Fractures of the distal radius: controversies in treatment, rehabilitation and management of complications
Lozano Calderon, S.A.

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Chapter 1


Chapter one is a general review of the anatomy of the distal radius. It explains in a very concise manner, basic anatomic concepts and landmarks form the distal radius necessary to understand ideas and statements further in the thesis. It is part of a book chapter written by the PhD candidate to “The Handbook of Fractures”

Chapter 2

Nazzal J, Lozano Calderón SA, Jupiter JB, Rosenzweig, Randolph M, Lee SGP. “A Histologic Analysis of the Effects of Stainless Steel and Titanium Implants Adjacent to Tendons: An Experimental Rabbit Study”


There is an increasing trend in the treatment of distal radius fractures towards open reduction and internal fixation instead of closed reduction and any type of percutaneous fixation; especially if the fracture involves the articular surface. Two materials are used for internal fixation devices: 316L stainless steel and titanium alloy (titanium-6-aluminum, 4-vanadium). Both have demonstrated to provide adequate fracture fixation in clinical human research and animal models; however, there is no evidence indicating whether stainless steel or titanium is better suited for osteosynthesis of fractures of the hand or wrist. Some advocate for Titanium due to its less stress shielding forces when compared to steel; its biocompatibility and its markedly decreased artifact streaking and scatter during radiological imaging exams. Others prefer stainless steel due to the tissue blackening caused by titanium black debris generation, and the increased cytokine production documented with this material in addition to the higher cost that represents its use. Also it is widely documented that stainless steel implants are easier to remove than those made from titanium, facilitating in numerous occasions subsequent treatment after the initial open reduction and internal fixation.
In this study we analyzed the soft-tissue response to both, titanium and stainless steel implants, when used to fix distal radius fractures in a rabbit model. The bone implant interface, tenosynovium, and overlying extensor tendons and muscles were studied histologically to determine the soft-tissue and inflammatory response to both materials and their time correlation.

We confirmed in this animal model that production of metallic and particulate debris is a consequence of active excursion of the undersurface of the extensor tendons over the dorsal surface of the implant. These particles then are uptaken by macrophages, which activate fibroblasts and inflammatory cells. These particles then become surrounded by collagenous fibers. The cytokines produced by inflammatory cells ultimately compromise the infrastructure of the tendon causing its final rupture. We found a correlation between time and the number of generated debris particles and cells.

We did not find any difference in the degree of inflammation and tissue response to titanium and stainless steel implants.

Chapter 3

Lozano Calderón SA, Doornberg J, Ring D. “Retrospective comparison: Volar plate vs. Percutaneous Fixation of Distal Radius Fractures”.

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The operative treatment of unstable fractures of the radius has become well accepted in order to limit the potential for re-displacement in a cast, arthritis, stiffness, weakness, and pain related to malunion[1, 2, 50, 51, 64, 65]. External fixation has been associated with stiffness of the hand and wrist and an increased potential for reflex sympathetic dystrophy (now known as chronic regional pain syndrome type I[66], even though the etiology of this condition has not been totally clarified. Recent evidence from animal models has suggested P substance signaling as the main mechanism explaining the complex regional pain syndrome type I (CRPS-I). According to Guo's and Offley's findings, P substance is responsible of the vascular changes and the altered nociceptive response observed in a model where rats developed CRPS-I after casting or sustained tibial fractures.[66] However, the connection between the methods of fixation and the
probability of any of them causing P substance release or other physiologic mechanisms etiologically responsible of CRPS-I have yet to be addressed.

More recently, it has been recognized that the wrist is like the hand in that external fixation and other percutaneous fixation techniques have the benefit of not causing additional trauma and scarring of the tendons[67-69]. In particular, dorsal plates have been problematic in this regard and have been associated with diminished results with respect to external fixation in a prospective randomized trial of the treatment of articular fractures. (Ellis, weiland, 2006)

Volar plate fixation has gained acceptance recently as a means of providing stable internal fixation, while avoiding the tendon problems associated with dorsally applied plates.[35, 37, 70, 71] There is more room for a volar implant, and there have been fewer complications when volar implants are used for volar Barton’s (shearing) fractures or for Smith’s fractures (extra-articular volar bending fractures)[35, 37, 70, 71]; although rupture of the flexor pollicis longus is occasionally observed[45, 72, 73]. Volar plate fixation of dorsally displaced fractures is most reliable when a plate with screws that lock to the plate is used—so-called angular stable fixation.[35, 37, 70, 71]

We reviewed a single surgeon’s consecutive experience with extra-articular and simple articular fractures of the distal radius to determine whether volar plates are comparable to percutaneous fixation or if they are associated with stiffness and tendon problems similar to dorsal plates. Because the surgeon changed his preferred treatment option at a relatively discrete point in time, but not the indications for surgery, a retrospective cohort study looking at patients treated percutaneously and those treated with a volar plate has value. Both groups were assessed in terms of functional outcomes and complication rates. We did not find statistically significant differences between patients treated with either method of fixation in terms of function, complications or final radiographic result.

Chapter 4

The original Barton's fracture[74]—a shearing fracture of the margin of the articular surface with subluxation of the radiocarpal joint—seemed to be volar in direction. However, currently at least in North America the eponym “Barton fracture” is used to refer to the more common and prevalent volar shearing fracture of the distal radius[75-80]. It has become clear that volar marginal shearing fractures with volar radiocarpal subluxation are far more common. As a result, the eponym Barton now refers more commonly to this volar fracture. While numerous papers have been written regarding volar shearing fractures of the articular surface, very little data have been provided regarding dorsal shearing fractures, with the exception of one area of overlap with dorsal shearing fractures—radiocarpal fracture-dislocations.

In this chapter we present a retrospective case series of 20 patients with this type of distal radius fracture, presenting their functional outcome after open reduction and internal fixation through single dorsal, single volar and combined volar dorsal approach. Pitfalls for treatment are suggested and some guidelines of pattern fracture evaluation to understand this uncommon fracture of the distal radius. Our hypothesis stated that dorsal shearing fractures involve a wider spectrum of fracture patterns that do not fit in any of the conventional classification systems. These different patterns may be characterized in a subclassification system that could guide treatment and proportionate pitfalls that might improve the final outcome of a severe injury in which prognosis is not particularly good now days.

Chapter 5

Lozano Calderón SA, Jupiter JB, Mudgal Ch, Ring D. “Prospective Randomized Comparison of Early and Late Wrist Mobilization after Volar Plate Fixation of a Fracture of the Distal Radius”

*In Press Journal of Bone and Joint Surgery [Am]*

Over the last three decades, operative treatment of distal radius fractures has become increasingly common compared to non-operative treatment[64, 69, 81-88]. Over the last 15 years there has been a trend towards more invasive, internal plate fixation of fractures of the distal radius[89, 90]. One argument in favor of internal fixation for these fractures is that, similar to other periarticular fractures, it would be beneficial to allow early movement of the wrist articulation. There is not, however,
any data to support this statement. In fact, data regarding external fixation that either
immobilizes the wrist or allows wrist motion suggest that early wrist mobilization is not
as important as the overall alignment of the bone in terms of final wrist motion. This
question is important in patient care and in decision-making regarding these fractures.
Additionally, many companies use this claim as a marketing point in spite of the lack
of evidence. We performed a prospective controlled randomized trial in which we
compared the functional results at three and six months in patients who sustained wrist
fractures and were treated surgically with volar plates, after receiving either early or late
rehabilitation protocols. We did not find any significant differences in terms of DASH
scores when comparing both groups—early vs. late rehabilitation-. Secondly, we did
not find significant differences between both groups in regards to final range of motion,
level of pain or grip strength.

Chapter 6

Brouwer K, Lozano Calderón SA, Doornberg J, Ring D, Goslings JC,
Kloen P. “Long-term Functional Outcomes of Distal Radius Osteotomy
for the Treatment of Distal Radius Malunion”

Submitted Journal of Bone and Joint Surgery [Am]

Union with deformity is the most common complication following a distal radial
fracture[91, 92]. This deformity can be intra-articular, affecting either the radiocarpal
or radioulnar joints; extra-articular characterized by metaphyseal angulation and loss of
length, or it may be a combination of both[91, 92].

Corrective osteotomies have been proven to be an effective treatment for
symptomatic malunion[91-101]. Event though, it is a challenging procedure that has
many pitfalls in order to achieve a good result.

There is short and medium term outcome evaluation in the published literature[91-93,
95, 96, 99-158]. However, there is a lack of evidence supporting subjective and objective
functional and radiological long-term outcomes in patients with distal radius malunion,
treated with extra or intra articular distal radius osteotomy. [102, 127-129, 159-162]

Chapter 6 reviews retrospectively the long-term functional outcomes of a
cohort of 12 patients treated at the Academisch Medical Centre (AMC), Amsterdam.
Through independent student t test and one-way ANOVA analyses different radiological parameters are analyzed as variables susceptible to change over time. The functional results at 13 years follow-up are compared to those reported for the short-term and medium term in other cases series in order to compare and test differences.

Corrective osteotomy of the distal radius for the correction of distal radius malunion is an adequate surgical treatment, which provides satisfactory radiological and functional results in the long-term follow-up. However, results deteriorate with time. These changes depend on patient age and post-traumatic and non-traumatic arthritic changes.

Chapter 7


As previously stated corrective osteotomies have been proven to be an effective treatment for symptomatic malunion [94, 144]. A variety of techniques have been used, however there has remained concern regarding the indications for surgical intervention in the presence of underlying osteoporosis as well as the recognized morbidity associated with autogenous iliac crest bone grafting [163-165]. Technical advances including the use of precontoured internal fixation devices with angular stable fixation, as well as the use of osteointegration biomaterials have offered some advantages. The contoured implants facilitate osteosynthesis by providing higher stability even in osteopenic bone. [166-172] These implants afford osseous fixation that allows early motion and rehabilitation [50]. Also their precontoured shape maintains desirable patterns of alignment, congruency and inclination of the distal radius after corrective osteotomy [2, 50, 90]. These properties reduce the probabilities of screw loosening and consequent loss of reduction [4, 20]. Following osteotomy and achievement of proper angulation and alignment, there will exist a three-dimensional defect that must be filled in order to adequately support the bone fragments [173-177]. Autogenous bone grafts have been widely used for this purpose. They have a recognized potential for donor site morbidity, in particular those involving corticocancellous variants [163, 165, 178]. Materials such as polymethylmethacrylate
(PMMA) and osteoconductive biomaterials such as Norian Skeletal Repair System (Norian SRS)® offer structural support eliminating effects of donor site morbidity [173-177]. Experience with polymethylmethacrylate (PMMA) has shown lack of osseous integration. In contrast, prospective randomized trials demonstrated good clinical and radiological results with osteoconductive synthetic materials such as Norian SRS®.

In this chapter we presented a new surgical technique involving the use of these described technologies in order to treat elderly patients with osteoporosis and distal radius malunion. Final functional outcomes after treating patients with this innovative surgical technique are comparable to the reported in other standard techniques.