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

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
DISCUSSION AND CONCLUSIONS
The following is the discussion of all the different chapters in regards to treatment, rehabilitation and management of complications of fractures of the distal radius covered in this thesis. As stated in the introduction, the areas of more controversy according to the literature review are biomaterials, modalities of fixation, dorsal shearing fractures treatment, rehabilitation and distal radius malunion treatment. Through each chapter, relevant points and conclusions about these areas were addressed. In general, our results demonstrated how more important than the type of material is the time that an implant remains embodied and surrounded by living tissue when treating fractures in regards to the inflammatory response. Our research also showed how the different methods of fixation currently available for the treatment of distal radius fractures are comparable in terms of outcomes and rates of complications, even though the nature of complications is different. Regarding dorsal shearing fractures, we could prove that they have different and particular patterns that once identified, may facilitate the use of treatment pitfalls and thus could improve the poor functional outcome associated with this injury. One of the most controversial areas, rehabilitation modalities, proved not to affect the final functional outcome in patients treated with volar plates after sustained distal radius fractures. Independently of the protocol -late or early- results were comparable in both groups at the highest level of evidence, a prospective controlled randomized trial (PCRT).

Lastly and to conclude, we found the corrective osteotomy of the distal radius an adequate treatment but not perfect for distal radius malunions that deteriorates with time. A modification of the technique using stable angle implants and Norian cement showed to be safe, reliable and predictable.

We continue now with a more detailed discussion by chapter of each of the major conclusive statements listed above.

**Chapter 1**

“Anatomy Review”

**Chapter 2**

“Tendon Rupture, severe inflammation and tissue blackening... who is guilty? Biocompability and costs... who is the winner?”
Titanium and stainless steel are the two metals used for plate and screw fixation. Advocates of titanium claim less stress shielding (1-3), better biocompatibility (4-6), and decreased interference with CT and MR imaging when compared to steel (7, 8). Advocates of stainless steel point out that titanium generates black debris and tissue inflammation (9, 10) with consequent increased cytokine production (11, 12); higher costs (13); and hardware removal difficulties (14-20). There is very little scientific data to guide the decision regarding implant material.

The Pi-plate was associated with frequent tendon irritation and tendon rupture, and the fact that the plate was made of titanium was felt to be an important factor (14, 15, 21). Some research suggested that is the material itself what contributes to tenosynovitis and tendon ruptures (11, 12, 14, 15). Lowry and Gainor (14) compared patients with titanium and stainless steel plates on the dorsal surface of the distal radius in terms of tendon ruptures and tenosynovitis. They reported a higher prevalence in the Titanium group, which led them to conclude that titanium plays an etiological role in inflammatory response. However, other research has proposed plausible factors such as location of the plate in the second dorsal and other extensor tendon compartments (22). Additionally, other data has suggested that sharp plate edges (17, 18), broken plates or prominent screws (16) are more important causes of tenosynovitis and tendon rupture associated with the use of the Pi plate.

Our rabbit model demonstrated no statistical significant differences between titanium or stainless steel in terms of particle production, cell number or cell type response. Within the limitations of our study design, including potential differences between rabbits and humans, we conclude that the inflammatory response of tendons to titanium and stainless steel is comparable. If future research in this area is felt to be worthwhile, we would suggest looking at the inflammatory mediators produced by exposure to each material.

In my opinion, tenosynovitis and tendon rupture associated with dorsal wrist implants is a multifactorial phenomenon. Our findings suggest that the material may be a relatively unimportant factor. Our clinical recommendation would be routine removal of dorsal implants from the distal radius after fracture healing, particularly when there is crepitation of the tendons over the implant with wrist and digit motion.
Chapter 3

“Percutaneous fixation: Simpler to the surgeon, faster healing to the patient and less scarring tissue for the wrists... Volar plates: Earlier motion, faster return to regular activities, better life quality and lower risk infection. What should I use in my patient?”

The two best options for operative fixation of a fracture of the distal radius are percutaneous or external fixation methods and internal volar plate fixation. These treatments are being compared in several ongoing prospective randomized trials, but our retrospective data provides an initial view of the advantages and disadvantages of each technique.

External fixation/percutaneous fixation has been associated with stiffness, chronic regional pain syndrome and patient discomfort (both physical and psychological)(23-38). Advantages of this method include limitation of additional trauma and scarring of tendons, and the preservation of fracture haematoma(27-38).

The disadvantages of plates include the need for additional surgical trauma with potential scarring of tendons, especially when the plate is placed dorsally(15, 39-65). Benefits, on the other hand, include the potential for early motion and more comfort to the patient in activities of daily living(15, 39-65).

In our study the cohorts were comparable demographically and the number of patients per group allowed us to make comparisons between both cohorts with an 80% statistical power at a p level set at 0.05 level to detect differences of 10 points in our primary outcome measure, the DASH score. This study has the advantage of the same surgeon performing all surgeries. Initially, he used percutaneous fixation to treat patients with extraarticular or intraarticular non-complicated fractures, and then changed his practice to open reduction and internal fixation with plates, for the same surgery indications.

Our findings in this study were very interesting, since we did not find any substantial difference between both groups in terms of subjective evaluation (DASH score), the final clinical outcomes (Modified Mayo Wrist Score, Modified Gartland and Werley Score), final range of motion or the grip strength. The rate of complications was comparable as well even though they were different in both groups.

We could conclude from this study that both methods of fixation are comparable in terms of final outcome and that their differences and possible complications in addition to the surgeon’s experience are factors that account as input when a final
therapeutic decision is made for a patient. For example, an older patient with basal limited function and significant co-morbidities that can become complicated if a long surgical time is used, will benefit more from a short and less invasive procedure such as percutaneous fixation. An active patient, such as a professional athlete, may benefit more from a plate that will allow faster returning to normal motion and activities than a percutaneous method that will be for him/her more an inconvenience.

In this chapter, our hypothesis was rejected. There were not substantial differences between both modalities of treatment in terms of subjective outcome, functional outcome, range of motion and/or grip strength. Incidence of complications was very small in both cohorts but they were different between both groups. However, the sample size is not large enough to determine the significance of this finding and future research is needed to address this issue. Our recommendation is to utilize either method according to the necessities of the patient, the surgeon experience and other factors such as level of activity, co-morbidities, bone quality, etc.

Chapter 4

“Dorsal sharing fractures of the Distal Radius... why they are so rare?
Plated dorsally? Not even think about it!!”

This chapter covers one of the areas in which not much is published in the literature(66-70) and therefore is a study that uses a descriptive case series design due to the extremely low incidence and prevalence of this injury pattern in the general population(69-71). In addition to the low incidence and prevalence rates of this injury, we believe that many of them are considered dorsal radiocarpal dislocation since there is significant overlapping between these two(72-79). Even though it is speculative, it seems to be plausible that the mechanism of these fractures to occur is a primary shearing force over the distal radius surface; more biomechanical research is needed in this regard to confirm information that currently is mere theory.

In our case series we used as inclusion criteria the presence of a fracture of the dorsal articular margin of the distal end of the radius and the presence of radiocarpal subluxations or complete dislocation. Using these criteria we included the 20 patients reported in our series but we could typify four patterns of injury that included those two conditions plus other findings that can mislead the diagnosis. These groups as we explained in the chapter were: 1. Impaction of the majority of the distal radius
surface with a relatively intact volar metaphyseal fracture line; 2. Radiocarpal fracture-dislocation with rupture of the radiolunate ligaments (true radiocarpal dislocation); 3. Radiocarpal fracture-dislocation with fracture of the volar portion of the lunate facet where the radiolunate ligaments insert; and 4. Central articular impaction with relatively sparing of the radial styloid and the volar most portion of the lunate facet. Some will think that these patterns of fracture are just other fractures and not Dorsal shearing fractures. However, none of these types or subgroups is well described in the existing classifications. We consider very important to report them since they may determine important pitfalls of treatment that can improve the patient functional outcome.

In this chapter we accomplished our main objective, to describe with more detail this type of fracture. After this review we consider that a dorsal shearing fracture is more related with the mechanism of injury (shearing) than with the fracture pattern findings since, as we described, these can be more complex than only a fracture of the dorsal rim of the intraarticular distal radius.

The patterns that we reported occurred in conjunction to the main characteristics described at the beginning. For example, central articular impaction occurred in some cases in addition to the intraarticular distal radius dorsal rim fracture with carpal subluxations or luxation. The complexity of these subdivisions and the experience through treating surgically these patients proportioned some pitfalls that we considered important to report. The combined approach is often necessary since the visualization of the fracture, the reduction itself, and the dorsal plate buttressing are easier to accomplish from a dorsal approach. The additional volar approach is often required for realignment and fixation of displaced volar fragments, product of ligament avulsion. Sometimes when these volar fragments are to small, techniques with wires and suture to incorporate the capsule to the fixation are very useful in the final fracture reduction. Often, when most of the articular surface is dorsally impacted with a relatively non displaced metaphyseal volar fracture line and not central impaction, a single volar approach is enough to reduce the fracture, but as a general rule to treat these patients only volarly is extremely challenging and the dorsal approach can significantly facilitate the surgery to the surgeon.

Regarding our second hypothesis, we could verify that the subjective functional outcome of these patients is comparable to those that have suffered another type of distal radius fracture. In terms of objective functional outcome the results are no satisfactory in more than 50% of the patients, explaining the inherit complexity of this injury.
To conclude, we could say from this chapter that Dorsal shearing fractures of the distal radius are complex injuries that occur most likely because of a shearing force that involves the dorsal rim of the distal radius when the wrist is in full flexion or in some extension. Even though this theory is plausible, future research is required to describe with more detail and document better the injury mechanism to occur for this fracture. Acceptable functional outcomes that can leave quite significant residual impairment can be expected in these patients after surgical treatment which ideally should be performed through a combined (dorsal and volar) approach. Different subtypes of the fracture that involve the volar surface of the radius need to be addressed in order to offer a better treatment to the patient. Surgeons need to be aware that one of the most challenging parts of the surgery is to obtain restoration of the volar tilt, neutral alignment should be considered satisfactory due to the complexity of this part of the procedure. A final recommendation but none the less important, is the routine removal of the dorsal plate after consolidation to avoid subsequent tenosynovitis or tendon rupture associated with plating in this location. Even though these are complex injuries, satisfactory function can be reached after surgical treatment.

Chapter 5

“Rehabilitation after Surgical treatment of Distal Radius fractures... No pain no gain?”

Open reduction and internal fixation of distal radius fractures is currently a method widely used today (5, 15, 39, 42-46, 50, 54, 57-59, 61, 64, 65, 80-88). As stated in different parts of this thesis, supporters of this system emphasize the advantage of early motion when using these implants (5, 15, 39, 42-46, 50, 54, 57-59, 65, 83-88). However, recent investigations from McQueen in 1996 suggest that more than early mobilization, what is relevant in terms of final outcome and prognosis is the final and adequate alignment of the fracture (25, 26). In her research, McQueen used a PCRT design to compare the functional outcome in distal radius fractures after using bridging and non-bridging external fixators. Her findings concluded that for the final functional outcome, alignment was more important than mobilization. Outcome was better in bridging fixators (good alignment but not mobility) than in non-bridging fixators (better mobility but sacrificing alignment) (25, 26).
Our design provides, as well, level 1 of evidence through a PCRT. (This could not be a blind study since the type of therapy is impossible to hide from the patient and get his/her cooperation.) We assessed subjects 3 and 6 months after the injury using subjective instruments, DASH Score, and objective functional outcome measures, Modified Mayo Wrist Score and Modified Gartland and Werley Score. Our findings demonstrate that in terms of the DASH score both groups were not comparable at the 3-month evaluation since higher scores were seen in the early rehabilitation group. These differences were not evident at the six-month evaluation when both groups scored similarly and did not differ in a statistical significant mode. There were not substantial differences in both groups at three and six-month evaluations according to the Modified Mayo Wrist Score and the Modified Gartland and Werley Score. However, rates of improvement of the scores were significant within each group, demonstrating the utility of both protocols for rehabilitation. Recovery of wrist motion and grip strength was not comparable between both rehabilitation protocols at the three-month evaluation. At this point of evaluation a better range of motion and grip strength was perceived in the early protocol group when compared to the late. However, rates of pain improvement and the DASH score were lower. At the final evaluation, 6 months after surgery, both groups were comparable in terms of subjective functional and objective functional results.

From this study and this chapter, we can conclude that early and late rehabilitation are both useful and adequate in the rehabilitation of patients that were treated with volar plating for non-complicated distal radius fractures. Even though better results are seen initially in the early group in terms of motion and grip strength, pain recovery and subjective improvement is not as satisfactory as it is seen in the late group at this point of evaluation, 3 months. Similarly, even though pain and subjective rate of improvement were seen to be higher in the late group at three months of evaluation, motion and strength outcomes were not as satisfactory as those in the early group. Six months after surgery, both groups were comparable in every assessed outcome.

We consider that giving the fact that both protocols are comparable in the long term, their prescription should be based in other variables such as patient personality, occupation, pain tolerance and expectations of the patient (i.e. A patient with low tolerance to pain will benefit more from a late protocol since this modality will help to improve first the amount of pain. Conversely, a very active and driven patient would benefit from an early protocol since its structure is closer to his perception of improvement).
Chapter 6

“Long term of distal radius osteotomies for distal radius malunion... Will my patient do better now?”

As discussed in the thesis, malunion of the distal radius is the most common complication following the treatment of distal radius fractures(89). Not much is written in terms of long term follow-up; however, this surgery has proved to be effective, in spite of its complexity, in the short and intermediate follow-up(89-97). In this chapter we evaluated the long-term outcomes of patients treated for distal radius malunion with distal radius osteotomy. This retrospective review, that averaged 13 years, allowed us to see what the results are. The available literature reports follow-ups no longer than 6 years with satisfactory results in terms of function and radiological alignment (98-114). We found that corrective osteotomies of the distal radius are a corrective and salvage procedure that provides acceptable results. However, they are not perfect and the prognosis in the long-term is as not as good as other authors may expected it to be after seeing the results in the short and medium-terms. The average DASH score was 39 points and it is relatively higher (worse function) to the reported DASH from other series of patients after surgical treatment of Distal Radius fractures through open reduction and internal fixation -less than 21 points- (115). Average Modified Gartland and Werley Score(116) and the Modified Mayo Wrist Score(117) were 10 and 62 points respectively. Our case series is the first one using these strict instruments of evaluation and therefore is expected that our results are not as satisfactory as other series that used more flexible instruments for functional outcome and therefore reported better results. Another reason for worse results when compared to medium-term and short-term follow-ups may be the fact that all of our patients but one developed symptomatic post-trauma or age related arthritis. To differentiate between the both is an impossible task and probably they just simply coexist.

Contrary to the functional outcomes, radiological correction maintained adequate values along time. We did not find statistically significant differences between the obtained parameters after initial correction and fixation and the parameters seen at the 13-year follow-up. The consistency in radiological alignment along time, the arthritic changes and the fair functional results make the association of fair functional outcomes and arthritis plausible.
Discussion and Conclusions

In conclusion, correctives osteotomies of the distal radius are an adequate and reliable treatment for distal radius malunions even though their complexity is quite significant. Rate of improvement is inferior in the long-term when compared to what is seen in other patients that received treatment for distal radius fractures through open reduction and internal fixation or who have received corrective osteotomies in the short and medium term. With time it is natural that results tend to be worse, probably due to the coexistence of post-traumatic and age-related arthritis. Functional objective and subjective outcomes that can be expected vary between poor and fair. It seems that these are more related to the presence of arthritis more than to radiological alignment. Corrective osteotomies of the distal radius are an effective and useful but challenging and not perfect procedure for the treatment of distal radius malunions.

Chapter 7

“Distal radius malunion in the elderly... with that osteoporotic bone, surgery? Do not even think about it!!! Better to leave it as it is!!”

In this chapter, we proposed an innovative technique that addresses some of the difficult points in the treatment of patients with distal radius malunion when their age has an impact on their bone quality. As described in the previous chapter, a corrective osteotomy creates a three-dimensional defect that needs to be filled with bone graft in most cases to guarantee union and healing. As it has been proven by several research studies, osteoporotic and osteopenic bone are very susceptible to internal fixation materials. In general, the poor bone quality does not allow adequate support of the hardware, ending in osteosynthesis failures and refracture of the wrist. This surgery in the elderly gets even more complicated due to the scarce sources to obtain iliac bone in order to graft the defect created by the osteotomy.

Our technique using locking compression plates and Norian cement solves these difficulties, improving the functional outcome of the patient and recovery time because of the absence of donor site morbidity and the stability provided by the implant without requiring bicortical screw purchase in a bone with very thin cortices. Locking compression systems are ideal for periarticular fractures (such as the distal radius) where small fracture fragments are present and where there is no support in the contralateral side of the fracture. Since the screw heads lock into the
corresponding threads on the screw hole of the plate, forces are transmitted to the plate through this connection, countermanding toggling forces in the bone plate interface(61, 62, 64). Additionally, because compression is not necessary, the vascularity is preserved, maintaining a more favorable environment for fracture healing(61, 62, 64, 132). Pitfalls for the placement of this device include the surgeon awareness of adequate reduction before placing the plate since fragment manipulation is not possible after a locked screw is placed above or below the fracture(61, 62, 64, 132). Corrections in reduction imply removing completely the implant and placing it again, an undesirable situation in a patient in which bone quality is not the best(61, 62, 64, 132). Another important point for the surgeon to consider is the lack of tactile feedback while tightening the screws(61, 62, 64, 132).

The advantages of Norian cement are its ability to osteointegrate and its biocompatibility, which help support the fracture while consolidation takes place in a weak bone as it occurs in osteoporotic patients(127-131). Norian’s high compressive strength and fast setting at physiological pH and temperature make it desirable when compared to other substitutes such as PMMC(127-131). Additional advantages in radiologic imaging convert this material into a good alternative to bone graft(127-131).

Our case series present acceptable clinical results in terms of subjective evaluation, objective functional outcomes and radiological results. However, we are aware of the statistical limitation of this study as a non-comparative case series. Our achieved purpose for this chapter is to offer an alternative in a procedure that in general is challenging in the population previously described. More studies with larger samples and comparative in nature need to be done to address the real impact of this surgical technique when compared to current treatment alternatives.

**To conclude...**

As we could see, at least the “dogmas” discussed in this thesis in regards of the treatment, rehabilitation and the management of complication of distal radius fractures, can and should be approached in a questioning attitude. Many of them that have been defended and positioned throughout years with several publications in the available literature, have been proved to be weak or at least questionable through the chapters of this thesis and its discussion. Abundant research is required to improve the quality
of treatment of our patients and to clarify and standardize our treatments. As stated in the initial part of this discussion, significant advances are difficult to achieve with strict epidemiological research. Therefore in years to come, we will have comparable options of treatments that may fit the characteristics of our patients from a holistic perspective, more than particular and specific treatments for “fractures”. The pathway of science requires effort and time and after the conjoined effort of the scientific community, we will experience a significant advance. Meanwhile, we should walk this pathway humbly, following the discipline of the scientific method and motivated by the desire of finding the truth and for the love for knowledge.

REFERENCES


39. Axelrod TS, McMurtry RY. Open reduction and internal fixation of comminuted, intraarticular

40. Bell JS, Wollstein R, Citron ND. Rupture of flexor pollicis longus tendon: a complication of volar


42. Campbell DA. Open reduction and internal fixation of intra articular and unstable fractures of the

43. Carter PR, Frederick HA, Laseter GF. Open reduction and internal fixation of unstable distal radius
Mar;23(2):300-7.

44. Constantine KJ, Clawson MC, Stern PJ. Volar neutralization plate fixation of dorsally displaced

45. Damron TA, Jebson PJ, Rao VK, Engber WD, Norden MA. Biomechanical analysis of dorsal plate

46. Drobetz H, Kutscha-Lissberg E. Osteosynthesis of distal radial fractures with a volar locking screw

47. Fitoussi F, Ip WY, Chow SP. Treatment of displaced intra-articular fractures of the distal end of the

open reduction and internal fixation with T-type plate]. Zhonghua Wai Ke Za Zhi. 2002 2002///
Feb;40(2):120-3.

of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating
versus mini open reduction, percutaneous fixation, and external fixation. J Hand Surg [Am]. 2005

50. Hahnloser D, Platz A, Angwerm D, Trenz O. Internal fixation of distal radius fractures with dorsal


52. Handoll HH, Madhok R. Surgical interventions for treating distal radial fractures in adults.


Discussion and Conclusions | 145

1935.
87. Smith DW, Brou KE, Henry MH. Early active rehabilitation for operatively stabilized distal radius
Discussion and Conclusions


