https://doi.org/10.35839/repis.5.4.946

What do we know about the treatment of distal radius fractures with external fixators after 30 years. Experience and a brief bibliographic review

Que sabemos del tratamiento de las fracturas del extremo distal de radio con fijadores externo luego de 30 años. Experiencia y breve revisión bibliográfica

Mauro R. Vivas[1,a]

Abstract

Introduction. Fractures of the distal end of the radius are a great subject of controversy due to their great variability in radiological patterns and patient type. The clinical radiological disagreement remains unresolved which is the best method. We decided to develop our experience with external fixation and conduct a brief review on the subject. **Aim**. A literature search was conducted by two of the most comprehensive and up-to-date health search engines on everything related to fractures of the distal end of the radius treated with external fixators in the last 30 years. **Materials and methods**. A search was carried out with the acronym "fracture distal radius with external fixator" in MEDLINE and ProQuest Health & Medical Complete, where a total of 1367 articles were obtained, of which 243 articles were selected. **Results and conclusions**. The data we obtained were very promising regarding the treatment of radius fractures with external fixators, which is an undisputed method in some types of fractures, promoting respect for soft tissues and biological treatment of fractures without forgetting the rapid rehabilitation that is achieved with the external fixator.

Keywords: fracture distal radius external fixator.

Resumen

Introducción: Las fracturas del extremo distal de radio son un gran tema de controversia debido a su gran variabilidad de patrones radiológicos como de tipo de paciente. La discordancia clínico radiológica sigue sin resolver cual es el mejor método. Decidimos desarrollar nuestra experiencia con fijación externa y realizar una breve revisión sobre el tema. **Objetivo**: Se realizó una búsqueda bibliografía por dos de los buscadores más completos y actualizados sobre salud acerca de todo le referente a fracturas de extremo distal de radio tratados con fijadores externos en los últimos 30 años. **Materiales y métodos**: Se realizó una búsqueda con las siglas "fracture distal radius with external fixator" en el MEDLINE y ProQuest Health & Medical Complete donde se obtuvieron 1367 artículos en total de los cuales se seleccionaron 243 artículos que respondían a nuestro interés. **Resultados y conclusiones**: Los datos que obtuvimos fueron muy satisfactorios con respecto al tratamiento de fracturas del radio con fijadores externos. Podemos concluir que es un método indiscutido en algunos tipos de fracturas, que promueven el respeto a las partes blandas y al tratamiento biológico de las fracturas sin olvidarnos de la rápida rehabilitación que se logra con el fijador externo.

Palabras clave: fractura distal del radio con fijadores externos.

[1]Orthopedics and Traumatology Service High Complexity Hospital El Cruce SAMIC Buenos Aires, Argentina

ORCID:
[a]https://orcid.org/0000-0002-3820-9745

Corresponding author:
Dr. Mauro R. Vivas

Postal Address: High Complexity Hospital El Cruce SAMIC Buenos Aires, Argentina.

Email: vivasmauro@hotmail.com

Reception date: february 21, 2021
Approval date: october 01, 2021

Quote as: Vivas MR. Que sabemos del tratamiento de las fracturas del extremo distal de radio con fijadores externo luego de 30 años. Experiencia y breve revisión bibliográfica. Rev. Peru. Investig. Salud. [Internet]; 5(4): 247-253. Recuperado de: http://revistas.unheval.edu.pe/index.php/repis/article/view/946

Introducción

Before to focused to the treatment of fractures of the distal end of the radius (FEDR) with external fixators (EF) we must make some exceptions about this type of injury, since they have multiple qualities, characteristics and patients who suffer from them.

The FEDRs occur in all age groups, due to this, they present independent characteristics to each one of them. In young patients, they are generally high-energy fractures, which are usually complex, multifragmentary and require intensive treatment due to the high demand for activity that these patients have. At the other extreme, we have elderly patients with low bone stock, low demand, and which are usually caused by low-energy accidents; and between both groups we have a range of fracture patterns that combine all these characteristics and it is where the discussion about which is the most indicated treatment is generated. Furthermore, it should not be overlooked that no method has managed to resolve clinical radiological dissociation.

In the 1980s external fixation had its boom, W Herzberg et al. in 1990 they analyzed various external fixators to determine which was safer due to the number of devices on the market without reaching a conclusive answer (1). From the 90s, publications on the subject increased exponentially and many authors confirmed the usefulness of external fixation for its use.

The objective of this research is to analyze how current external fixation is after more than 30 years of its boom in daily practice based on the experience obtained and the publications made during the last 30 years.

Materials and methods

A bibliographic search was carried out through two of the most popular and updated search engines offered by the Argentine Association of Orthopedics and Traumatology. The search was carried out with the following keywords "fracture distal radius wirst fixator external".

1. A total of 768 articles were obtained through PUBMED or MEDLINE, most of which were Abstrac. All articles presenting all words were selected and veterinary articles were excluded. A total of 194 articles were selected.
   The selected articles were 70% from 1990/2010, 18%

from the eighties and 7% from the last 10 years. More than half were retrospective clinical studies, 23% prospective branched and only 12 articles were meta-analyzes.

2. Through ProQuest Health & Medical complete, the search was carried out with the same methodology with which we obtained 654 articles, but only the full texts were selected, for a total of 46 with full texts. Which were 62% from the 2000s, more than half comparative, 3 prospective branches, and only one was meta-analysis.

Based on the articles analyzed, we consider dividing the controversial topics and trying to get an answer to them without stopping at each article.

Indication at present

The vast literature recommends open reduction and internal fixation (ORIF) as the gold standard method for the treatment of adult distal radius fractures (2). However, it is known and the bibliographic evidence is overwhelming that certain types or patterns of fractures treated with FE obtain good results as well. Following this line, it is clear that type 23C2 and 23C3 fractures of the AO / ASIF classification, open fractures, those with severe soft tissue injury or compartment syndrome, the external fixator is the best approach for initial and even definitive treatment (2,3,4).

What type of fixative is the most suitable

During the last 30 years, different types of fixators with particular characteristics have been developed; however, there are two well-defined design lines, the fixators that bridge the joint (FE brigding) and those that do not (FE non-brigding).

The FE brigding were the first to be designed and their fundamental characteristic is that of “bridging” the joints of the carpal region and being able to generate ligamentotaxis, which is nothing more than the application of distraction forces through the uninjured extrinsic ligaments of the wrist, bringing the fracture fragments to their anatomical position, thus avoiding their tendency to collapse and re-displacement due to lack of bone stock. The Shanz nails (CZ) are placed in the distal radius fragment and in the metaphysis of the second metacarpal.

The FE NonBrinding, in contrast to the FE Brinding, promote the stabilization of the fracture with the placement of the Schanz nails (CZ) between the fracture lines. This type of fixator requires at least 1 cm of distal radius fragment to anchor the CZs (2,3). Its advantage over its adversary is that it leaves the radiocarpal joint free, without using ligamentotaxis and in this way "it would reduce reflex sympathetic dystrophy (DSF)" so feared by our colleagues, a topic that we will develop below.

Wan-Li Gu et al. In 2015, conducted a systematic review and meta-analysis comparing bridging vs. “Non-bridging” where they conclude that the “non-bridging” fixators showed an increase in infection in the pins and rupture of the extensor apparatus of the thumb, but without being statistically significant (5).

Within the analyzed literature there are many articles on the properties of the Hoffman tutor (6,7), which will not be emphasized but rather will analyze the general properties of external fixation on the wrist.

Ligamentotaxis

The first concepts on ligamentotaxis were coined by the professed Vidal in 1977 from the studies of Dr. Bhöhler where he describes how forces applied to undamaged extrinsic ligaments of the wrist correct the fragments of the fractures to their anatomical position thus avoiding their collapse due to lack of bone stock (8). Later, the concept of Capsuloligamentotaxis was added, where the capsule is included as a stabilizing element.

The articles that talk about ligamentotaxis refer to their tension and their tendency to produce the DSF. The data obtained was that a distraction less than 5mm. of the radiocarpal joint, it would not cause limitation of the mobility of the last three fingers or pain; These signs and symptoms are taken as an element to evaluate excessive distraction (8). There are studies that consider that it is not beneficial to perform ligamentotaxis and that the neutral position is sufficient, but they do not differentiate between fractures with collapse or multifragmentary or without it (9).

With regard to SDF, there is no article that compares patients treated with EF without ligamentotaxis, EF with ligamentotaxis and with preserved treatment (reduction and plaster), so we cannot affirm that it is a cause, but we cannot rule out that it is a promoter factor either. of this pathology in predisposed patients (10,11).

Fig. 1. Excessive distraction favors reflex sympathetic dystrophy.

Osteoporosis and external fixator

Currently, the treatment with fixed-angle blocked plates is promoted for the treatment of FEDR in patients with osteoporosis or the elderly, however published articles have not shown significant results where the best long-term result is observed compared to the FE (12).

In addition, nails with hydroxyapatite have been used to improve anchorage in the bone, a material that allows greater integration in the bone and less risk of loosening. Another factor evaluated in some studies was the risk of

loss of reduction or migration of the nail, which was not very significant with respect to the control group (12).

Bone Graft and External Fixator

The use of bone graft in FEDR in patients with a low stock of the same or in collapsed fractures has not shown greater stability or differences in the results in unstable fractures (13,14). On the other hand, the placement of the graft requires the opening of the damaged fracture focus of the fracture hematoma, when external fixation promotes a closed reduction and a more biological consolidation.

Fig. 2. Gustilo 1 exposed fracture Masc. 43 years

Combined Treatments

Many times, it was necessary to use combined treatments with Fe for the treatment of unstable and / or comminuted fractures, either because no other method can produce ligamentotaxis or as a complement to other methods that have not achieved the necessary stability. Combinations and / or associations of FERD treatment with external fixation are described below:

1. **Kirshner wire**: The use of this percutaneous nailing allows us to keep the reduction achieved and the height of the radial styloid firmer in very unstable fractures (15).
2. **Shanz Nails:** Continuing with the stabilization of the distal fragment, the use of a 5th Shanz nail was promoted within the Small AO type fixators to stabilize the distal radius fragment.
3. **PALM:** The De Palma method (1952) stabilizes the fracture by reducing it together with the ulna, improving the stability of the distal radius ulnar joint. The original method was associated with the use of casts.
4. **Intramedullary nailing**: Kirshner wires have been used as a guide within the medullary canal to avoid re-displacement, which have not shown a much more satisfactory result than the control group in the few series published in this regard.
5. **Plates and Screws**: within what is the internal fixation method with plate and screws, we find an immense market of types of plates, whether they are malleable, with fixed angles, blocked or simply designed for the middle or radial column. In these cases, the FE becomes a coadjuvant tool in cases where the surgeon has not been satisfied with the stability of the fracture, either due to technical errors, lack of bone stock or due to the comminuted lesion (16,17, 18,19,20).

All these methods that have been used for the stabilization of the fracture in a combined way for its treatment tell us how complex it is to achieve a clinical and radiological result suitable for the needs of our patients.

Plaster VS. External Fixator

Cast treatment has been a fundamental pillar in the treatment of this type of fracture for many years; However, paradigms change due to advances in surgical techniques and patient demands. Therefore, confining a patient to prolonged treatments with immobilization of the elbow and hand is not as tolerated as in years past.

The possibility of rapid recovery and rehabilitation of said limb during treatment makes external fixation an excellent method in cases of bilateral wrist fractures (21). Ju et al. In their meta-analysis did not find statistically significant differences in quality of life and function in elderly patients between operated and non-operated patients (22), which converts external fixation, as it is a relatively invasive procedure and low risk of collapse, an interesting alternative in patients with low levels of command and high surgical risk.

Techniques Complications

The articles that discuss the placement of Shanz nails reveal, in cadaveric studies as well as retrospectively in clinical studies, that it is a safe method with a very low risk of injury to the tendon, nerves or the venous system. John A. McAuliffe et al. In 2005, they reported in their work 14% of global complications in reference centers, between 4 and 10% of infection in the pin tract without deep infections and 1% of loss of fracture control (22).

The safe placement according to the technique of the nails in the radius, we recommend the opening with blunt disclosure of approximately 7 to 9 mm of incision, dissecting the muscle longitudinally to avoid blockages in the mobility of the wrist.

In the case of the nails that go in the second metacarpal, the oblique inclination at 45 degrees protects us from injuring both the vascular bundle and the extensor tendon. The innervation at this level is generally more towards the palm, so we should not run any risk (23).

Brüske et al. Have reported about 10% of carpal tunnel syndrome in FERD C2 and C3 of the AO classification, which they have treated with favorable evolution, associating decompression of the median nerve and the placement of external fixation (24,25,26).

There are many articles that compare the general complications between external fixation and internal fixation, an example of this is the publication of Dr. Yuan et al. where they conclude in their review and meta-analysis that external fixation presents a higher rate of global complications but when the quality is evaluated with the Grade system it is low (27). For their part, Gouk et al. They

report in their meta-analysis that despite presenting a higher rate of complications (peri-nail infections), the DASH result at 12 months, global complications, and implant replacement were not statistically significant when comparing EF and volar plates; In its conclusion, it highlights the multiple variables not analyzed that can generate changes in the final results (28).

Classifications

We have all learned that the usefulness of classifications has to give us a guide on how to treat such fractures, however in the case of FEDR many classifications have been created with their own names that describe the type of stroke without giving us an idea of how to treat them.

It is not the reason for this article to make a passage through all the classifications, however the two classifications that have been used mainly in the analyzed articles were the Firkland classification and OA / ASIF (29). Despite this, Latin American articles use the Fernández Classification to take basic treatment guidelines (30).

We consider that the AO / ASIF Classification is the most general classification, highly reproducible among professionals when it comes to having a common language. However, this is nothing more than a schematic classification of the type of fracture line, which begins with stable extra-articular fractures until reaching unstable intra-articular ones (31).

We have not found a classification that includes fundamental factors when thinking about treatment, such as trauma energy, soft tissue, bone quality and the functional demand of the patient prior to trauma.

Unstable fractures

Many radiological parameters have been described to assess FEDR instability, such as palmar scale, radial scale, radial length, ulnar discrepancy, as well as degree of comminuteness and lack of bone stock. All of these elements are useful as predictors of outcome. However, they are not sufficient to evaluate the fracture, nor does it assess the instability of the distal radius ulnar joint, which causes a lot of pain and early osteoarthritis if it goes unnoticed (32,33).

Fig. 3. Male patient. 28 years to 4 years of post-surgical follow-up.

Three Column Theory

The theory of the three columns evaluates the three load points that are: the internal or ulnar column, the average or lunate and external or radial (34).

This concept is important to keep in mind when planning treatment since both literature and experience show us the difficult task of reducing the middle column when it presents a collapse or “Die Punch” of the lunate fossa, an injury that brings us Considering that internal fixation is the ideal method for this problem.

Radiology VS. Clinic

When evaluating clinical results with respect to radiological results, a very linear relationship was not found for both satisfactory and poor results.

The literature supports internal fixation with plates and screws with great radiological and functional results in young active patients, but when clinical results are compared, no direct relationship has been found between clinical and radiological results in older patients (22).

Comparative articles between external and internal fixation have not favored any method when DASH scores are analyzed after 12 months (28).

Conclusion

More than 30 years have passed since the expansive appearance of External Fixation in the general treatment of fractures. Today we know that the gold standard is internal fixation with internal fixation, however, this method does not present significantly superior results over external fixation when it comes to exposed, comminuted fractures, osteoporosis and even when it is bilateral. In addition, it has a low rate of serious complications and a low learning curve, which is why it can be useful in patients with low demand and high surgical risk.

I would like to thank Dr. Colleta, Daniel, Vaccareli, Alberto, Cordano, Osvaldo and all colleagues from Dr. Eduardo Wilde's Orthopedics and Traumatology service for their invaluable support and experience in this treatment method.

Funding Source

I do not have a source of financing

Authors' contributions

I have no conflict of interest

Conflicts of Interest

No contribution from other authors

References

1. Herzberg W, Overbeck E, Herzberg R, Deckelmann G.Comparative theoretical study of various external

fixation devices for the stabilization of distal radius fractures. Unfallchirurg. 1990 Jun;93(6):257-62.
2. Rongières M. Is the external fixator yet useful for treating fractures of the distal radius? Eur J Orthop Surg Traumatol. 2018 Dec;28(8):1495-1497. doi: 10.1007/s00590-018-2237-4. Epub 2018 Jun 4. PMID: 29869273.
3. Eichenbaum MD, Shin EK. Nonbridging external fixation of distal radius fractures. Hand Clin. 2010 Aug;26(3):381-90, vi-vii. doi: 10.1016/j.hcl.2010.04.006. Epub 2010 Jun 9. PMID: 20670803.
4. Brogan DM, Richard MJ, Ruch D, Kakar S. Management of Severely Comminuted Distal Radius Fractures. J Hand Surg Am. 2015 Sep;40(9):1905-14. doi: 10.1016/j.jhsa.2015.03.014. Epub 2015 Aug 1. PMID: 26243322.
5. Gu WL, Wang J, Li DQ, Gong MZ, Chen P, Li ZY, Yang LF, Liu W, Zhou Y. Bridging external fixation versus non-bridging external fixation for unstable distal radius fractures: A systematic review and meta-analysis. J Orthop Sci. 2016 Jan;21(1):24-31. doi: 10.1016/j.jos.2015.10.021. Epub 2015 Dec 11. PMID: 26686771.
6. Gjengedal E, Slungaard U.Compound fracture of the distal end of the radius treated with Hoffmann's method of external fixation. Tidsskr Nor Laegeforen. 1979 Jan 10;99(1):24-6.
7. Poirier P. Traitement des fractures articulaires de l'extrémité inférieure du radius par fixateur externe d'Hoffman [Treatment of articular fractures of the distal end of the radius using Hoffman's external fixator]. Ann Chir. 1994;48(1):74-7. French. PMID: 8161163.
8. Vidal J, Buscayret C, Fischbach C, Brahin B, Param M, Escare P. Une methode originale dans le traitement des fractures conminutives de l´extremite inferieure du radius: le taxis ligamentaire. Acta Orthop Belg 1977; 43:781-9
9. van Raay JJ, Boot C, Oostvogel HJ,.External fixation of unstable wrist fractures. van der Werken C.al results. Acta Chir Belg. 1992 Jan-Feb;92(1):19-25.
10. Rongières M. Place du traitement par distraction externe ou interne dans les fractures de l'extrémité distale du radius [Is external or internal distraction useful for treating distal radial fractures?]. Hand Surg Rehabil. 2016 Dec;35S:S86-S88. French. doi: 10.1016/j.hansur.2016.03.014. Epub 2016 Oct 26. PMID: 27890218.
11. Neumann K, Clarius M, Gutsfeld P. Fixateur extern oder Spickdrahtosteosynthesen bei instabilen distalen intraartikulären Radiusfrakturen älterer Patienten [External fixator or bone pin osteosyntheses in unstable distal intra-articular radius fractures in elderly patients]. Langenbecks Arch Chir Suppl Kongressbd. 1996;113:912-3. German. PMID: 9102023
12. Wu GB, Dong KF, Xu XH, Chen XL, Liang XH. Case-control studies on external fixator for the treatment of comminuted distal radius fractures in senile. Zhongguo Gu Shang. 2009 Sep;22(9):678-80.
13. Fasolini F, Lichtenhahn P, Fernandez DL.Complex distal radius fracture: value of spongiosa-plasty in combination with external fixator treatment. Helv Chir Acta. 1994 Dec;60(6):863-6.
14. Brunner R, Regazzoni P, Pfeiffer K. Distal intra-articular radius fractures: indication for the external fixator. Helv Chir Acta. 1986 Apr;52(6):861-4.
15. Zhong CY, Shou YP, Zhang LC.Dynamic external fixator combined with K-wire in treatment of unstably distal radius fracture. Zhongguo Gu Shang. 2010 Dec;23(12):955-6.
16. Wang XK, Yang FJ, Su XL. Clinical observation of manipalation and small splints external fixation for the treatment of distal fractures of radius. Zhongguo Gu Shang. 2010 Aug;23(8):573-4.
17. Chen SX, Kang L, Chen HQ, Situ J, Zhao CD, Ding LJ, Liu HG.Clinical randomized controlled trial on splint external fixation combined with Chinese herbs in treating distal radius fractures of elderly patients. Zhongguo Gu Shang. 2008 Mar;21(3):181-3.
18. Petrać B, Petrać A.Combination of open osteosynthesis and external fixator in distal multi-fragment joint fractures of the radius. Methodology and results. Unfallchirurg. 1992 Feb;95(2):83-6.
19. Zhang Y, Wang Y, Xie J. [Treatment of distal radius fracture by combination of external fixator and volar approach fixation]. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2007 Mar;21(3):269-71. Chinese. PMID: 17419208.
20. Zhang Y, Wang Y, Xie J. [Treatment of distal radius fracture by combination of external fixator and volar approach fixation]. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2007 Mar;21(3):269-71. Chinese. PMID: 17419208
21. Zhao MY, Bai Y, Yang M. [Treatment of child ultra-radius distal fracture of back to back with manipulative reduction and external fixation of splint and plaster]. Zhongguo Gu Shang. 2009 Aug;22(8):635-6. Chinese. PMID: 19753996.
22. Ju JH, Jin GZ, Li GX, Hu HY, Hou RX. Comparison of treatment outcomes between nonsurgical and surgical treatment of distal radius fracture in elderly: a systematic review and meta-analysis. Langenbecks Arch Surg. 2015 Oct;400(7):767-79. doi: 10.1007/s00423-015-1324-9. Epub 2015 Aug 30. PMID: 26318178.
23. McAuliffe JA. Combined internal and external fixation of distal radius fractures. Hand Clin. 2005 Aug;21(3):395-406. doi: 10.1016/j.hcl.2005.03.003. PMID: 16039451.
24. Toulemonde JL, Cronier P, Coppo B, Tary P, Guntz M. External fixation of comminuted fractures of the distal extremity of the radius : technical details. J Chir (Paris). 1981 Sep;118(8-9):487-91.
25. Brüske J, Niedźwiedź Z, Bednarski M, Zyluk A. Acute carpal tunnel syndrome after distal radius fractures--long term results of surgical treatment with decompression and external fixator application. Chir Narzadow Ruchu Ortop Pol. 2002;67(1):47-53.
26. Zhang QL, Zhu XD, Li GD, Tang H, Li M, Wu DJ. Treatment of type C3 distal radius fracture resulted from high-energy injuries by volar plate in combination with external fixator. Chin Med J (Engl). 2009 Jul 5;122(13):1517-20. PMID: 19719940.
27. Yuan ZZ, Yang Z, Liu Q, Liu YM. Complications following open reduction and internal fixation versus external fixation in treating unstable distal radius fractures: Grading the evidence through a meta-analysis. Orthop Traumatol Surg Res. 2018

Feb;104(1):95-103. doi: 10.1016/j.otsr.2017.08.020. Epub 2017 Oct 12. PMID: 29031702.
28. Gouk CJC, Bindra RR, Tarrant DJ, Thomas MJE. Volar locking plate fixation versus external fixation of distal radius fractures: a meta-analysis. J Hand Surg Eur Vol. 2018 Nov;43(9):954-960. doi: 10.1177/1753193417743936. Epub 2017 Dec 11. PMID: 29228851.
29. Metz S, Kuhn V, Kettler M, Hudelmaier M, Bonel HM, Waldt S, Hollweck R, Renger B, Rummeny EJ, Link TM. Comparison of different radiography systems in an experimental study for detection of forearm fractures and evaluation of the Müller-AO and Frykman classification for distal radius fractures. Invest Radiol. 2006 Sep;41(9):681-90. doi: 10.1097/01.rli.0000233326.94998.b0. PMID: 16896303
30. Fernández D, Jupiter J: Fracturas de la Extremidad Distal del Radio. Springer-Verlag, 1996.
31. Rundgren J, Bojan A, Mellstrand Navarro C, Enocson A. Epidemiology, classification, treatment and mortality of distal radius fractures in adults: an observational study of 23,394 fractures from the national Swedish fracture register. BMC Musculoskelet Disord. 2020;21(1):88. Published 2020 Feb 8. doi:10.1186/s12891-020-3097-8Li D, Liu Y, Li D, Tang W, Yin Q. Identification of a novel three-column classification for double-column die-punch fractures of the distal radius. Exp Ther Med. 2020;19(3):1871-1877. doi:10.3892/etm.2020.8434
32. 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.
33. Kömürcü M, Kamaci L, Ozdemir MT, Ateşalp AS, Başbozkurt M. Radius distal uç kiriklarinin (AO tip C2-C3) eksternal fiksatörle tedavisi [Treatment of AO type C2-C3 fractures of the distal end of the radius with external fixation]. Acta Orthop Traumatol Turc. 2005;39(1):39-45. Turkish. PMID: 15805753.
34. Li D, Liu Y, Li D, Tang W, Yin Q. Identification of a novel three-column classification for double-column die-punch fractures of the distal radius. Exp Ther Med. 2020 Mar;19(3):1871-1877. doi: 10.3892/etm.2020.8434. Epub 2020 Jan 8. PMID: 32104243; PMCID: PMC7026990.
35. Ochen Y, Peek J, van der Velde D, Beeres FJP, van Heijl M, Groenwold RHH, Houwert RM, Heng M. Operative vs Nonoperative Treatment of Distal Radius Fractures in Adults: A Systematic Review and Meta-analysis. JAMA Netw Open. 2020 Apr 1;3(4):e203497. doi: 10.1001/jamanetworkopen.2020.3497. PMID: 32324239; PMCID: PMC7180423.
36. Rongières M. Is the external fixator yet useful for treating fractures of the distal radius? Eur J Orthop Surg Traumatol. 2018 Dec;28(8):1495-1497. doi: 10.1007/s00590-018-2237-4. Epub 2018 Jun 4. PMID: 29869273.
37. Povacz P, Breitfuss H, Klampfer H. Ist der statische Fixateur externe eine geeignete Methode zur Behandlung von Mehrfragmentfrakturen des distalen Speichenendes? [Is the static external fixator a suitable method in the treatment of multi-fragmented fractures of the distal radius?]. Handchir Mikrochir Plast Chir. 1996 Nov;28(6):302-5. German. PMID: 9064254
38. R P Jakob. Distraction of unstable distal comminuted radius fractures with an external fixation device: a new way of treatment. Z Unfallmed Berufskr. 1980;73(3):115-20.
39. Cronier P, Talha A, Toulemonde JL, Jaeger F, Guntz M. Résultats de la distraction par fixateur externe métacarporadial dans les fractures de l'extrémité distale du radius. A propos de 97 cas [Results of distraction by way of external metacarporadial fixation in fracture of the distal end of the radius. Apropos of 97 cases]. J Chir (Paris). 1991 Jan;128(1):8-12. French. PMID: 2016372.
40. Váchal J, Stehlík J, Jiricka J. Lécení zlomenin distální části predloktí zevní fixací [Treatment of fractures of the distal part of the forearm using external fixation]. Acta Chir Orthop Traumatol Cech. 1989 Dec;56(6):473-83. Czech. PMID: 2633590.
41. Rommens PM, Broos PL.External fixation of distal radius fractures: indication, technique and functionNed Tijdschr Geneeskd. 1990 Aug 18;134(33):1607-11.
42. Pennig D, Heck S, Möhring R. External fixation with motion capacity and radius fractures. Methods and results. Unfallchirurg. 2011 Feb;114(2):105-13.
43. Seitz W, Putman M, Dick H. Limited open surgical approach for external fixation of the distal radius fractures. J Hand Surg 1990; 15:288
44. Seitz W. External fixation of distal radius fractures. Orthop Clin North Am 1993; 24:255-64.
45. Fiala O, Dědek T, Grmela M, Mihula A. Nase zkusenosti s lécením zlomenin distálního konce rádia metodou zevní fixace [Personal experience with the treatment of fractures of the distal end of the radius using an external fixation method]. Rozhl Chir. 1989 Sep;68(8-9):541-4. Czech. PMID: 2814688.
46. Gradl G, Gierer P, Ewert A, Beck M, Mittlmeier T. Der radio-radiale Fixateur am Handgelenk--eine Option zur frühfunktionellen Behandlung der distalen Radiusfraktur [Radio-radial external fixation in the treatment of distal radius fractures allows for free wrist motion]. Zentralbl Chir. 2003 Dec;128(12):1014-9. German. doi: 10.1055/s-2003-44837. PMID: 14750062
47. Melik N, Togninalli D, Biegger P. Retrospektive Analyse konsekutiv behandelter distaler Radiusfrakturen mit Fixateur externe [Retrospective analysis of consecutively treated distal radius fractures with the external fixator]. Unfallchirurg. 1994 Dec;97(12):645-8. German. PMID: 78556 Akmaz I, Pehlivan O, Kiral A, Solakoğlu C, Arpacioğlu O. Instabil distal radius kiriklarinin eksternal fiksasyon ile tedavisinde erken dönem sonuçlar [Short-term results of external fixation of unstable distal radial fractures]. Acta Orthop Traumatol Turc. 2003;37(2):126-32. Turkish. PMID: 12704251.10.
48. Wagner HE, Jakob RP. Operative Behandlung der distalen Radiusfraktur mit Fixateur externe [Surgical treatment of distal radius fracture with external fixation]. Unfallchirurg. 1985 Nov;88(11):473-80. German. PMID: 4071074.
49. Yu MQ, Bi HZ, Hou RP. [Treatment of conumminuted fractures of distal radius with percutaneous transfixation-pin fixation combined external fixator].

Zhongguo Gu Shang. 2009 Aug;22(8):575-6. Chinese. PMID: 19753970.
50. Zhang Y, Wang Y, Xie J. [Treatment of distal radius fracture by combination of external fixator and volar approach fixation]. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2007 Mar;21(3):269-71. Chinese. PMID: 17419208
51. Hofer HP, Passler J, Wildburger R, Schweighofer F. Die Wertigkeit der externen Fixation in der Behandlung von Speichenbrüchen an distaler Stelle [The value of external fixation in the treatment of radius fractures of the distal end]. Aktuelle Traumatol. 1992 Feb;22(1):19-24. German. PMID: 1348386
52. Jakob RP, Ballmer P. Die Behandlung der distalen Trümmer-Fraktur mit dem Fixateur externe. Indikation und Technik [The treatment of distal splinter fractures using an external fixator. Indications and technic]. Z Unfallchir Versicherungsmed Berufskr. 1989;82(1):5-13. German. PMID: 2500792.
53. Delaere O, Hoang P. Le fixateur externe dans les fractures instables de l'extrémité distale du radius. Revue de la littérature récente [The external fixator in unstable fractures of the distal end of the radius. Current literature review]. Acta Orthop Belg. 1991;57(4):374-81. French. PMID: 1772013.
54. Faupel L, Ecke H, Rehm K. Operationsindikation und Verfahrenswahl beim distalen Radiusbruch--Draht, Platten, Fixateur externe [Surgical indications and choice of procedure in distal radius fractures--wire, plates, external fixation]. Unfallchirurgie. 1984 Oct;10(5):245-9. German. doi: 10.1007/BF02585780. PMID: 6516030
55. Micić I, Mitković M, Mladenović D, Karalejić S, Milenković S, Gajdobranski D. Spoljasnji fiksator po mitkoviću u lecenju kominutivnih intraartikularnih preloma distalnog okrajka radijusa [External fixator by Mitkovic in the treatment of comminuted intraarticular fractures of the distal radius]. Med Pregl. 2004 Sep-Oct;57(9-10):473-9. Serbian. doi: 10.2298/mpns0410473m. PMID: 15675622.