5 points.

Conclusions: Minimally invasive technique decreases surgical injury and complications. It is an option in patients with metaphyseal comminution, severe soft tissue injuries and high energy trauma. Percutaneous volar locked compression plate allows to obtain a stable fixation and to restore distal radius anatomy in radius fractures with metaphyseal involvement.

Key words: Distal radius; metaphyseal fractures; locked volar plates; percutaneous plating.

Level of Evidence: IV

Osteosíntesis percutánea con placas volares bloqueadas en fracturas metafisarias distales de radio. Descripción de la técnica y resultados preliminares

Resumen

Objetivo: Evaluar los resultados objetivos y subjetivos obtenidos luego de una osteosíntesis con placas en T bloqueadas volares, colocadas mediante una técnica mínimamente invasiva, en fracturas de radio distal con extensión metafisaria.

Materiales y Métodos: Evaluación retrospectiva de seis pacientes adultos que presentaron fracturas inestables de radio distal, extrarticulares o articulares parciales, con extensión metafisaria, tratadas quirúrgicamente con placas en T largas de

Conflict of interests: This study was carried out with no financial aid

compresión bloqueadas volares, mediante una técnica mínimamente invasiva, entre 2007 y 2012. Edad promedio: 40.17 años. Fracturas de tipo 23A3 (n = 6) de la Clasificación AO/OTA. Se realizó la reducción indirecta, bajo radioscopia y, a través de dos pequeñas incisiones, se deslizó, en forma percutánea, una placa bloqueada volar en T. Se analizaron los parámetros radiográficos, el rango de movimiento y la fuerza. Los resultados subjetivos fueron evaluados usando la escala DASH y la escala analógica visual.

Resultados: Tiempo de consolidación promedio: 2.4 meses. Los resultados radiográficos no mostraron diferencias significativas entre el primero y el último control al año de seguimiento. Flexión y extensión promedio: 70° y 60°, pronación y supinación: 79° y 80°, respectivamente. Fuerza de prensión promedio: 78,4%. Puntaje DASH 19,82; escala analógica visual 1,5 puntos.

Conclusiones: Las técnicas mínimamente invasivas reducen el daño quirúrgico y las complicaciones. Son una opción en pacientes con daño grave de partes blandas, conminución metafisaria y trauma de alta energía. La colocación de placas volares bloqueadas percutáneas es un procedimiento técnicamente demandante, permite obtener fijaciones estables y restaurar la anatomía radial en fracturas de radio distal con extensión metafisaria.

Palabras clave: Radio distal; fracturas metafisarias; placas bloqueadas volares, osteosíntesis percutánea.
Nivel de Evidencia: IV

Introduction

Although there is controversy over what the best treatment for distal radius fractures is, volar locked plates have shown good X-ray and functional results in unstable distal radius fractures, allowing the surgeon to get stable fixation that might allow the patient early joint motion without reduction loss, using a volar approach even in comminuted fractures with dorsal displacement, with need neither of bone graft nor of bone substitutes. [1-3] The conventional technique of open reduction and internal fixation with plates involves a wide approach and detachment of soft tissues so as to get anatomic reduction, impairing blood supply to the fracture fragments,[4] something that may increase the risk of infection and delayed union.[5] "Internal biological fixation" by minimally invasive techniques and low contact implants came up with the aim of preserving blood supply to and trophic factors for the fracture hematoma, decreasing surgical trauma and the possible complications associated with the treatment of complex metaphysis-diphysis or peri-articular fractures in the lower limb that could not be adequately treated with intramedullary nailing;[6-9] then, it started to be used in the upper limb, especially in humerus fractures; [10-14] however, little has been published about its use in distal radius fractures. [15-17]

The aim of this study is to assess the objective and subjective results associated with osteosynthesis with volar locked T-plates using a minimally invasive technique, in distal radius fractures with metaphysis involvement.

Materials and Methods

We evaluated retrospectively six adult patients who had suffered unstable distal radius fractures, with no involvement of the joint or with partial involvement of it, with distal radius metaphysis involvement, treated surgically by stabilization with long volar locked T-plates, using a minimally invasive technique from 2007 to 2012. The patients were five males and one female, who averaged 40.17 years old (ranging from 26 to 54). In three of them the fracture occurred in their left limb (they were right-handed), whereas in the other three, the fracture occurred in their right limb (they also were right-handed). Fractures were classified as stated by the AO/OTA[18] system as type 23A3. All of them were closed fractures. Regarding mechanisms of injury, all of them were high-impact fractures—five occurred in car crashes while the remaining one was consecutive to a height fall. Two cases showed ulnar styloid process fracture and, two others a fracture at the ulnar neck level. Time from the injury to the surgery was, on average, three days (ranging from cero to five). Only one patient showed median nerve neuropraxia signs at the time of admission, that's why this patient was considered as an emergency case and operated on accordingly. Three patients showed associated fractures in the lower limb (Table 1).

Surgery was performed with patients in a supine position, with their affected upper limb placed on a fluoroscopic operating table and using regional anesthesia (mid-humeral block anesthesia, when this one was the only injury) or general anesthesia (in patients with lower limbs fractures which were simultaneously treated). First of all, we carried out upper limb traction and executed indirect reduction maneuvers under fluoroscopy; then, we performed the distal approach, which was oblique following the inclination orientation of the distal radius, between the flexor carpi radialis muscle and the radial artery, from an area proximal to the crease of the wrist to 2-3 cm proximally (which was an adequate opening for the distal segment of the T-plate) (Figure 1). The flexor carpi radialis tendon is retracted ulnarly, while the radial artery is protected and retracted radialy; on the deep plane, it is possible to see the distal end of the pronator quadratus muscle, which is released at that level using a periosteal elevator and forming a sub-muscle canal, which the plate is slid retrogradely through. Once the plate is slid, it is aligned with the radius shaft, and adequate plate length and placement level are confirmed fluoroscopically; then,

Table 1. Patients: demographic data

N.°	Age (yers)	Gender	Classification AO/ OTA	Associated ulnar fracture	Ulnar osteosynthesis	Type of fracture	Mechanism of injury	Associated injuries	Associated conditions	Dominant limb	Implant	Distal screws Pegs	Proximal screws	Plate model	Follow-up (months)	Bone healing (months)
1	43	M	23A3	Distal ulnar fracture	Tension band	Closed	Car crash (motorcycle vs. car)	CET. Distal ulnar fracture Third metacarpal fracture Ipsilateral acetabulum fractue	No	No	4 x 9 holes volar LCP	3	3 locking	V-07	48	2
2	45	M	23A3	Ulnar styloid process fracture	No	Closed	Car crash (bicycle vs. motorcycle)	Gustillo IIIB Open Shinbone fracture /amputation, CET	Diabetes mellitus type 1, High blood pressure, Hypercholesterolemia	No	4 x 8 holes volar LCP	3	4 locking	V-07	12	3
3	54	F	23A3	No	No	Closed	Car crash (car)	No	High blood pressure, Smoking	Yes	4 x 6 holes volar LCP	4	2 locking	V-05	74	3
4	43	M	23A3	Ulnar neck fracture	No	Closed	Car crash (motorcycle vs. Car)	Median nerve neuropraxia	No	No	4 x 9 holes volar LCP	3	3 locking	V-07	12	2
5	30	M	23 A3	No	No	Closed	Height fall	No	No	Yes	4 x 4 holes volar LCP	4	1 locking 1 compression	V-07	12	2
6	26	M	23 A3	Ulnar styloid process fracture	No	Closed	Car crash (motorcycle vs. car)	No	No	Yes	4 x 6 holes volar LCP	4	2 locking 1 compression	V-07	12	2.5
Media	40.17											3.5	2.8		28.3	2.41

LCP = locking compression plate; CET = cranioencephalic trauma

Figure 1. Percutaneous technique. Volar approach. Note the proximal and distal approaches, and also the plate placement.

a proximal 1 to 2 cm-approach is made, at the level of the plate proximal holes (Figure 1). First of all, it is necessary to fix one of the proximal screws (preferably in one oval hole, so as to carry out corrections in the plate placement level, if necessary) and indirect reduction maneuvers are re-executed (traction, flexion and ulnary deviation of the wrist) until we get adequate reduction and adequate level of the implant with respect to the distal radius, and then the distal pegs are fixed. Traction of the muscles attached to the distal radius (brachioradialis and pronator quadratus) might make reduction difficult if only attempted by traction maneuvers and, when reduction tried by this method is insufficient, a periosteal elevator or a lever can indirectly help with reduction when this is attempted under fluoroscopy, with no need of widen approaches (Figure 2). Last of all, the rest of the proximal screws are fixed.

Figure 2. A Anterior-posterior and lateral wrist X-rays; type 23A3 fracture. **B** Intrasurgical image. Note indirect reduction of the displaced proximal metaphyseal fragment using a lever placed through the distal approach **C.** Postoperative result: Osteosynthesis with a 4 x 9-hole volar locked T-plate for the distal radius. **D** Bone healing at month 2

We used 3.5 mm long pre-molded volar locked plates for the distal radius (Implant/Aval Pro, Argentina), type V-05 in one case[17] and type V-07 in five cases.[1] Plates length averaged 4 x 7 holes (ranging from 4 x 4 to 4 x 9). In one of the cases of fracture at ulnar neck level, we performed fixation with tension bands using Kirschner pins and wire. Even though we considered that radius osteosynthesis was stable, we decided to put the patients into a brachipalmar cast for immobilization during six weeks so as to decrease stress at the ulnar fracture level (four patients); to unify criteria, we also gave immobilization during the same amount of time to the two patients with no associated injury. During the postoperative period we recommended immediate fingers motion and keeping the upper limb elevated and sustained by a sling. At week six we removed the cast and recommended smooth active motion, independent during one week and with kinesiotherapy assistance later.

We carried out X-rays follow-up (wrist anterior-posterior and lateral X-ray views) in the immediate postoperative period, and then, at weeks 3 and 6 and months 3, 6, 9 and 12 after the surgery. We compared immediate postoperative X-rays with X-rays taken one year after the surgery, assessing in every X-ray changes in radial height (normal value: 12 mm), radial inclination (normal value: 22º) and volar inclination (normal value: 11º). We recorded all the demographic data available in the patients' medical histories. At the end of the follow-up, the objective assessment was carried out evaluating range of motion (ROM) with agoniometer and grasp strength with a dynamometer. Subjective evaluation was performed using the DASH (*Disabilities of the Arm, Shoulder and Hand*) score [19] whereas pain perception was evaluated by the visual analogue scale (VAS);[20] the questionnaires were answered one year after the surgery.

Results

Average follow-up was 28.3 months (ranging from 12 to 74). Fractures healed, on average, in 2.4 months (ranging from 2 to 3). In the immediate postoperative X-rays, average radial height was 14 mm (ranging from 10 to 17); average radial inclination was 23º (ranging from 21 to 26) and average volar inclination was 10.5º (ranging from 8 to 14.5). When we compared these figures with the results that we got in 12-month postoperative X-rays, differences were not statistically significant (p ≥0.05) (Table 2). With respect to the functional results registered at the final follow-up, figures for ROM were: average flexion 75° ± 10°, average extension 70° ± 20°, average radial deviation 25° ± 11°, average ulnar deviation 25° ± 10°, average supination 77 ± 10°, average pronation 78 ± 9 (Figures 3 and 4). When we compared these figures with those of the contralateral limb, we found significant differences only in supination and pronation (p ≤0.05). Average grasp strength was 86% as compared to the unaffected limb (p ≥0.05) (Table 3). The DASH score averaged 19.82 (ranging from 1.6 to 55.83) and VAS scoring for pain perception was 1.5 (ranging from cero to five) (Table 3). All of the patients expressed conformity with the surgical wound. In the patient that suffered median nerve compression symptoms following the fracture, symptoms improved after the surgical reduction with no need of nerve release; twelve months after the surgery, there were neither sign nor symptoms of neuropraxia. Only one patient complained about paresthesia on the median nerve innervation's territory following work reintegration, because of which it was necessary to release the nerve at carpal tunnel level and remove the plate twelve months after the surgery, with improvement of the symptoms. We recorded no case of infection or tendon irritation.

Discussion

Distal radius fractures show a bimodal distribution; the first group is that of the elderly with poor bone quality who show injuries caused by low-impact accidents; the second group includes young adults with fractures secondary to high-impact trauma. The latter group generally shows complex fractures, with involvement of the metaphysis-diaphysis area which is difficult to treat and with fractures in other bones that take longer to recover.[3] Patients in this series belong to the second group. We included six consecutive cases of extra-articular or partially-articular distal radius fractures with metaphysis involvement treated with percutaneous minimally invasive techniques using principles of indirect reduction and stabilization by pre-molded locked T-plates for distal radius which were placed bridging the fracture; we got good results. The main limitations that we find in this study are the retrospective design, the lack of a control group and the limited number of patients; however, the results that we got with this technique are promising and we believe that it has to be taken into account at the time of treating this sub-group of distal radius fractures with metaphysis involvement.

Table 2. Immediate postoperative and 12-month follow-up X-ray values

	Immediate poestoperative X-ray values	12-month follow-up X-ray values	p
Radial height (mm)	14 ± 2	13 ± 1.6	≥0.05
Radial inclination (°)	23 ± 2	23 ± 2.5	≥0.05
Volar inclination (°)	11 ± 2	10,5 ± 1.9	≥0.05

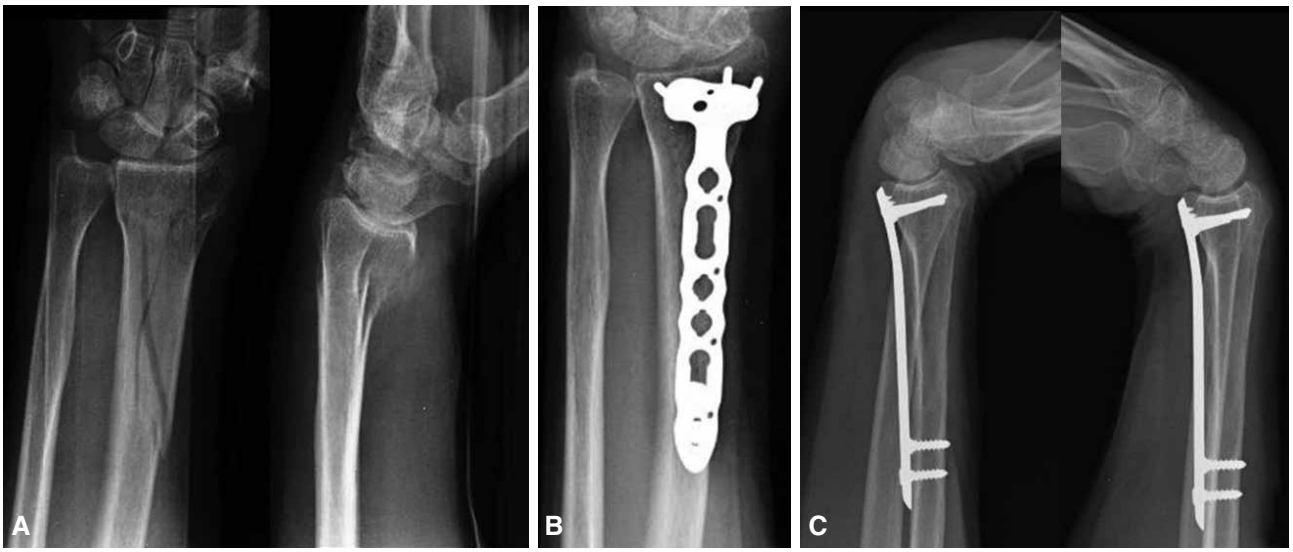

Figure 3. A. Anterior-posterior and lateral X-rays. Type 23A3 fracture. **B.** Reduction and osteosynthesis with a 4 x 6-hole locked T-plate and bone healing at month 2. **C.** Functional X-rays five years after the surgery.

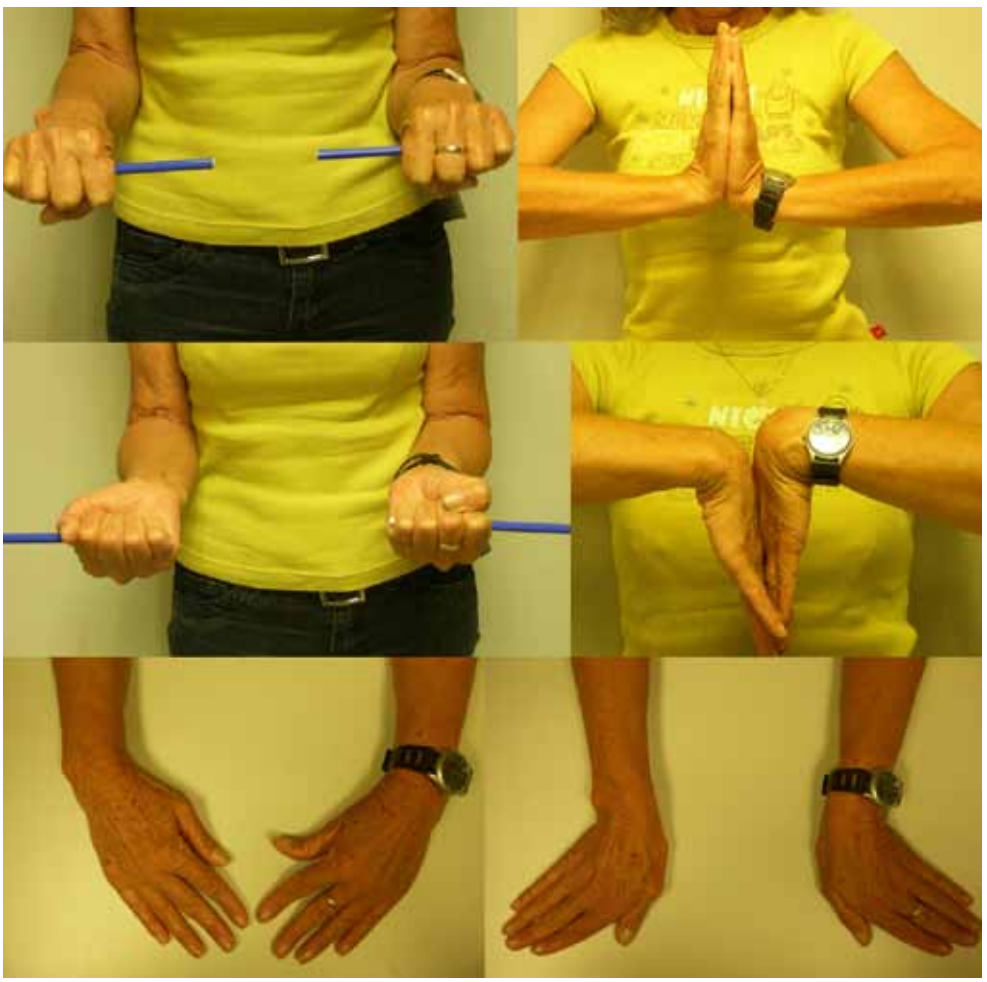

Figure 4. Functional results in the same patient five years after the surgery.

Table 3. Objective and subjective functional outcomes at final follow-up

Grasp strength—% of unimpaired upper limb	86%	p ≥0.05
Flexion (°)	75 ± 10	p ≥0.05
Extension (°)	70 ± 20	p ≥0.05
Radial deviation (°)	25 ± 11	p ≥0.05
Ulnar deviation (°)	25 ± 10	p ≥0.05
Supination (°)	77 ± 10	p ≤0.05
Pronation (°)	78 ± 9	p ≤0.05
DASH	19.82 (1.6-55.83)	
Visual analogue scale	1.5 (0-5)	

Minimally invasive techniques with percutaneous plates were popularized by Krettek;[7,8] in his studies, he describes osteosynthesis with conventional plates slid through submuscle tunnels using limited approaches; in those times, he also showed in corpses greater preservation of periosteal blood supply as compared to conventional reduction techniques.[21] Fixed-angle locked plates were another breakthrough that contributed to the concept of biological osteosynthesis; by reducing the contact area with the bone surface they avoid periostal friction and decrease vascular damage. It is necessary neither to mold the plate nor to press the implant against the bone because stress is concentrated around the connection between the threaded screw and the plate. In the beginning, this technique was meant for long-bone injuries in the lower limbs with combined fracture patterns, peri-articular or metaphysis involvement including the shaft, poor bone quality and serious injuries of the soft tissues. Over the past years, this approach started to be used in upper limbs fractures.

There is no evidence (Level I) of what the best treatment for distal radius fractures is.[3] In spite of the good results associated with the conventional open reduction and internal fixation technique, this one implies wide exposure and great damage to blood supply, what causes larger scars and consequent rigidity. [22] Blood supply to the distal radius is based on two arterial archs coming from the anterior interosseous artery; the distal arch blood vessels are near the distal joint line, whereas the proximal arch can be found at the pronator quadratus level; these nourishing vessels are at risk at the time of detaching this muscle while performing the conventional approach.[22] Sliding the implant percutaneously, these vascular pedicles and periosteal blood supply might be kept. Experimental and clinical studies using minimally invasive approaches have shown lower bone infection rates along with reduction of osteonecrosis and the risk of new fractures. [9] In the series that we assessed, patients suffered neither infection nor another fracture. By keeping the pronator quadratus, likelihood of flexor tendons irritation by the plate decreases, and this muscle might also contribute to decreasing postoperative pain and rigidity. Although our number of cases is too low for us to affirm positively that there is a cause-effect relationship here, in the patients that we assessed we did not find tendon complications and pain perception was minimal—1.5 points in the VAS at the final follow-up.

There are few reports on distal radius fractures treated using this technique. Sen et al.[15] describe the procedure in one case and recommend its indication in fractures types 23A2, A3, B1 and B2; these authors conclude that the greatest problem is to get adequate reduction through a small approach. Imatani et al.[5] present five cases with functional results similar to the ones achieved in this sample. Zenke et al.[16] compare conventional osteosynthesis to minimally invasive plate osteosynthesis (MIPO) in extra-articular and intra-articular distal radius fractures treated with volar locked compression plates, and got functional and X-ray results that did not differ significantly between the two groups; with respect to complications, in the group of conventional osteosynthesis, there was one case of tendon rupture, one case of median nerve irritation and one case of material loosening; in the other group, they registered only one case of screw protrusion at joint level. At the time of comparing our results with those obtained in series treated with conventional techniques,[23,24] there were no differences in the X-ray results; however, registered bone healing time in those series was 3 to 4 months—longer than in this sample, with average time of two months.

Conclusions

Minimally invasive procedures are considered as the ideal treatment for patients with extended soft tissues injuries consecutive to high-impact car crashes, because they reduce the surgical injury and complications rates. Small approaches that are far from the fracture save the injured soft tissues, preserve bone biology, and contribute to bone healing and reduction of complication rates (infection, new fractures). Fixed-angle volar locked compression plates that are used percutaneously allow the surgeon to get stable reduction in this sub-group of fractures, to restore radial anatomy, and to keep the reduction long with minimal X-ray changes. However, these are demanding procedures—the most frequent problem associated with this method is bone mal-alignment due to the impossibility to explore the fracture line directly. Restoration of the right length, rotation and the angular alignment of the bone are to be achieved using indirect reduction methods and techniques. The surgeon has to be prepared to perform this procedure with continuous fluoroscopy. [8,9]

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