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The results of intramedullary nailing in children who developed redisplacement during cast treatment of both-bone forearm fractures

Alçı tedavisi sırasında tekrar deplase olmuş çocuk önkol kırıklarında ntramedüller çivileme sonuçları

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Amaç: Bu çalışmada önkol çift kırığı sonrası uygulanan alçı tedavisi sırasında redüksiyon kaybı görülen çocuk hastalarda intramedüller çivileme sonuçları değerlendirildi.

Çalışma planı: Önkol çift kırığı nedeniyle redüksiyonun başarısız olması üzerine 28 çocuk hastaya (19 erkek, 9 kız; ort. yaş 10.6; dağılım 8-15) konservatif tedavinin ortalama dördüncü haftasında (dağılım 3-6 hafta) açık (n=8) veya kapalı (n=20) redüksiyon sonrasında intramedüller çivileme uygulandı. Tespitte ilk 10 hastada K-teli, 18 hastada titanyum elastik çivi kullanıldı. Tek kemik tespiti dört hastada (%14.3) yapılabildi. Kötü kaynama maksimum radial eğimin miktarı ve yerleşimine bakılarak değerlendirildi ve sağlam tarafla ve benzer yaştaki çocuklardan oluşan kontrol grubuyla karşılaştırıldı. İşlevsel sonuçlar Grace ve Eversmann'ın ölçütlerine göre değerlendirildi. Hastalar ortalama 14 ay (dağılım 12-18 ay) izlendi.

Sonuçlar: Tek kemik tespiti yapılan bir hastadaki kaynamayan ulna kırığı dışında bütün olgularda normal dizilim sağlanabildi ve ortalama yedi haftada (dağılım 6-8 hafta) kaynama elde edildi. Kırık taraftaki ortalama maksimum radius eğimi ve maksimum radial eğim yerleşimi sağlam taraf ve kontrol ekstremitelere göre anlamlı farklılık göstermedi (p>0.05). İşlevsel sonuçlar 25 hastada (%89.3) mükemmel, iki hastada (%7.1) iyi, bir hastada (%3.6) kabul edilemez bulundu. Hiçbir hastada enfeksiyon ya da nörapraksi, çivi çıkarılması sonrasında yeniden açılanma, kırık ve ekstremite eşitsizliği görülmedi.

Çıkarımlar: Alçı tedavisi sırasında redüksiyon kaybına uğrayan önkol çift kırıklarında intramedüller tespit, mükemmel anatomik ve işlevsel sonuçları yanı sıra güvenli, ucuz ve erken harakete izin veren bir yöntemdir.

Anahtar sözcükler: Çocuk; önkol; kırık tespiti, intramedüller; radius kırığı/cerrahi; nüks; ulna kırığı/cerrahi.

Objectives: We assessed the results of intramedullary nailing in children who developed redisplacement during cast treatment of both-bone forearm fractures.

Methods: Twenty-eight children (19 boys, 9 girls; mean age 10.6 years; range 8 to 15 years) were treated with intramedullary fixation upon failure of initial reduction of both-bone forearm fractures after a mean of four weeks (range 3 to 6 weeks) of cast treatment. Intramedullary fixation was performed following closed (n=20) or open (n=8) reduction using K-wires in the first 10 cases, and titanium elastic nails in 18 cases. Single bone fixation was possible in four (14.3%) cases. For malunion assessment, the amount and location of the maximum radial bow were measured and compared with the normal side and with corresponding extremities of age-matched controls. Functional results were assessed using the Grace-Eversmann criteria. The mean follow-up was 14 months (range 12 to 18 months).

Results: Except for a nonunion of the ulna in one patient who underwent single bone fixation, all correction losses could be restored to normal alignment and united within a mean of seven weeks (range 6 to 8 weeks). The amount and location of the maximum radial bow did not differ significantly from those of the normal side and control extremities (p>0.05). Functional results were excellent in 25 patients (89.3%), good in two patients (7.1%), and unacceptable in one patient (3.6%). None of the patients developed infection, neurapraxia, or after removal of the nail, angulation, refracture, or extremity length discrepancy.

Conclusion: Intramedullary fixation for correction losses during cast treatment of both-bone forearm fractures is a safe and inexpensive treatment, allowing early mobilization and providing excellent anatomic and functional results.

Key words: Child; forearm; fracture fixation, intramedullary; radius fractures/surgery; recurrence; ulna fractures/surgery.

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Maintaining acceptable reduction is not always possible and redisplacement during cast treatment may ocur in pediatric forearm fractures.[1-6] When reangulation during cast immobilization occurs, treatment options include remanipulation of the fracture, open reduction and internal fixation or intramedullary nailing following open or closed reduction. The aim of the current study is to assess the radiologic and functional results of intramedullary nailing in children who suffered correction loss during cast treatment of forearm fractures.

Patients and method

Between the years 2000 and 2003, 41 children who suffered correction loss during cast treatment because of diaphysial forearm fractures were remanipulated under general anaesthesia. Remanuplation was successful and conservative treatment was continued in 13 patients. In 28 patients remanuplation was unsuccessful and they were treated by closed or open reduction followed by intramedullary nailing. These 28 patients were included into the study. Of these 28 patients 15 were initially reduced and followed weekly by us while 13 were first seen with unacceptable alignment. Thus, 15 cases who were followed by us from the beginning were considered as true late displacements but we can not comment on the remaining 13 cases whether they were true late displacements or late recognition of earlier displacements as we could not obtain earlier x-rays. There was't ant accompanying injuries in any patient. There were 19 boys and 9 girls. Mean age was 10.6 (8-15) years. Both radius and ulna were fractured in all patients. There were 19 middle third and 9 proximal third fractures in radius. There were 26 middle third and 2 proximal third fractures in ulna.

Angulations more than 15 degrees on either planes for children younger than 10 years and more than 10 degrees on either planes for children that are 10 years old or older were considered as unaccepted correction loss and treated surgically. Unacceptable correction loss was present in radius in 10 patients, in ulna in 4 patients and in both bones in 14 patients. Mean angulation in radius was 15.2 (8-28) degrees on AP plane and 23.6 (19-28) degrees on lateral plane. Mean angulation in ulna was 17.3 (14-26) degrees on AP plane and 21.7 (16-29) degrees on lateral plane. Patients were on a mean of 4 (3-6) weeks of conservative treatment when they were operated.

Operative technique

When acceptable reduction was lost during cast treatment, the child was admitted to the operating room and a remanuplation was performed under general anaesthesia. Following remanuplation alignment was checked under image intensifier. If alignment could be restored and was stable with full supination and pronation for both bones, then remanuplation was considered successful and conservative treatment was continued. If alignment could not be restored (8 patients) or was not stable with full supination and pronation (20 patients) in any of the bones, then remanuplation was considered unsuccessful and these patients were treated with intramedullary nailing. We started nailing with the bone with greater malalingment following remanuplation. After nailing the bone with greater malalingment, we checked the alignment and stability of the other bone in full supination and pronation for single bone fixation. If the bone which was not fixed was stable in full supination and pronation, then surgery ended with single bone fixation. For intramedullary nailing of radius; a distal dorsal incision over Lister's tubercle on the radius was performed and a titanium elastic nail or a K-wire was introduced through a 2.5 mm oblique drill hole just proximal to the physis up to the fracture end of the distal fragment. Then reduction was checked under image intensifier and the nail was introduced to the proximal fragment if reduction could be obtained. If closed reduction could not be obtained then it was performed from a limited open approach. Percutaneus osteotomy was not performed in any case. For intramedullary nailing of ulna; a proximal incision as described by Amit et al 7 was performed and a titanium elastic nail or a K-wire was introduced from the olecranon apophysis down to the fracture end of the proximal fragment. Then reduction was checked under image intensifier and the nail was introduced to the distal fragment if reduction could be obtained. If closed reduction could not be obtained then it was performed from a limited open approach.

K-wires in 10 patients (in the years 2000 and 2001) and titanium elastic nails in 18 patients (between years 2001 and 2003) were used for intramedullary fixation. K-wires or titanium elastic nails with a diameter of nearly two-third of the istmus medulla were used in all cases (TENs of 2.0, 2.5 and 3.0 mm and K-wires of 2.0 to 3.0 mm). All nails were prebent prior to introduction. The apex of the angulation of the nail was 3 times the medullary diameter. The apexes of the nails were seated in fracture sites and the convexities were directed to radial in radius and ulnar in ulna. Thus the oval and tight structure of the interosseous membrane was restored.

Postoperative care

Postoperative plaster cast or splint was not applied. Patients were allowed for immediate active movement. The limb was supported in an arm sling for 3 weeks.

Union was assessed by the presence of obliteration of fracture lines on both AP and lateral views radiologically and by the absence of pain and bony tenderness at fracture site. At latest follow-up malunion was quantified by measurement of the amount and location of the maximum radial bow in relation to the contralateral, normal forearm as described by Schemitsch and Richards.[8] (Figure 1) The location of the maximum radial bow in operated forearms was further compared with a control group. Control group consisted of the true AP x-rays of age-matched (11 boys, 9 girls , mean age 10.1 (7-15) years) children, who were assessed for forearm trauma but did not have any kind of fractures neither on current assessment nor before and had full range of supination and pronation on first week following the trauma. Limb-length discrepancy was assessed by measurement of the distances between lateral epicondyle of the humerus and radial styloid process in both limbs. Functional results were assessed according to the criteria of Grace and Eversmann.[9] (Table 1) Significance of differences between maximum radial bows on both sides and locations of maximum radial bows on both sides and in control group were assessed by paired t test.

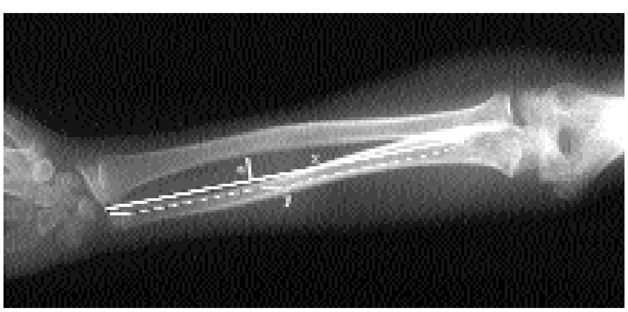

Figure 1. Assessement of malunion according to Schemitsch and Richards. y: The distance between the most unlar edge of radius in wrist and bicipital tubercule in milimeters. a: The line from the site of maximum radial bow and perpendicular to line ‘y’ in milimeters. x: Distance between bicipital tubercule and line ‘a’ in milimeters. Maximum radial bow is the height of line ‘a’. The location of maximal radial bow is x/y X 100.

Table 1. Functional assessement according to Grace and Eversmann.[9]

	Bony union	Pronation-supination
Excellent	+	%90 of nonoperated side
Good	+	%80 of nonoperated side
Acceptable	+	%60 of nonoperated side
Non- acceptable	–	Less than %60 of nonoperated side

Results

Patients were followed up for a mean of 14 (12-18) months. Intramedullary fixation was performed following closed reduction in 20 and open reduction in 8 patients. Open reduction was necessary for radius in 3, for ulna in 1 and for both bones in 4 patients. In 24 patients both bones were fixed while radius only was fixed in 4 (Figure 2a, 2b, 2c, 2d).

All correction losses could be restored to normal alignment ranges and united except a nonunion of an ulna in one patient with single bone fixation. The nail in the radius migrated into the bone and it was not possible to remove it in the same patient. The patient with the ulnar nonunion (fracture line persisted on x-rays but there was no abnormal movement, pain or bony tenderness on fracture site) and radial nail migration refused any further operations. His rotation of the forearm was more than 90% of the contralateral normal forearm. He plays football in junior’s league by wearing a splint.

Union was achieved in a mean of 7 (6-8) weeks. (Figure 3a and 3b, 3c, 3d, 3e). Mean time for nail removal was 4.5 (3-5) weeks.

Restoration of the normal radial bow in normal location with relation to contralateral normal fore-

Table 2. Parameters concerning operated, nonoperated and control group extremities.

	Operated Extremity	Nonoperated Extremity	Control Group	Difference (Operated-Nonoperated Extremity)	Difference (Operated-Nonoperated Extremity)
Mean Maximum Radial Bow (mm)	9.2±2.7	9.5±2.6	9.4±2.4	0.3±1.5 (p>0.05)	0.2±1.1 (p=0.78)
Mean Location of Maximum radial Bow (%)	60±4	61±3	60±3	0.3±3.4 (p>0.05)	0.1±3.0 (p=0.094)

arm was possible in all patients. One patient (3,5 %) lost 3mm of the radial bow. Loss in radial bow was between 1 and 2 mm in 19 (68 %) patients. Loss in radial bow was less than 1mm in 8 (28,5 %) patients. There was no significant difference between the mean maximum radial bows of fractured and contrlateral sides (p>0.05). There was no significant difference between the mean maximum radial bows of fractured sides and the control group (p>0.05) (Table 2). Location of the maximum radial bow was within 5 % of that of the uninjured side in 27 (96.5 %) patients and within 10 % in 1 (3.5 %) patient. Mean difference between the locations of maximum radial bows of the operated and nonoperated extremities of the treated children was not significant (p>0.05). Mean difference between the locations of maximum

Figure 2. **(a)** Correction loss on the 5 th week of conservative treatment in an 8 years old girl. **(b)** The patient was treated with single bone fixation.**(c)** Postoperative 18th month AP graphies of operated (left) and nonoperative (right) extremities. **(d)** Postoperative 18th month lateral graphies of operated (left) and nonoperative (right) extremities.

radial bows of the operated extremities and control group was not significant ($p>0.05$) (Table 2). Functional result was excellent in 25, good in 2 and unacceptable in 1 patients. Rotation of the forearm was more than 90% of the contralateral normal forearm in 26 patients. Result was considered as unacceptable in the patient with nonunion of the ulna.

No infections or neuropraxias were detected in any patients. Neither reangulations nor refractures were observed following nail removal. There were no limb-length discrepancies.

Discussion

Majority of paediatric forearm fractures can be successfully treated with closed reduction and cast immobilization. Depending on the age of the patient, 10 to 15 degrees of angulation is mostly accepted in diaphysial fractures of children.[3-6,10] Generally angulations beyond these ranges are not acceptable and desired alignment is tried to be achieved by remanuplations or surgeries. From the functional level, while relation between rotational malalignment and limitation in supination or pronation is significant, relation between angular deformities and forearm rotation is not clear enough. Correlation between residual angular deformities and forearm rotation is reported to be weak or unclear in several studies.[11-14] But as a rule, a patient with an unaccepted angular alignment should be considered as at risk for restriction in supination and pronation.

There are several reports in the literature studying correction loss during conservative treatmet of pediatric forearm fractures1.[15-18] According to Voto et al, factors responsible for redisplacement are a loose cast at the fracture site (> 1cm) and failure to achieve an accurate three point molding1. Procter et

Figure 3. **(a, b)** Correction loss on the 4 th week of conservative treatment in an 11 years old boy. **(c)** He was treated with both bones fixation. **(d)** Postoperative 14th month AP graphies of operated (right) and nonoperative (left) extremities **(e)** Postoperative 14th month lateral graphies of operated (right) and nonoperative (left) extremities.

al reported the reasons for redisplacement as a complete initial displacement of the fracture and failure to achieve anatomic reduction.[15] Chess et al decribed the cast index an expressed that it should normally be 0.718. They reported that redisplacent in all cases was associated with an inproper cast molding which is caracterized by a cast index which is higher than normal. In the study of Haddad and Williams factors related to redisplacement were reported as the displacement of the fracture and failure to achieve anatomic reduction.[17] But all of these reports involves the fractures of distal forearm. The study of Bhatia and Houdsen involves also the fractures of forearm shaft. In this study cast molding and padding was repoted to be corelated to redisplacement and cast indicis over 0.8 and 0.3 respectiveley were found to be important risk factors for redisplacement.[19] Our study does not aim to assess the risk factors for redisplacement. But when the cases included in the study had been examined from this perspective, it had been found that both the cast and padding indicis were higher than normal in 24 of 28 cases.

If satisfactory alignment is failed to be maintained by conservative means then surgical management becomes necessary. In case of a correction loss during cast treatment of a child's forearm fracture, surgical options include open reduction and internal fixation either by plate or intramedullary device.[6,20-22] Open reduction and plate fixation is associated with higher rates of complications like infection, synostosis and refracture.[6,20] It also has some disadvantages like large exposure for internal fixation and plate removal and need for application of a splint following plate removal. In a comparative study of intramedullary nailing versus plate fixation in forearm fractures of children, Van der Reis et al16 reported that intramedullary fixation provides early motion, easy hardware removal, minimal soft tissue dissection, excellent cosmoses and a short operative time.[23]

Schemitsch and Richards 8 reported that restoration of the normal amount and location of the radial bow was related to the functional outcome in adults. A good functional result was associated with restoration of the normal amount and location of the radial bow. We had 2 (7 %) patients in our series with rotation of the forearm between 80 to 90% of the rotation of contralateral forearm (functionally good results) In 26 (93 %) patients rotation was more than 90 % of the normal forearm. One of the patients with good results had 1 to 2 mm loss of radial bow and the location of the bow was at 5% of the contrlateral normal forearm. The other patient had 2 mm loss of radial bow and the location of the bow was at 10% of the contralateral normal forearm. One patient with 3 mm radial bow loss had excellent result.

Single bone fixation is preferred by some authors in primary forearm fractures of children.[24-26] Myers et al[26] treated 50 children with both bones fractures with elastic stable intramedullary nails. Their selection criteria for single bone fixation was the same as ours. They reported good functional outcome in all patients with single bone fixation and added that the results of their study suggest that the functional outcome is the same whether one or both bones were fixed. One of the main differencences between their and the current study's results is that they could perform single bone fixation in 50% of patients using the same selection criteria with us. Single bone fixation was possible in 14 % of the cases respecting the same criteria in our series. The reason for this clear difference may be that all of the cases in our series were cases in which the reduction could not be maintained during cast treatment indicating already a significant unstable fracture. In single bone fixation some authors fix radius alone while some authors fix ulna alone. We used the same selection criteria as Myers et al[19] did. The first choice of Flynn and Waters[25] was to fix the ulna with an intramedullary pin as this is the least invasive and most easily removed internal fixation. The criterion for radial fixation was impossibility of closed reduction of the radius and they preferred plate fixation of the radius in these cases. Our experience suggests that intramedullary nailing of ulna is the least invasive option but removal of the radial pin is as easy as the removal of the ulnar one. Kirkos et al[24] plated radius in all cases as it is this bone which has the more complicated function of the two forearm bones. Herring[27] found single bone fixation to be attractive because stabilization of ulna prevents the development of a cosmetically unacceptable bow and provides a fulcrum against which the radius can be maintained in an improved position. In our cases we made the decision following remanuplation of the fractures. We started nailing with the bone with greater malalignment following remanuplation. Malalignment following remanuplation was greater in radius in 21 cases and in ulna in 7 cases. But radius was not stable in any cases following nailing of ulna. Ulna was stable in 4 of 21 cases following nailing of the radius and single bone fixation was possible in these cases. Shoemaker et al found that some of the reduction of the nonfixed bone will be lost over time.[28] We did not see any reduction loss in 4 cases with the ulna unfixed. An ulnar nonunion without correction loss was observed in one of these 4 cases. We do not believe that ulna could have united if it had been nailed as the nonunion was hypertrophic without correction loss and intramedullary nailing does not provide any axial stability and rigid compression on fracture site. But we can not make any further comments about the occurrence of this nonunion.

Cullen et al[29] reported complications like loss of reduction, nail migration, infection, decrease in range of motion, radial/ulnar synostosis and neuropraxias in 10 out of 20 patients among them 4 required reoperations. Our complication rate was not as high as they reported. They and Lascombes et all[23] recommend fixation of both radius and the ulna in order to reduce the risk of loss of reduction. We did not experience any loss of reduction in our series with single bone fixation obeying the stability criteria that is described. We recommend checking the stability of the bone which is not fixed in full supination and pronation if single bone fixation is to be performed.

We could not manage closed reduction in 8 patients thus there was a need for open reduction. Van der Reis et al 23 reported that the more proximal the fracture, the more difficult the reduction and maintenance of reduction. Reduction is also more difficult when the radial fracture is proximal to the ulnar fracture.[31] We agree with them as there was a need for open reduction in 8 out of 11 fractures in the proximal third. Intramedullary fixation is used for patients with open fractures or for patients with closed fractures in whom obtaining acceptable closed reduction is not possible. We advocate intramedullary fixation in children who suffers late correction loss during cast treatment of forearm fractures. It provides excellent anatomic and functional results and is safe, inexpensive and allows early motion.

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