



Comparison between locked intramedullary nailing and plate osteosynthesis in the management of adult forearm fractures

Erişkinlerdeki önkol kırıklarının tedavisinde kilitli intramedüller çivi ve plak-vida osteosentezi yöntemlerinin karşılaştırılması

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Amaç: Erişkinlerdeki önkol çift kırıklarının cerrahi tedavisinde uyguladığımız iki farklı yöntemin sonuçları değerlendirildi.

Çalışma planı: Önkol kırıklı 42 erişkin hasta geriye dönük olarak incelendi. Bunlardan 22 hasta (7 kadın, 15 erkek; ort. yaş 32; dağılım 18-69) açık redüksiyon ve plak-vida ile tespit yöntemi, 20 hasta (6 kadın, 14 erkek; ort. yaş 33; dağılım 18-70) kapalı redüksiyon ve kilitli kanaliçi çivi yöntemi ile tedavi edildi. Kırıklar AO/OTA sistemine göre sınıflandırıldı. Hastalar, son kontrollerde Grace-Eversmann ölçütlerine göre ve DASH (Disabilities of the Arm, Shoulder and Hand) skoru ile değerlendirildi. Ortalama takip süresi plak-vida grubunda 30 ay (dağılım 12-45 ay), kilitli kanaliçi çivi grubunda 23 aydı (dağılım 12-34 ay) idi.

Sonuçlar: Ortalama ameliyat süresi plak-vida grubunda 65 dk (dağılım 40-97 dk), kanaliçi çivi grubunda 61 dk (dağılım 35-90 dk) idi ($p>0.05$). Ortalama kaynama süresi kanaliçi çivi grubunda anlamlı derecede daha kısa bulundu (10 hafta ve 14 hafta; $p<0.05$). Grace-Eversmann ölçütlerine göre, plak-vida grubunda 18 hastada (%81.8) mükemmel ve iyi, dört hastada (%18.2) kabul edilebilir sonuç; kanaliçi çivi grubunda 18 hastada (%90) mükemmel ve iyi, iki hastada (%10) kabul edilebilir sonuç elde edildi. Ortalama DASH skoru ise sırasıyla 15 (dağılım 4-30) ve 13 (dağılım 3-25) bulundu; iki grup arasında fonksiyonel sonuç ve DASH skoru açısından anlamlı fark görülmedi ($p>0.05$). Ameliyat sonrası komplikasyon plak-vida grubunda üç hastada (%13.6), kanaliçi çivi grubunda iki hastada (%10) görüldü.

Çıkarımlar: Erişkinlerdeki önkol çift kırıklarının cerrahi tedavisinde iki tespit yönteminin fonksiyonel iyileşme ve hasta memnuniyeti açısından sonuçları benzer bulundu.

Anahtar sözcükler: Erişkin; kemik çivisi; kemik plağı; diyafiz/yaralanma; kırık tespiti, intramedüller; radius kırığı; ulna kırığı.

Objectives: We evaluated the results of two different surgical methods for the treatment of adult diaphyseal fractures of both forearm bones.

Methods: Forty-two adult patients with forearm fractures were retrospectively evaluated. Of these, 22 patients (7 women, 15 men; mean age 32 years; range 18 to 69 years) underwent open reduction and plate-screw fixation, and 20 patients (6 women, 14 men; mean age 33 years; range 18 to 70 years) underwent closed reduction and locked intramedullary nail fixation. The fractures were classified according to the AO/OTA system. The patients were assessed using the Grace-Eversmann criteria and the DASH (Disability of the Arm, Shoulder and Hand) questionnaire. The mean follow-up was 30 months (range 12 to 45) with plate-screw fixation, and 23 months (range 12 to 34) with intramedullary nailing.

Results: The mean operation time was 65 minutes (range 40 to 97 min) with plate-screw fixation, and 61 minutes (range 35 to 90 min) with intramedullary nailing ($p>0.05$). The mean time to union was significantly shorter with intramedullary nailing (10 weeks vs. 14 weeks; $p<0.05$). According to the Grace-Eversmann criteria, the results were excellent or good in 18 patients (81.8%) and acceptable in four patients (18.2%) treated with plate-screw fixation, compared to 18 patients (90%) and two patients (10%), respectively, treated with intramedullary nailing. The mean DASH scores were 15 (range 4 to 30) and 13 (range 3 to 25), respectively. The two groups did not differ significantly with respect to functional results and DASH scores ($p>0.05$). Postoperative complications were seen in three patients (13.6%) and two patients (10%) with plate-screw fixation and intramedullary nailing, respectively.

Conclusion: The two fixation methods yield similar results in terms of functional healing and patient satisfaction in the management of adult forearm fractures.

Key words: Adult; bone nails; bone plates; diaphyses/injuries; fracture fixation, intramedullary; radius fractures; ulna fractures.

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The goal in the treatment of both bone forearm diaphyseal fractures in adults is to regain axial and rotational stability.^[1,2] Open reduction and internal fixation with plates have been proposed by many authors.^[3-8] However, this technique has some disadvantages such as extensive soft tissue damage, evacuation of the fracture hematoma and periosteal damage due to the direct contact pressure of the plate.^[3-5] Another potential disadvantage of this technique may be refracture following plate removal which has been reported as high as 11-20%.^[5,9-11]

Unlocked intramedullary nailing technique results in less damage to the soft tissues and vascular supply compared to open reduction, but may not adequately control rotation, especially in segmental fractures.^[9,12,13] Another important advantage of intramedullary implants is their stress sharing behaviour which leads to secondary periosteal callus formation.^[14] The distinct advantage of locked intramedullary nailing technique is the capacity of preventing shortening in metaphyseal, comminuted and segmental diaphyseal forearm fractures.^[15-19]

In this retrospective study, the results of patients who had undergone open reduction and internal fixation with plates and patients who had undergone closed reduction and locked intramedullary nailing for the management of adult both bone forearm fractures were compared.

Patients and methods

Charts and radiographs of forty-two adult patients who were surgically managed for both bone forearm fractures during 2004-2007 were reviewed. Of these, 22 patients (7 women, 15 men; mean age 32 years; range 18 to 69 years) underwent open reduction and plate-screw fixation, and 20 patients (6 women, 14 men; mean age 33 years; range 18 to 70 years) underwent closed reduction and locked intramedullary nail fixation. Patients with open epiphyseal plates and patients with additional extremity fractures were excluded from the study.

Fractures were classified using the Arbeitsgemeinschaft für Osteosynthesefragen (AO/OTA) [20] classification; the most common fracture type was A3 in both groups. There were two patients in group I and one patient in group II with Gustilo-Anderson type 1 open fracture.^[21] The duration from injury to surgery was 4 days (range 1-7 days) in group I and

three days in group II (range 1-5 days). One gram of first generation cephalosporine was administered pre-operatively.

Surgical technique

The surgical technique of locked intramedullary nailing of adult forearm fractures have been described by Crenshaw.^[9] Tourniquet was used in all patients. With the patient supine on a radiolucent table, and under general or regional anesthesia the extremity is prepared. With the elbow flexed at 90 degrees, a 1-cm incision was made at the olecranon. Under fluoroscopic control, a 1.9-mm Kirschner wire was driven into the ulnar medullary canal following closed reduction of the fracture. Using a 6-mm reamer, the entry point is drilled for approximately 2.5 cm. The medullary canal is enlarged using manual reamers with 0.5-mm increments. Then a 2.4 mm guide wire is used to temporarily fix the fracture to enable reduction of the radial fracture. Another incision of 2-cm long was made on the radial side of Lister's tubercle with the wrist and forearm prone. The medullary canal of radius is entered approximately 5-mm from articular surface and beneath the extensor carpi radialis brevis tendon. Using a 1.9-mm Kirschner wire and a 6-mm cannulated reamer, the medullary canal is reamed. The last manual reamer was left in place. Using the x-ray of the uninjured forearm as a template, the length of intramedullary nails were calculated. Both nails were prebent to conform to the radial bow and the gentle S-shape of the ulna. First, a fully threaded 2.7-mm self-tapping screw was used to interlock the nearest hole to the insertion handle and the stability is checked; a 2.7-mm unicortical screw may be used to lock the nail at the nondriving end if satisfactory stability is not achieved. The temporary ulnar wire is then removed and the ulna is fixed in the same fashion (Figure 1).

If secure rigid fixation is obtained, an elastic compressive bandage is applied. However, for the proximal 1/3 forearm fractures, a cast brace or a removable orthosis is used for 2-3 weeks with the elbow at 90 degrees of flexion and forearm in supine or neutral position. Following immobilization, active range-of-motion exercises were allowed until radiological callus was observed. If secure fixation can not be obtained, a long arm cast was applied with elbow at 90 degrees of flexion. The immobilization with cast is continued until satisfactory callus is observed



Figure 1. Twenty nine year old male patient suffered a forearm fracture after a direct blow (AO type 22B3) (a) Preoperative A-P and lateral radiographs showing a mid-diaphyseal both bone forearm fracture (b) Early postoperative radiographs of the same patient after closed reduction and locked intramedullary nailing. (c) Anteroposterior and lateral radiographs taken 18 months after the operation showing satisfactory union and alignment

radiologically. Active flexion/extension and supination/pronation exercises are then encouraged.

In patients who had undergone open reduction and internal fixation with plates, a volar Henry incision is used for the 1/3 proximal and middle diaphyseal

fractures and a dorsal approach for the distal 1/3 fractures.^[22] An incision at the medial subcutaneous border of ulna is used for the ulnar fractures. Meticulous care is taken on avoiding periosteal stripping. 3.5 mm dynamic compression plates are used in all fractures.



Figure 2. Twenty six year old female sustained a displaced diaphyseal forearm fracture (AO type 22 A3) in a fall from height (a) Preoperative A-P and lateral radiographs showing a mid-diaphyseal both bone forearm fracture (b) Early postoperative radiographs of the same patient after open reduction and internal fixation with plates (c) Anteroposterior and lateral radiographs taken 12 months after the operation showing satisfactory union and alignment.

The length of the plate and the number of the screws are calculated depending on the fracture type; but as a general rule, at least 3 screws (6 cortices) on either side of the fracture are used for fixation. At the end of the operation, tourniquet is released, bleeding is controlled and suction drains are used for both of the surgical sites. Suction drains are removed at the second postoperative day. No external support for immobilization is used. Early active range of motion as tolerated is encouraged.

All patients were followed up monthly until union. Radiographic assessment was performed at 3, 6, and 12 months. The mean follow up was 30 months (range 12-45) in group I, and 23 months for group 2. Extension of trabeculae or callus formation across the fracture on A-P and lateral radiographs, and absence of tenderness across the fracture were accepted as union.

Primary autogenous bone grafting was used in three patients in group I. Closed reduction of the fracture was performed in all patients in group 2 and bone grafting was not used.

At the last assessment, the amount of forearm rotation was measured by a surgeon who is not involved in the study by using a goniometer. Functional outcome was calculated using the system described by Grace and Eversman.^[8] An excellent rating meant that there was union of the fracture and at least 90% of normal rotation arc of the forearm. A good rating required that the fracture be united and that a minimum of 80% of the rotatory arc be present. For an acceptable result, union of the fracture and a minimum of 60% of normal rotation of the forearm had to be present. An unacceptable result meant that there was a nonunion or that the patient had < 60% of normal rotation of the forearm.

Patient-rated outcome was assessed with the Disability of the Arm Shoulder Hand questionnaire (DASH).^[23] The DASH ascertains overall function of the upper extremity and a score of zero indicates a perfectly functioning arm, whereas a score of 100 points indicates complete impairment of upper extremity.

Statistical analysis was performed with Mann-Whitney U-test using SPSS 11.5 for Windows software package; a p value less than 0.05 was considered significant.

Results

In group 1, the mean operation time was 65 min (range 40-97), the mean blood loss as 60 ml (range 20-240 ml). In group 2, the mean operation time was 61 min (range 35-90); closed reduction of the fractures were performed in all patients and there was no blood loss. There was no statistically significant difference in the mean amount of operation times of two groups ($p>0.05$). However, there was significant difference in the mean blood loss ($p<0.05$).

The mean bone healing time was 14 weeks (range 10-20 weeks) in group 1 and 10 weeks (range 9-12 weeks) in group 2. There was significant difference in bone healing times ($p<0.05$).

Closed fractures healed in average of 10 weeks (range 9-14 weeks) and open fractures healed in an average of 14 weeks (range 9-21 weeks). There were not enough number of patients with open fractures to perform a statistical analysis.

Using the rating system of Grace and Eversmann, 18 patients (%81.8) had an excellent ($n=14$) or good ($n=4$) result, 4 (%18.2) had an acceptable result in group 1. The mean DASH score in group 1 was 15 points (range 4-30); there was mild-moderate limitation in forearm pronation in one patient. Using the rating system of Grace and Eversmann, 18 patients (%90) had an excellent ($n=16$) or good ($n=2$) result, 2 (%10) had an acceptable result in group 2. The mean DASH score in group 2 was 13 points (range 3-25); there was mild limitation in forearm pronation in one patient in this group as well. There were no statistically significant difference in the mean DASH and Grace - Eversmann scores of two groups ($p>0.05$).

Postoperative complications were observed in three patients (%13.6) in group 1 and in two (%10) patients in group 2. Superficial infection was observed in two patients with a closed fracture and one patient with an open fracture; all three patients recovered after one week of parenteral antibiotics followed by one week of oral antibiotics treatment. Deep infection was not observed in this study. Pull out of the locking screws were observed in two patients in group 2. Symptoms resolved after removal of these two screws.

The plates were removed by a secondary operation in twelve patients in group 1. Refracture was not observed in these group of patients. The intramedullary

nails were removed in five patients and the screws were removed in two patients in group 2. Nonunion, iatrogenic neurovascular injury and compartment syndrome were not observed in this study.

Discussion

It is generally accepted that surgical management is the ideal treatment of adult diaphyseal fractures of both forearm bones. Conservative management or surgical management using inadequate implants is associated with a high rate of complications.^[5] However, there is no consensus about the ideal surgical management method and postoperative rehabilitation protocol.

Anderson et al.^[3] reported a %96.3 of union in ulnar and %97.8 of union in radial fractures in 330 forearm fractures of 258 patients using open reduction and internal fixation with compression plates. Fracture union rates were reported to be as high as %87 - %98 in some other papers.^[24-27] Bone union was observed in all patients in group 1 (%100). Using locked intramedullary nails, Hasty and Crenshaw^[17] reported bone union in all patients (%100). Bone union in all patients were reported by Visna et al.^[19] in 118 fresh fractures of 78 patients, and by Gao et al.^[18] in 18 patients with adult both bone forearm fractures using locked intramedullary nailing. Using locked intramedullary nails, Weckbach et al.^[28] reported one nonunion and two delayed unions in 29 patients, and Moerman et al.^[29] reported %94 union rate. Lee et al.^[30] reported only one nonunion in 27 patients. All patients in group 2 had closed reduction and union was achieved in all patients.

There is no consensus about the mean healing time in patients who had undergone open reduction and internal fixation. Anderson et al.^[3] achieved bony union in an average of 7.4 weeks using open reduction and internal fixation using plates. Leung et al.^[27] used various implants for osteosynthesis and reported an average union time as 17 weeks for Limited Contact Dynamic Compression Plate (LC-DCP) group. In patients with simple fracture pattern (A type), Stevens et al.^[26] observed bony union in an average of 22 weeks with dynamic compression plates (DCP) and in average of 33 weeks with locking compression (LCP) plates. The mean time to definite radiological bony union in the open reduction and internal fixation group in this study is relevant with the literature. Gao et al.^[18] reported the mean time to union as 10 weeks for closed fractures and 14 weeks in open fractures using locked

intramedullary nails. Lee et al.^[30] observed bony union in an average of 14 weeks in 27 patients and Weckbach et al.^[28] in 4.4 months in 29 patients. The mean time to achieve bone healing was shorter in group 2.

Leung et al.^[27] achieved excellent and good results in %98 of the patients who had undergone open reduction and internal fixation with DCP. Moed et al.^[7] reported excellent and good results in %85 of the 50 patients who were managed with plate osteosynthesis. Schemitsch et al.^[2] reported excellent and good functional results in %80 of the 55 patients who were managed with plate osteosynthesis. The authors also concluded that the restoration of the radial bow was important in the reconstitution of the normal architecture of the forearm and in the restoration of rotation of the forearm and grip strength.^[2] However, the anatomical bowing of radius may not always be reconstructed with straight forearm plates. When straight forearm plates used, difficulty in restoring the normal anatomical bowing of radius was observed in our experience. In the locked intramedullary technique, prebending a straight nail to gain excellent forearm function is also necessary to restore the normal radial bow.^[9] An angulation of less than 10 degrees in any plane has been shown not to interfere with any limitation in forearm range of motion.^[31,32] With locked intramedullary nails, Gao et al reported %72, Visna et al %88.6, and Lee et al %92 excellent and good results. In this study, excellent and good results were obtained in %81.8 of the patients in group 1 and %90 of patients in group 2.

The mean DASH score of patients managed with locked intramedullary nails was reported as 13.7 by Weckbach et al.^[28], 15 by Lee et al.^[30], and 19 by Gao et al.^[18] The mean DASH score was 15 in group 1 and 13 in group 2, indicating mild residual impairment in both groups. Obtaining almost similar scores by both methods demonstrate that, there is no statistically significant difference between two techniques in patient satisfaction if good surgical technique is performed.

Crenshaw et al.^[15] reported that the belief that the forearm interlocking intramedullary nails always be interlocked was wrong; rotational stability of the fractures after inserting nails as well as the location and type of fractures would help in decision making of static interlocking. Dynamic interlocking technique was used in all of the fractures in group 2 and static interlocking was thought not to be necessary due to the stability achieved.

When proper length or diameter of intramedullary nails are not selected, intraoperative complications may be observed.^[15-17] Selecting a small nail may result in rotational instability and, on the contrary, selecting a too long nail may result in further comminution or additional fracture.^[15] A meticulous preoperative planning is mandatory. Cortical perforation of the volar aspect can be prevented by bending the tip of the 3-mm reamer. No intraoperative iatrogenic bone damage was observed in this study.

Iatrogenic posterior interosseous nerve injury may be observed during locked intramedullary nailing. It has been reported that by inserting the proximal locking screw of the radial nail within 30 mm from the radial head with the forearm in neutral rotation may minimize this risk.^[33] Static interlocking was not used in this study and iatrogenic posterior interosseous nerve injury was not observed.

Bone grafting of comminuted forearm fractures is controversial. Moed et al.^[7] recommended autogenous bone grafting in all fractures when interfragmentary compression is not obtained. Bone grafting was used in 4 patients in group 1. Sage^[34] recommended bone grafting of all forearm fractures fixed with intramedullary nails. On the contrary, Cotler et al.^[35] reported a 93% union rate using the Schneider forearm nail without added bone graft. Using interlocking nails and bone-grafted material saved from the portal and manual reamers, Hasty and Crenshaw^[17] reported similarly good results. It is clear that bone grafting is not necessary when fractures are treated with interlocking intramedullary nails using a closed technique. Since all fractures were reduced by closed technique, bone grafting was not used in group 2.

Fluoroscopy is not necessary in open reduction and internal fixation of adult both bone forearm fractures. However, it is an absolute necessity to use fluoroscopy if closed reduction and biological fixation with locked intramedullary nailing is the goal. The exposure of the surgeon and the surgical team to radiation beam may be a disadvantage of the method.

The classical AO principles regarding the anatomy, stability, biology and mobilization of the fractures are still valid. However, current AO principles advocate absolute stability, which was once recommended for almost all of the fractures, for only intraarticular and for some special fractures only. Forearm fractures are

accepted as intraarticular fractures. The main reason for this is that elbow and wrist motion are in close relationship and that the common belief that forearm pronation-supination can only be preserved by rigid osteosynthesis. Intramedullary nails provide relative stability which results in secondary callus formation.^[20]

In the comparison of two fixation methods in the management of adult forearm fractures we have observed similar results in terms of functional healing and patient satisfaction. We think both methods can be used in the management of adult forearm fractures with strict obey to the surgical technique.

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