Ann Med Res

Current issue list available at AnnMedRes

Annals of Medical Research

journal page: www.annalsmedres.org

Effectiveness of the modified Lafontaine criteria in predicting loss of reduction in distal radius fracture

Necati Dogan[a,*], Cafer Ozgur Hancerli[b], Gurkan Caliskan[c]

[a] *Basaksehir Çam and Sakura City Hospital, Department of Orthopaedics and Traumatology, Istanbul, Türkiye*
[b] *Bahçeşehir University, Faculty of Medicine, Medical Park Göztepe Hospital, Department of Orthopedics and Traumatology, Istanbul, Türkiye*
[c] *University of Health Sciences, Kanuni Sultan Süleyman Training and Research Hospital, Department of Orthopaedics and Traumatology, Istanbul, Türkiye*

ARTICLE INFO

Keywords:
Distal radius fractures
Effectiveness
Modified lafontaine criteria
Loss of reduction

Received: Jun 24, 2024
Accepted: Sep 19, 2024
Available Online: 26.09.2024

DOI:
10.5455/annalsmedres.2024.06.119

Abstract

Aim: This study aimed to retrospectively test the ability of the modified Lafontaine criteria to predict loss of reduction in distal radius fractures treated conservatively.

Materials and Methods: Between January 2019 and July 2021, a total of 171 patients aged 50-60 years diagnosed with distal radius fractures and treated with closed reduction and short arm casting were evaluated radiologically. Patients were categorized into two groups based on the modified Lafontaine criteria: Group 1 included patients meeting fewer than three criteria, while Group 2 included those meeting three or more criteria. Parameters such as age, gender, fracture side, fracture type (according to AO classification), follow-up period, radial length, and volar tilt degree after initial reduction were compared with their respective values at the last follow-up. Additionally, changes between values obtained at the last follow-up and those after initial reduction were analyzed.

Results: According to the modified Lafontaine criteria, 68 patients were classified into Group 1 and 103 patients into Group 2. Both groups exhibited similar distributions in terms of age, fracture side, and follow-up period ($p>0.05$). However, Group 2 showed a significantly higher proportion of females compared to Group 1 ($p=0.004$). Furthermore, Group 2 differed significantly from Group 1 in terms of fracture distribution ($p=0.024$). Radial lengths and volar tilt degrees after initial reduction showed no significant differences between the groups ($p>0.05$). At the last follow-up, it was observed that changes in radial length, volar tilt degree, and reduction loss were significantly greater in Group 2 ($p<0.05$). Analysis of differences between values at the last follow-up and after initial reduction indicated that radial length and volar tilt decreased or changed significantly more in Group 2 ($p<0.05$).

Conclusion: The modified Lafontaine criteria significantly predict higher reduction losses when three or more criteria are present. This study demonstrates that using three criteria as a cut-off can forecast average reduction loss. However, further research is necessary to delve into the individual effects of Lafontaine criteria, their combinations, and their clinical implications.

Introduction

Distal radius fractures can usually be treated with closed reduction and casting. However, intra-articular displaced fractures, volar or dorsal Barton fractures, and unacceptable anteroposterior and lateral angulations may require surgical treatment [1, 3].

Although radiological values were initially accepted in patients treated with closed reduction and casting, the loss of reduction over time is a concern for clinicians. For clinicians, the instability parameters described by Lafontaine and modified over time are useful for predicting loss of reduction. These parameters include severe osteoporosis, initial dorsal angulation amount, initial radial shortening amount, dorsal fragmentation, volar fragmentation, intra-articular extension, radial shortening amount and the presence of an accompanying ulnar fracture [4,5]. If these parameters are 3 or higher, the fracture is considered unstable and is prone to displacement. In the presence of 3 or more criteria, re-reduction or even surgical fixation is recommended [4,5].

*Corresponding author:
Email address: drnecatidogan@gmail.com (Necati Dogan)

The ability of the modified Lafontaine criteria to predict loss of reduction has been limitedly examined in the literature. Additionally, there is not enough information on the amount of reduction loss.

This study seeks to address whether, according to the modified Lafontaine criteria, the reduction loss is indeed greater in the presence of three or more parameters compared to fewer than three parameters, and whether this reduction loss can be predicted and will exceed the acceptance criteria. To investigate these hypotheses, this study aimed to retrospectively test the ability of the modified Lafontaine criteria to predict loss of reduction in distal radius fractures treated conservatively.

Materials and Methods

Study design

A retrospective analysis was conducted on distal radius fractures in patients aged 50-60 years, who were followed up and treated with closed reduction and short arm casting between January 2019 and July 2021. The study was approved by the Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (No: KAEK/2024.04.76). All patient medical information was anonymized, thus waiving the requirement for informed consent. Our study was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion and exclusion criteria

Patients with distal radius fractures aged 50-60 years, who underwent closed reduction and short arm circular casting, were included in the study. Patients with irregular or incomplete radiological follow-up and those who required re-reduction or surgical intervention during follow-up were excluded from the study. Additionally, patients with multiple fractures, open fractures, high-energy fractures, or ulnar variance pathology at baseline or follow-up were excluded.

Creation of comparative groups

According to the modified Lafontaine criteria, patients with less than three criteria were designated as Group 1, while those with three or more criteria were designated as Group 2 (Table 1).

First intervention criteria and follow-up method

For patients diagnosed upon emergency admission, control radiographs were taken in the emergency room after closed reduction and casting. All patients with a maximum reduction in radial length of 8 mm, volar tilt between dorsal 5 and volar 20 degrees, ulnar variance within the normal range (+2 mm/-2 mm), and minimal intra-articular stepping (max 2 mm) were followed conservatively [6]. Additionally, some patients outside these parameters received conservative treatment due to comorbidities, low functional expectations, or personal preference for conservative treatment. All patients were treated by orthopedic surgeons of similar experience.

Patients were called for routine check-ups in the 2nd and 4th weeks. After radiological union was achieved—typically by the 4th week, but sometimes in the 5th or 6th week—the cast was removed, and physical therapy exercises were initiated.

Table 1. The modified Lafontaine criterias.

Severe Osteoporosis	Present	5
	Absent	166
Ulna Styloid Fracture	Present	93
	Absent	78
Dorsal Fragmentation (more than 50%)	Present	106
	Absent	65
Palmar Fragmentation	Present	20
	Absent	151
Intra-articular Fracture	Present	23
	Absent	148
Initial Dorsal Angulation (more than 20 Degrees)	Present	103
	Absent	68
Initial Displacement (more than 1 cm)	Present	21
	Absent	150
Initial Radial Shorter (more than 5 mm)	Present	115
	Absent	56
The modified Lafontaine criterias	<3 criteria	68
	≥ 3 criteria	103

Data collection

Data collected included age, gender, fracture side, fracture type (AO classification), radial length, and volar tilt degree after the first reduction, as well as radial length and volar tilt degree at the last follow-up. Additionally, the change in these measurements from the initial post-reduction values to the last follow-up values was calculated. All measurements were performed using the same radiological imaging system and by the same principal investigator.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 26 (IBM, Chicago, IL, USA). Descriptive statistics (mean, standard deviation, median, frequency, ratio, range) and data distribution were evaluated using the Shapiro-Wilk test. Student's t-tests were used to compare the data between the two groups. Statistical significance was set at $p<0.05$ for all analyses.

Results

According to the modified Lafontaine criteria, Group 1 comprised 68 patients, while Group 2 comprised 103 patients. The mean age was 54.61 years for Group 1 and 54.28 years for Group 2. Regarding gender distribution, the female-to-male ratio was 1.51 in Group 1 and 3.9 in Group 2. For fracture side, the right-to-left ratio was 0.78 in Group 1 and 0.56 in Group 2. According to the AO classification, Group 1 included 63 patients with type A2 fractures, 3 with B2, 1 with C1, and 1 with C2. Group 2 included 1 patient with A1, 76 with A2, 10 with A3, 6 with B2, 3 with B3, 4 with C1, and 3 with C2 fractures.

Table 2. Demographic data of patients and the parameters that were followed.

		Group 1 The modified Lafontaine Criteria < 3 n = 68	Group 1 The modified Lafontaine Criteria ≥ 3 n = 103	P value
Age	Avg ± SD Min–max (median)	54.61 ± 2.94 50–59 (54)	54.28 ± 2.64 50–59 (55)	0.448
Gender	Female Male	41 (61%) 27 (39%)	82 (80%) 21 (20%)	**0.004**
Fracture side	Right Left	30 38	37 66	0.289
Fracture type (AO 23)	A1 A2 A3 B2 B3 C1 C2	0 63 0 3 0 1 1	1 76 10 6 3 4 3	**0.024**
Follow-up time (months)	Avg ± SD Min–max (median)	52.79 ± 9.23 33–66 (55)	51.63 ± 9.69 36–66 (52)	0.430

Table 3. Comparison of radiological parameters between groups.

		Group 1 The modified Lafontaine Criteria < 3 n = 68	Group 1 The modified Lafontaine Criteria ≥ 3 n = 103	P value
Radial length after the first reduction	Avg ± SD Min–max (median)	11.08 ± 2.25 5–15.6 (11)	10.56 ± 2.35 1.7–15 (10.4)	0.149
Radial length at last follow-up	Avg ± SD Min–max (median)	9.32 ± 2.75 0–14.5 (9.75)	7.91 ± 3.15 0–15 (8)	**0.001***
Amount of change in radial length	Avg ± SD Min–max (median)	1.89 ± 1.98 0–7.4 (1)	2.93 ± 2.48 0–12 (2.2)	**0.001***
Volar tilt after the first reduction	Avg ± SD Min–max (median)	6.86 ± 5.46 (-8) – (+20) (8)	6.49 ± 5.82 (-10) – (+20) (7)	0.674
Volar tilt at last follow-up	Avg ± SD Min–max (median)	3.63 ± 7.62 (-15) – (+18) (4)	1.58 ± 8.39 (-30) – (+20) (4)	**0.049***
Amount of change in volar tilt	Avg ± SD Min–max (median)	4.5 ± 5.17 0–25 (3)	7.01 ± 6.23 0–25 (5)	**0.002***

The average follow-up period was 52.79 months for Group 1 and 51.63 months for Group 2 (Table 2).

Both groups had similar distributions in terms of age, fracture side, and follow-up period ($p>0.05$). Group 2 showed a higher proportion of females compared to Group 1 ($p=0.004$). There was a significant difference in fracture distribution between Group 1 and Group 2 ($p=0.024$) (Table 2).

The average radial length after initial reduction was 11.08 mm in Group 1 and 10.56 mm in Group 2. There was no significant difference in radial length after initial reduction between the groups ($p = 0.149$). The radial length at the last follow-up was 9.32 mm in Group 1 and 7.91 mm in Group 2, with Group 2 showing a significantly lower radial length ($p=0.001$). Evaluating the change between initial reduction and final follow-up, Group 1 had an average reduction of 1.89 mm, whereas Group 2 had a reduction of 2.93 mm, indicating greater radial height loss in Group 2 ($p=0.001$) (Table 3).

The average volar tilt after initial reduction was 6.86 degrees in Group 1 and 6.49 degrees in Group 2, with no significant difference between the groups ($p=0.674$). At the last follow-up, the volar tilt was 3.63 degrees in Group 1 and 1.58 degrees in Group 2, showing a significantly lower volar tilt in Group 2 ($p=0.049$). Evaluating the change between initial reduction and final follow-up, Group 1 had an average change of 4.5 degrees, whereas Group 2 had an average change of 7 degrees, indicating a greater angular change in volar tilt in Group 2 (p=0.002) (Table 3).

No surgical interventions were performed or requested by any patients during the follow-up period, and there were no complications requiring intervention.

Discussion

Our study found that when the modified Lafontaine criteria are ≥ 3, distal radius fractures exhibit significantly higher reduction losses compared to criteria <3. In Group 1, the average radial height loss was 1.89 mm, while volar tilt changed by an average of 4.5 degrees. In contrast, Group 2 showed greater reduction loss with an average radial height decrease of 2.93 mm and a volar tilt change of 7 degrees.

Distal radius fractures have been extensively studied in the literature, with various treatment algorithms and radiological criteria proposed. Predicting loss of reduction after reduction is a critical focus, although detailed investigations into these parameters remain limited. Lamartina et al. explored numerous parameters and their relationships, highlighting displacement without detailed analysis of displacement magnitude [5]. In our study, we specifically examined radial length and volar tilt, aiming to quantify average reduction loss. Continued prospective studies are essential for expanding clinical knowledge and informing practice.

One of the significant parameters contributing to fractures in displacement is osteoporosis. Particularly in patients with impacted and metaphyseal defects, achieving appropriate length and reduction becomes quite challenging. A study investigating this issue has revealed that osteoporosis leads to an average increase of approximately 1 mm in ulnar variance [7]. Age and osteoporosis are independent factors [8,9] crucial for predicting displacement in distal radius fractures [10]. Our study focused on patients aged 50-60 to standardize the cohort, as age significantly impacts clinical outcomes and treatment decisions, particularly favoring conservative management in older adults [11]. Some studies identify age as a primary factor associated with reduction loss within Lafontaine criteria [12].

Female gender is another significant predictor of reduction loss [9]. Group 2 in our study exhibited a higher proportion of females, aligning with literature indicating higher displacement risk among women, possibly due to osteoporosis incidence under 60 years.

Fracture type also significantly influences displacement risk [9]. Group 2 demonstrated a higher incidence of complex fracture types, consistent with literature associating multicomponent and intra-articular fractures with increased displacement risk. In a comprehensive and highly recent study, parameters predicting displacement have been discussed, and the amounts of displacement have been determined. According to this study, age, fracture type, and ulnar variance have been identified as key predictive factors for displacement [13].

Radial shortening lacks a universally accepted clinical threshold in the literature. In our study, Group 2 experienced an average radial shortening exceeding initial thresholds by 6 mm, highlighting substantial shortening compared to Group 1. While this level did not necessitate surgery, it could pose significant challenges in younger patients. Literature suggests that poor radiological parameters may not affect long-term clinical outcomes in elderly patients [11,14], but this conclusion may not apply to younger populations based on current evidence. Continued research is warranted to better understand the clinical implications of these findings and refine treatment strategies for distal radius fractures. Another publication emphasizing the importance of pre-reduction dorsal angulation and ulnar variance suggests that displacement risk is significantly elevated with ulnar variance greater than 5 mm, dorsal angulation exceeding 20 degrees, and dorsal comminution. However, it is argued that the decision regarding surgery should be left to the patient. The absence of absolute thresholds in the literature necessitates that surgical decisions be individualized for certain patient groups [15].

Volar tilt resulted in significantly greater loss of reduction in Group 2. Although the literature suggests a wide range of volar tilt (5 degrees dorsal to 20 degrees volar) [5] can tolerate these reduction losses, our study observed higher average reduction loss in Group 2 patients. Dorio et al. identified ulnar variance and volar tilt as critical parameters affecting function, with other factors having minimal impact [16]. In our study, patients with ulnar variance issues were excluded, and volar tilt was generally within the ideal range for functional outcomes. However, when the modified Lafontaine criteria were 3 or higher, Group 2 exhibited greater changes in volar tilt, averaging 7 degrees. Predicting the tolerance for 7-degree deviations in displacement could aid in surgical decision-making and reduction strategies. Given the significant impact of volar tilt and ulnar variance on clinical outcomes [16], these parameters merit careful consideration.

Loss of reduction in distal radius fractures can also impact carpal alignment, potentially leading to functional impairments. Consequently, it is believed that dorsal displacement is one of the undesirable parameters, particularly after reduction [17].

Radiological lower limits are specified in some studies, yet many indicate comparable long-term outcomes even when functional radiological limits are exceeded [11,14,18]. Similarly, Ruzika et al. proposed that surgical treatment initially surpasses conservative methods, but yields comparable long-term results. They noted satisfactory functional and cosmetic outcomes despite visible deformities in conservative treatments [19-21]. Recent studies also suggest that 10-year outcomes of conservative treatment are independent of radiological parameters [22]. Conversely, poor radiological unions may restrict activity and cause pain in patients under 65 years [23]. These findings continually challenge the correlation between radiological parameters and clinical outcomes.

The modified Lafontaine criteria effectively predict reduction loss, yet their clinical equivalence remains underexplored in the literature. Furthermore, the individual effects of all radiological parameters on reduction loss need separate investigation. While some studies have examined these parameters individually, few have analyzed their combinations or discussed the clinical significance of reduction loss [9]. Emerging parameters, such as volar hinge or metaphyseal dorsal collapse, have been identified as independent factors contributing to displacement [24, 25].

In future research, clearer radiological benchmarks and systematic analyses of these parameters may enhance prediction accuracy of average displacement amounts and inform early surgical intervention decisions. This study and forthcoming research could facilitate early surgical decisions by predicting borderline reduction losses, thereby mitigating adverse effects of delayed surgeries on patients.

Limitations

Due to its retrospective nature, this study lacks adequate data standardization. Prospective randomized studies are essential for robust conclusions. Moreover, large-sample studies are needed to investigate the individual effects of each parameter comprehensively. While these parameters' impacts on reduction loss are discussed, their implications for clinical outcomes warrant further exploration.

Conclusion

The modified Lafontaine criteria effectively identify patients at higher risk for reduction loss when three or more criteria are present. This study demonstrates that using three criteria as a cutoff point can predict average reduction loss. However, further detailed investigations are warranted to assess the individual impacts of the modified Lafontaine criteria and different combinations thereof on reduction loss. Additionally, future studies should explore the clinical implications of these findings in greater depth.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Financial support

The authors declare that this study has received no financial support.

Ethical approval

Approval has been granted by Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (No: KAEK/2024.04.76) (Date: 25/04/2024).

References

1. Liporace FA, Adams MR, Capo JT, Koval KJ. Distal radius fractures. J Orthop Trauma. 2009 Nov-Dec;23(10):739-48. doi: 10.1097/BOT.0b013e3181ba46d3. PMID: 19858984.
2. Zhao L, Tang YB, Su JC. [Research advancement of the distal radius fracture]. Zhongguo Gu Shang. 2010 Aug;23(8):638-41. Chinese. PMID: 20860151.
3. Sevimli R, Ertem K, Aslantürk O, Ari B. Mid term results of radial metaphyseal core decompression on Kienböck's disease. Eur Rev Med Pharmacol Sci. 2017 Dec;21(24):5557-5561. doi: 10.26355/eurrev_201712_13992. PMID: 29271986.
4. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. J Bone Joint Surg Am. 2006 Sep;88(9):1944-51. doi: 10.2106/JBJS.D.02520. PMID: 16951109.
5. LaMartina J, Jawa A, Stucken C, Merlin G, Tornetta P 3rd. Predicting alignment after closed reduction and casting of distal radius fractures. J Hand Surg Am. 2015 May;40(5):934-9. doi: 10.1016/j.jhsa.2015.01.023. Epub 2015 Mar 12. PMID: 25772286.
6. Doğan N, Büyükdoğan H, Çalışkan G, Genç Y, Şahin A, Ertürk C. Are external fixators as effective as volar plates in multi-fragmented radius distal intra-articular fractures (AO type C)? Eur J Orthop Surg Traumatol. 2023 Jul;33(5):1757-1765. doi: 10.1007/s00590-022-03351-7. Epub 2022 Aug 9. PMID: 35945390.
7. Ghodasra JH, Yousaf IS, Sanghavi KK, Rozental TD, Means KR Jr, Giladi AM. Assessing the Relationship Between Bone Density and Loss of Reduction in Nonsurgical Distal Radius Fracture Treatment. J Hand Surg Am. 2021 May;46(5):377-385.e2. doi: 10.1016/j.jhsa.2021.02.002. Epub 2021 Mar 16. PMID: 33741214.
8. Souza KE, Kellam PJ, Stephens AR, Kazmers NH. Evaluation of Risk Factors for Loss of Acceptable Alignment for Distal Radius Fractures That Are Nondisplaced or Minimally Displaced on Initial Presentation. J Hand Surg Am. 2022 Jan;47(1):54-61. doi: 10.1016/j.jhsa.2021.08.006. Epub 2021 Sep 29. PMID: 34598800.
9. Walenkamp MM, Aydin S, Mulders MA, Goslings JC, Schep NW. Predictors of unstable distal radius fractures: a systematic review and meta-analysis. J Hand Surg Eur Vol. 2016 Jun;41(5):501-15. doi: 10.1177/1753193415604795. Epub 2015 Sep 29. PMID: 26420817.
10. Makhni EC, Ewald TJ, Kelly S, Day CS. Effect of patient age on the radiographic outcomes of distal radius fractures subject to nonoperative treatment. J Hand Surg Am. 2008 Oct;33(8):1301-8. doi: 10.1016/j.jhsa.2008.04.031. PMID: 18929192.
11. Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC. A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. J Hand Surg Am. 2011 May;36(5):824-35.e2. doi: 10.1016/j.jhsa.2011.02.005. PMID: 21527140; PMCID: PMC3093102.
12. Leone J, Bhandari M, Adili A, McKenzie S, Moro JK, Dunlop RB. Predictors of early and late instability following conservative treatment of extra-articular distal radius fractures. Arch Orthop Trauma Surg. 2004 Jan;124(1):38-41. doi: 10.1007/s00402-003-0597-6. Epub 2003 Nov 8. PMID: 14608466.
13. Zhao HZ, Chen JG, Zhang HN, Xing JH, Liu MJ, Wang WM. Factors Associated with Re-Displacement after Nonsurgical Treatment of Distal Radius Fractures in Adults: A Retrospective Study. Orthop Surg. 2024 Jan;16(1):234-244. doi: 10.1111/os.13950. Epub 2023 Dec 1. PMID: 38041507; PMCID: PMC10782234.
14. Anzarut A, Johnson JA, Rowe BH, Lambert RG, Blitz S, Majumdar SR. Radiologic and patient-reported functional outcomes in an elderly cohort with conservatively treated distal radius fractures. J Hand Surg Am. 2004 Nov;29(6):1121-7. doi: 10.1016/j.jhsa.2004.07.002. PMID: 15576226.
15. Gluck JS, Chhabra AB. Loss of alignment after closed reduction of distal radius fractures. J Hand Surg Am. 2013 Apr;38(4):782-3. doi: 10.1016/j.jhsa.2012.08.001. Epub 2012 Oct 23. PMID: 23098633.
16. Dario P, Matteo G, Carolina C, Marco G, Cristina D, Daniele F, Andrea F. Is it really necessary to restore radial anatomic parameters after distal radius fractures? Injury. 2014 Dec;45 Suppl 6:S21-6. doi: 10.1016/j.injury.2014.10.018. Epub 2014 Oct 27. PMID: 25457314.
17. Dias R, Johnson NA, Dias JJ. Prospective investigation of the relationship between dorsal tilt, carpal malalignment, and capitate shift in distal radial fractures. Bone Joint J. 2020 Jan;102-B(1):137-143. doi: 10.1302/0301-620X.102B1.BJJ-2019-0738.R1. PMID: 31888368.
18. Jaremko JL, Lambert RG, Rowe BH, Johnson JA, Majumdar SR. Do radiographic indices of distal radius fracture reduction predict outcomes in older adults receiving conservative treatment? Clin Radiol. 2007 Jan;62(1):65-72. doi: 10.1016/j.crad.2006.08.013. PMID: 17145266.
19. Ruzicka A, Kaiser P, Schmidle G, Benedikt S, Kastenberger T, Arora R. Die konservative Behandlung der distalen Radiusfraktur [Conservative treatment of distal radial fractures]. Oper Orthop Traumatol. 2023 Dec;35(6):319-328. German. doi: 10.1007/s00064-023-00820-y. Epub 2023 Jul 5. PMID: 37407790.
20. Oldrini LM, Feltri P, Albanese J, Lucchina S, Filardo G, Candrian C. Volar locking plate vs cast immobilization for distal radius fractures: a systematic review and meta-analysis. EFORT Open Rev. 2022 Sep 19;7(9):644-652. doi: 10.1530/EOR-22-0022. PMID: 36125012; PMCID: PMC9624483.

21. Ahmed O, Balakrishnan P, Perumal R, Agraharam D, Velmurugesan PS, Jayaramaraju D, Rajasekaran S. A prospective randomized control trial comparing outcomes of casting, pinning, and plating for distal end of radius fractures (AO type A2, A3, C1, or C2) in the elderly population. Eur J Orthop Surg Traumatol. 2024 Apr 20. doi: 10.1007/s00590-024-03949-z. Epub ahead of print. PMID: 38642122.
22. Schmidt V, Gordon M, Petterson A, Buttazzoni C, Seimersson A, Sayed-Noor A, Mukka S, Wadsten M. Functional outcomes are restored a decade after a distal radius fracture: a prospective long-term follow-up study. J Hand Surg Eur Vol. 2024 Mar;49(3):322-328. doi: 10.1177/17531934231194682. Epub 2023 Sep 8. PMID: 37684021; PMCID: PMC10882947.
23. Ali M, Brogren E, Wagner P, Atroshi I. Association Between Distal Radial Fracture Malunion and Patient-Reported Activity Limitations: A Long-Term Follow-up. J Bone Joint Surg Am. 2018 Apr 18;100(8):633-639. doi: 10.2106/JBJS.17.00107. PMID: 29664849.
24. Mathews JS, Martyn TLB, Rao KS, MacLean SBM. The Volar Cortical Hinge: An Independent Risk Factor for Distal Radius Fracture Displacement. J Wrist Surg. 2023 Aug 21;13(3):222-229. doi: 10.1055/s-0043-1771376. PMID: 38808183; PMCID: PMC11129888.
25. Makhni EC, Taghinia A, Ewald T, Zurakowski D, Day CS. Comminution of the dorsal metaphysis and its effects on the radiographic outcomes of distal radius fractures. J Hand Surg Eur Vol. 2010 Oct;35(8):652-8. doi: 10.1177/1753193409338750. Epub 2010 Mar 17. PMID: 20237191.