

# Metakarp Kırıklarının Metokarpofalangeal Eklemden Girilmeden Retrograd İntramedüller K Telleri ile tedavisi: Yeni ve Pratik Bir Teknik

## Treatment of Metacarpal Fractures with Retrograde Intramedullary K Wires without Metacarpophalangeal Joint Entry: A Novel and Practical Technique

Mehmet Akdemir<sup>1</sup>, Çağdaş Biçen<sup>2</sup>, Mehmet Aykut Türken<sup>2</sup>, Ahmet Cemil Turan<sup>3</sup>, Abdullah Meriç Ünal<sup>4</sup>, Ahmet Ekin<sup>2</sup>

<sup>1</sup>Konya Akademi Hastanesi, Ortopedi ve Travmatoloji Bölümü, Konya, Türkiye.

<sup>2</sup>İzmir Üniversitesi Medical Park Hastanesi, Ortopedi ve Travmatoloji Bölümü, İzmir, Türkiye.

<sup>3</sup>İzmir Ekol Hastanesi, Ortopedi ve Travmatoloji Bölümü, İzmir, Türkiye.

<sup>4</sup>Süleyman Demirel Üniversitesi Tıp Fakültesi, Spor Hekimliği Bölümü, Isparta, Türkiye.

### ÖZ

**GİRİŞ ve AMAÇ:** İntramedüller K telleri ile tedavi edilen metakarp kırıklarının sonuçlarını değerlendirmek için retrospektif bir çalışma yaptık. Metakarp kırıklarının K-telleri ile tedavisinde çeşitli cerrahi teknikler uygulanmaktadır. Hastalar, metakarpofalangeal eklem korunarak, kırık hattından retrograd uygulanan intramedüller K telleri ile ameliyat edildiler.

**YÖNTEM ve GEREÇLER:** Çalışmamızda retro-antegrad intramedüller K telleri ile tedavi ettiğimiz 44 hastanın fonksiyonel ve radyolojik sonuçlarını değerlendirmeyi amaçladık. Hastalar, metakarpofalangeal eklemden girilmeden, kırık hattından ilerletilen 2 adet intramedüller K-teli ile opere edildiler. Klinik sonuçları değerlendirmek için Q-DASH skorlaması kullanıldı. Hastaların;opere edilen ve sağlam 5. metakarplarının son takip kontrolünde ölçülen lateral açılanmalarının istatistiksel farkı karşılaştırıldı. İstatistiksel analizler Bağımlı Örneklem t-Testi ile yapıldı.

**BULGULAR:** Tüm hastalarda kaynama elde edildi. Hastaların klinik Q-DASH skoru ortalama 1.32 (+/- 2.466) idi. Hastaların ortalama 5. metakarp açılanmaları ameliyat öncesi 57.20 (+/- 11.12), sonrasında ise 2.67 (+/- 3.92) derecedeydi. Tedavi sonundaki en son kontrolde ortalama 5. Metakarpofalangeal eklem hareket açıklığı sağlam elde 88.82 (+/- 1.317), opere edilen elde ise 88.84 (+/- 1.328) derecedeydi. 2 hastada 8-12 haftada gerileyen refleks sempatik distrofi gelişti. Preoperatif ve postoperatif 5. metakarp lateral açılanma dereceleri arasında istatistiksel olarak anlamlı fark olduğu görüldü(p: 0.000, p<0.05). Opere edilen elin ve sağlam elin 5. metakarpofalangeal eklemlerinin Eklem Hareket Açıklığı ölçümleri arasında istatistiksel açıdan fark saptanmadı(p: 0.323, p>0.05).

**TARTIŞMA ve SONUÇ:** Tanımladığımız yöntem metakarp kırıklarında; distal kırık parçanın zarar görmemesi, ekstansör mekanizmanın korunması ve iyi klinik sonuçlar ile tercih edilebilecek bir yöntemdir.

**Anahtar Kelimeler:** Metakarp kırığı, perkütan pin, K-teli, retrograd

### ABSTRACT

**INTRODUCTION:** We performed a retrospective study to assess the outcomes of metacarpal fractures treated with intramedullary K-wires. Various surgical techniques were described in treatment of metacarpal fracture with K-wires. The patients were operated with retrograde intramedullary K-wires preserving metacarpophalangeal joint by entering from fracture site.

**METHODS:** In our study we aimed to considerate functional and radiological outcomes of 44 patients whom we treated with retro-ante-grade intramedullary K-wires. Patients were operated with 2 intramedullary K-wires forwarded from fracture site without metacarpophalangeal entry. Q-DASH score was used for evaluating clinical outcomes. Statistical difference between lateral angulations of operated and contrlateral 5. metacarpals at the last control were compared. Statistical analyses were performed with Paired Sample T test.

**RESULTS:** Union was achieved among all patients. Mean clinical Q-DASH score of the patients was 1.32 (+/- 2.466). Mean lateral angulation of 5. metacarpals were 57.20 (+/- 11.12) degrees before and 2.67 (+/- 3.92) postoperatively. At last control, mean Range of Motion of 5. Metacarpophalangeal joint was 88.82 (+/- 1.317) degrees on healthy and 88.84 (+/- 1.328) degrees on operated hands. 2 patients suffered from reflex sympathetic dystrophy, which regressed in 8-12th weeks. Preoperative and postoperative lateral angulation of 5. metacarpals showed statistically significant difference(p: 0.000, p<0.05). Range of Motion degrees of 5. metacarpophalangeal joints of the operated and healthy hands didn't show any statistically significant difference(p: 0.323, p>0.05).

**DISCUSSION AND CONCLUSION:** The method we described could be chosen in metacarpal fractures with advantages such as; elimination of damage to the fractured distal metacarpal piece, preserving extensor mechanism and having good functional outcomes.

**Keywords:** Metacarpal fracture, percutaneous pin, k-wire, retrograde

### İletişim / Correspondence:

Uzm.Dr.Mehmet Akdemir

Konya Akademi Hastanesi, Ortopedi ve Travmatoloji Bölümü, Konya, Türkiye

E-mail:akdemir35.42@gmail.com

Başvuru Tarihi: 11.02.2020

Kabul Tarihi:09.03.2021

## INTRODUCTION

Fractures of the fifth metacarpal are common injuries and they constitute 1/3 of all hand fractures (1). The fifth metacarpal neck is the most common site of metacarpal fractures (2). Direct trauma to a wall or punching someone in the face with a fist are the most common etiologies. This is why this fracture is referred to as Boxer's fracture. Accidents and falls are the other less common reasons.

This fracture usually affects young males. The treatment is controversial and most of the fractures are treated conservatively with casts, splints and even bandages. Successful results with these treatments have been reported (3). Surgical interventions have many options: K wires, plates, external fixators and screws (4,5,6,7). Due to the minimal damage to the soft tissues, shorter surgical duration and patient satisfaction, percutaneous K wire methods have been preferred more recently (8). In this study, we want to introduce an easy method of metacarpal fracture fixation with closed reduction.

## PATIENTS AND METHODS

In our clinic indications for surgery were accepted as lateral angling equal to or more than 30°, rotation of more than 5° and translation of over 50%. In surgical treatment of metacarpal fractures we perform K wire fixation or plate fixation and in few cases we had to use external fixator. We implement K-wires mostly intramedullary and with closed reduction. Having obtained the approval of our institution's ethical committee, we retrospectively reviewed 56 consecutive patients whose metacarpal shaft and neck fractures were treated with retro-ante-grade intramedullary K-wires. The patients were operated by the same surgical team in our hospital. Patients with open physis, pathological fractures, multiple upper extremity injuries were excluded from the study. Only 44 patients were able to come to follow-up controls properly. 12 of them had to be excluded from the study during retrospective assessment. The patients were placed in the supine position under general or axillary anesthesia. Tourniquet was not used. The C-arm fluoroscopy was used as the operating table. Following the preparation of the surgical site, the metacarpal fracture line was palpated and the sharp tip of the K-wire was placed

intramedullary into the metacarpal through the fracture site. It was placed from the distal to the proximal aspect in an antegrade fashion manually without using any type of engine. Having confirmed the intramedullary position of the K-wire with fluoroscopy, it was drilled until exiting from the dorsal part of the wrist. Then K-wire was pulled from the wrist till the end of the wire past the fracture line. During this procedure, the wrist was placed in the maximal plantar flexion position. Due to rotational instability, the same procedure was repeated using a second K-wire. After placement of the 2nd K wire, closed reduction was performed and then K-wires were advanced towards the distal metacarpal subchondral area using the pliers and hammer under the guidance of fluoroscopy (Figure 1A,1B,1C,1D). Following visualization of the intramedullary position of the wires and successful reduction and fixation via fluoroscopy, the K-wires were bent under maximal flexion of the wrist and cut properly. Following this procedure, final AP, lateral and oblique fluoroscopic views were taken. After surgical site cleaning and applying a short arm splint at 30 degrees flexion position of the wrist, the operation was terminated. The short arm splint was applied upon the proximal metacarpophalangeal joint allowing the movement of all fingers including the 5th finger as well. All the patients were operated on with the same surgical procedure having fixation by 2 1.5 mm K-wire.



Figure 1; a: Placement of K-wire percutaneously from the metacarpal fracture site b: Moving forward K-wire proximally and exiting from dorsal part of the wrist. c: After pulling K-wires to the proximal of the fracture site, reduction and fixation with pushing K-wires in retrograde aspect with pliers and hammer d: At the end of procedure bending the wires on wrist.

Proximal interphalangeal and metacarpophalangeal passive and active range of motion (ROM) exercises were encouraged and begun the day after the operation. 4 weeks later, bone union was controlled radiologically and the K-wire(s) were removed in the outpatient clinic room. Finger ROM exercises continued and wrist ROM exercises were added after removal of the K-wires. The patients were given home-type active and passive wrist exercises for a week. Strengthening exercises were begun in the 5th week. At the end of the 6th week, daily activities were permitted with pain limit. The patients were called for the 6th and 12th-week visits. 12 weeks after the fracture, the clinical Quick DASH score was worked out for each patient. At the same control, Range of Motions of 5.metacarpophalangeal joints of both operated and healthy hands were measured with a goniometer.

Radiological evaluation was performed according to the preoperative, postoperative and control radiographies (Figure 2A,2B,3A,3B,4A,4B). The lateral neck-shaft angulation, translation, shortening and union were recorded. Radiological examination was performed by the same investigator. The measurements were made in a computerized manner using the Nova-Rad© program. The lateral collum-shaft angle was measured on oblique hand X-Rays. The diaphysis angle between the proximal fractures was measured. A shift of over 50% between the two fractures of the bones was assessed as translation. Bone bridging and callus formation were accepted as the criteria of fusion.

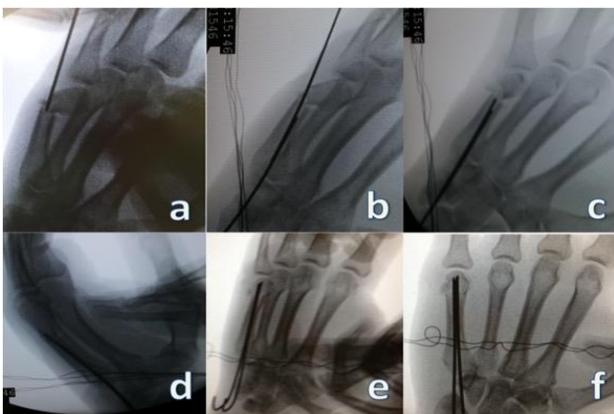


Figure 2; a: Placement of K-wire from the metacarpal fracture b: Pulling first wire to the proximal of the fracture site and placement of the second wire c,d: After reduction, pushing K-wires to the distal of the fracture site with pliers and hammer e,f: The fluoroscopic view of final reduction and fixation.

### Statistical Analysis

After measuring the values and changes in radiological program Nova-Rad© Microsoft© Excel© for Office 365 MSO software was used to determine means and ranges. The lateral metacarpal angulation before and after treatment was statistically compared. At the end of the treatment Range of Motion of 5th metacarpophalangeal joint of operated hand were compared with healthy hand. Statistical analysis was done using SPSS-17 IBM© program and paired samples t Test for dependent groups. Significance level was accepted as  $p < 0.05$ .

### RESULTS

A total of 44 patients with fifth metacarpal fracture were included in the study. Among these, 40 were male and 4 were female. The mean age was 34.61 (+/- 11.23) years. All fractures were in dominant hand. The cause of the fracture was fist punching in 42 patients and slipping in 2 patients. The mean follow-up duration of the patients was 32.79 weeks (12-113).

Radiologically, the fractures were middle 1/3 fractures in 2 patients and distal fractures in 42. The mean pre-operative lateral angulation was 57.20 (+/- 11.12) degrees and the post-operative lateral angulation was 2.68 (+/- 3.91) degrees at the follow up x rays on the day K-wires were removed. Union was achieved in all of the patients.

The mean clinical Q-DASH score of the patients was 1.318 (+/- 2.47). At the last control, mean Range of Motion of 5.metacarpophalangeal joint was 88.82 degree (+/- 1.317) at the operated hand and 88.84 degree (+/- 1.328) at the healthy hands.

Reflex sympathetic dystrophy was observed in 2 patients as complications, which regressed in 8-12th weeks. The K-wire was blocked in the subcutaneous area of one patient for whom a cutaneous incision was made under local anesthesia in order to pull the wire out. No profound infection was observed in any of the patients. In 1 patient, 15 degrees of lateral angulation loss was observed on the 6th week control visit following removal of the K-wire. There was no need for an additional surgical procedure for this patient. Extensor tendon injury or adhesion wasn't observed in any of the patients. No ulnar nerve branch functional loss or

causalgia was observed in any of the patients.

Statistically significant difference was found between means according to paired t Test for

dependent groups in lateral metacarpal angulation before and after treatment ( $p: 0.000$ ). According to these results; lateral angulation degrees of 5. metacarpals showed statistically significant difference at the end of the treatment. There was no statistically significant difference between Range of Motion degrees of 5. metacarpophalangeal joints of operated and healthy hand ( $p: 0.323$ ). It shows that at the end of treatment Range of Motions were similar at the operated side compared with the healthy side. (Table 1).

**Table 1; Mean and standard deviation values of radiologic and clinic scores. Values of significance level (p) between two paired groups. (std. deviation: standard deviation)**

	Mean	N	Std. Deviation	p value
Preoperative lateral angulation	57.20	44	11.12	0.000
Postoperative lateral angulation at the last control	2.68	44	3.91	
5th metacarpophalangeal Range of Motion, operated hand	88.82	44	1.317	0.323
5th metacarpophalangeal Range of Motion, healthy hand	88.84	44	1.328	

## DISCUSSION

Loss of hand function or poor cosmetic appearance may be encountered in case of any malunion, shortening and malangulations of the fifth metacarpal fractures (9,10). Many methods have been described in order to avoid such conditions. Close reduction and splint treatments are successfully performed on many patients (3). In cases which proper reduction and position can not be provided, surgical treatments are performed. These may commonly be divided into two groups as open and close reductions.

Direct and anatomical reduction of fracture is the advantage of open surgery. A careful surgical dissection reduces the risk of iatrogenic injuries of the nerves or tendons. The fixation methods preferred in open reduction are generally plate-screw systems. Cerclage wires and K-wires may be used in the fixation of the fractures in open reduction as well (11). In fractures that close

reduction can not be performed, K-wires could be used as fixation tools in open reduction. The most important advantage of the plate-screw system is allowing early movement due to the rigid fixation of the anatomical reduction, with no need of additional cast or splint stabilization (4,12). However, early plate-screw fixation is generally not recommended currently in 5th metacarpal fractures. Paradoxically, in spite of prolonged immobilization in patients with K-wire fixation, finger ROMs were found better compared to patients with plate fixation on the 6th-month control visit. The most important reason for this is the extensor tendon adhesions frequently observed following open surgeries (7). The other problems of open reduction and plate techniques are infection, scar, cost of the implant, additional surgical intervention for implant removal, nonunion and implant failure (13).

The most commonly preferred surgical method in metacarpal fractures is closed reduction and K-wire fixation (11). It doesn't necessitate an additional surgical dissection. It is easier to perform and the limitation of finger ROM is lower. It became particularly more popular with widespread use of C-arm fluoroscopy during surgery (5,6). The disadvantages include the inability to obtain exact anatomical reduction, difficulty in providing the length, especially in oblique and segmental fractures. Intra-articular wire migration or loss of reduction may be observed a short while. Although deep infection is so uncommon, pin-base infection is not rare (14). Since it is a semi-rigid method, an additional fixation is needed such as cast or splint (8). Many surgical techniques have been described in fixation with K-wires such as antegrade, retrograde, transverse or cross K-wires.

In the fixation method using transverse K-wires, one of the most important problems is the damage and possible fracture in the neighboring healthy metacarpal bone (14). Pin-base infections are more frequently encountered in fixation with transverse K-wires (15). Since the transverse K-wires pass through the interosseous muscles, early mobilization of the finger is difficult and painful (4). Furthermore, at least 2 K-wires should be placed at the distal part and 1 should be placed at the proximal part, as advised biomechanically (16).

Shaft fractures could be operated by this method, but it is hard to provide biomechanical strength in fractures close to the distal part. The vast majority of the fractures in the 5th metacarpal bone comprise

the distal metaphyso-diaphyseal region and it may be difficult to pass 2 K-wires through a small distal piece. However, in cases where there is dense edema surrounding the soft tissue and bony processes are not prominent, the transverse K-wire may be advantageous (17). In the method we described, the excessive soft tissue edema is not a disadvantage either.

Fixation with K-wires crossing the fracture line is not currently recommended because this fixation method leads to a distraction in the fracture line during the procedure, and generally multiple attempts of drilling of distal fragment are needed (18). This in turn particularly weakens the small distal fragment and reduces the stability.

Fixation with retrograde K-wire has been the most frequently preferred method (7,19). Fracture is reduced with the Jahss maneuver and intramedullary fixation is performed with 1 or 2 K wires advanced through the metacarpophalangeal joint. The most important problem of this method is the risk of damage to the extensor hood and limitation in the finger ROMs due to possible adhesions. Another issue is the risk of arthrosis caused by the K-wires passing through cartilage. Some authors continue to use K-wires retrogradely and preserve the carpal alignment, leaving the K-wire in the subchondral area (5).

Another method in the fixation of metacarpal fractures with K-wires is the antegrade method. It was described after the prevalent use of C-arm fluoroscopies (9). A dorsolateral incision is made proximal to the 5th metacarpal, bone window is opened using a drill and multiple K-wires are sent to the distal subchondral area via the intramedullary approach. The K-wires are cut proximally or bent and kept under the skin (9). Extensor hood and metacarpophalangeal joint exposure performed in the retrograde method could be avoided by this attempt. The disadvantages of this method are; need for an incision, second surgery necessity for removing K-wire, and K-wire migration into the distal joint (9).

In the method we defined, the K-wires are sent retrogradely through the fracture line, not through the metacarpophalangeal joint. Retrograde K-wire is pulled from proximal 5th metacarpal joint and the fracture is reduced via Jahss maneuver when the K-wire reaches the proximal aspect of the fracture line, then K-wires are advanced up to subchondral area using a hammer antegradely. The K-wire is

then bent at the wrist and kept out of the skin. In our method we tried to gather advantages of the antegrade and retrograde methods and avoid their complications. Our aim was to keep away from the extensor hood problems observed in the retrograde method and to eliminate the technical problems observed in the antegrade method, such as surgical dissection and bone window opening.

During passage of the K-wire no dissection is performed on the fracture line. Thus, the fracture hematoma is minimally affected and the fracture hematoma is not drained. Neither of our patients suffered from nonunion or infection. The removal of the K-wire from the proximal carpometacarpal joint and the distal carpal alignment have been considered as disadvantages at the literature (9,20). Here, it may be considered that the intra-articular K-wire removal from the joint surface may damage the joint, especially when the K-wires pulled back from the carpal raw joint may affect the wrist functions. However, we didn't observe loss of functions in the 5th metacarpal base joint or wrist in our patient group in the early period.

Another aim of the minimal dissection performed in the antegrade K-wire method is to prevent exposure of the dorsal sensory branch of the ulnar nerve (9). However, the ulnar nerve is located near ulnar side than the radial-central region where we sent our K-wires and thus, the risk of damaging ulnar nerve is low. In our patient group, no ulnar nerve complication was observed. Another problem is the passage of the K-wire through the extensor tendons while leaving from the proximal side and indirect limitation of finger flexion. In order to avoid this, we sent the K-wire in maximum flexion of the wrist and 5th metacarpal joint and pulled the K-wire back using a hammer as soon as it exit the skin, without drilling. Therefore, we tried to keep away from tangling of the K-wire with the extensor tendons.

K-wire diameter has an evident importance on stability of metacarpal fractures. In the biomechanical study of Hiatt et al.; fixation of a transverse metacarpal fracture with a single intramedullary 1.6 mm K-wire is found to be significantly more stable than fixation with 3 intramedullary 0.8mm K-wires (21). We performed our surgeries with 2 intramedullary 1.5 mm K-wires. But we couldn't compare the stability with another group.

The limitations of our study was the absence of a control group and randomization. It was a retrospective study. In our method, the tip of the K-wire is left outside and should be pulled-out. The tip forms a base for pin-base infections. It was observed in one of our patients. The other disadvantages are; immobilization of wrist in extension following the surgical procedure and splint use. Our study also lacks comparison of stability with counts and diameters of K-wires.

The method we described has important advantages such as; absence of multiple K-wire passage attempts during fracture reduction and K-wire fixation, and thereby elimination of damage to the fractured distal metacarpal piece, leaving the metacarpophalangeal joint free during the fracture fixation and afterwards, and preserving the extensor mechanism. Furthermore, union of all fractures and good functional outcome result in high patient satisfaction. We think that our new technique may be useful with these good outcomes and preventing the damage of the metacarpophalangeal joint.

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

The authors received no financial support for the research, authorship, and/or publication of this article.

## REFERENCES

- 1-Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. *J Hand Surg Am.* 2001;26(5):908–915. doi:10.1053/jhsu.2001.26322
- 2-de Jonge JJ, Kingma J, van der Lei B, Klasen HJ. Fractures of the metacarpals. A retrospective analysis of incidence and aetiology and a review of the English-language literature. *Injury.* 1994; 25(6): 365–369. doi:10.1016/0020-1383(94)90127-9
- 3-Jones AR. A custom brace for treatment of angulated fifth metacarpal fractures. *J Hand Surg Am.* 1996;21(2):319–320. doi:10.1016/S0363-5023(96)80132-8
- 4-Wong TC, Ip FK, Yeung SH. Comparison between percutaneous transverse fixation and intramedullary K-wires in treating closed fractures of the metacarpal neck of the little finger. *J Hand Surg Br.* 2006; 31(1): 61–65. doi:10.1016/j.jhsb.2005.06.022
- 5-Rhee SH, Lee SK, Lee SL, Kim J, Baek GH, Lee YH. Prospective multicenter trial of modified retrograde percutaneous intramedullary Kirschner

wire fixation for displaced metacarpal neck and shaft fractures. *Plast Reconstr Surg.* 2012;129:694–703. DOI:10.1097/PRS.0b013e3182402e6a

- 6-Kim JK, Kim DJ. Antegrade intramedullary pinning versus retrograde intramedullary pinning for displaced fifth metacarpal neck fractures. *Clin Orthop Relat Res.* 2015; 473(5): 1747–1754. doi:10.1007/s11999-014-4079-7

- 7-Facca S, Ramdhian R, Pelissier A, Diaconu M, Liverneaux P. Fifth metacarpal neck fracture fixation: Locking plate versus K-wire?. *Orthop Traumatol Surg Res.* 2010; 96(5): 506–512. doi:10.1016/j.otsr.2010.02.009

- 8- Greeven AP, Bezstarosit S, Krijnen P, Schipper IB. Open reduction and internal fixation versus percutaneous transverse Kirschner wire fixation for single, closed second to fifth metacarpal shaft fractures: a systematic review. *Eur J Trauma Emerg Surg.* 2016; 42: 169-75. DOI:10.1007/s00068-015-0507-y

- 9-Foucher G. "Bouquet" osteosynthesis in metacarpal neck fractures: a series of 66 patients. *J Hand Surg Am.* 1995; 20(3 Pt 2): S86–S90. doi:10.1016/s0363-5023(95)80176-6

- 10- Sletten IN, Nordsetten L, Husby T, Ødegaard RA, Hellund JC, Kvernmo HD. Isolated, extra-articular neck and shaft fractures of the 4th and 5th metacarpals: a comparison of transverse and bouquet (intra-medullary) pinning in 67 patients. *J Hand Surg Eur Vol.* 2012; 37(5): 387–395. doi:10.1177/1753193411431048

- 11- Kawamura K, Chung KC. Fixation choices for closed simple unstable oblique phalangeal and metacarpal fractures. *Hand Clin.* 2006; 22(3): 287–295. doi:10.1016/j.hcl.2006.02.018

- 12- Ozer K, Gillani S, Williams A, Peterson SL, Morgan S. Comparison of intramedullary nailing versus plate-screw fixation of extra-articular metacarpal fractures. *J Hand Surg Am.* 2008; 33(10): 1724–1731. doi:10.1016/j.jhsa.2008.07.011

- 13- Fusetti C, Meyer H, Borisch N, Stern R, Santa DD, Papaloizos M. Complications of plate fixation in metacarpal fractures. *J Trauma.* 2002; 52(3):535–539. doi:10.1097/00005373-200203000-00019

- 14- Botte MJ, Davis JL, Rose BA, et al. Complications of smooth pin fixation of fractures and dislocations in the hand and wrist. *Clin Orthop Relat Res.* 1992;(276):194–201.

- 15-Moon SJ, Yang JW, Roh SY, Lee DC, Kim JS. Comparison between Intramedullary Nailing and Percutaneous K-Wire Fixation for Fractures in the Distal Third of the Metacarpal Bone. *Arch Plast Surg.* 2014;41:768-72.

- 16- Galanakis I, Aligizakis A, Katonis P, Papadokostakis G, Stergiopoulos K, Hadjipavlou A. Treatment of closed unstable metacarpal fractures using percutaneous transverse fixation with

Kirschner wires. *J Trauma*. 2003; 55(3): 509–513.  
doi:10.1097/01.TA.0000029368.40479.A2

17- Potenza V, Caterini R, De Maio F, Bisicchia S, Farsetti P. Fractures of the neck of the fifth metacarpal bone. Medium-term results in 28 cases treated by percutaneous transverse pinning. *Injury*. 2012;43(2):242–245.  
doi:10.1016/j.injury.2011.10.036

18- Lee SK, Kim KJ, Choy WS. Modified retrograde percutaneous intramedullary multiple Kirschner wire fixation for treatment of unstable displaced metacarpal neck and shaft fractures. *Eur J Orthop Surg Traumatol*. 2013; 23(5): 535–543.  
doi:10.1007/s00590-012-1036-6

19- Gonzalez MH, Igram CM, Hall RF Jr. Flexible intramedullary nailing for metacarpal fractures. *J Hand Surg Am*. 1995; 20(3): 382–387.  
doi:10.1016/S0363-5023(05)80091-7

20- Faraj AA, Davis TR. Percutaneous intramedullary fixation of metacarpal shaft fractures. *J Hand Surg Br*. 1999; 24(1): 76–79.  
doi:10.1016/s0266-7681(99)90039-6

21- Hiatt SV, Begonia MT, Thiagarajan G, Hutchison RL. Biomechanical Comparison of 2 Methods of Intramedullary K-Wire Fixation of Transverse Metacarpal Shaft Fractures. *J Hand Surg Am*. 2015; 40(8): 1586–1590.  
doi:10.1016/j.jhsa.2015.03.035