ORIGINAL ARTICLE

Utility of the Three-Point Index in the determination of reduction loss during the conservative treatment of pediatric forearm mid-third fractures

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ABSTRACT

BACKGROUND: Forearm fractures constitute approximately 40% of all pediatric fractures. Generally, in conservative treatment,a plaster cast is applied with the elbow in 90° flexion. Success of the treatment depends on theprevention of the reduction in the correct position and suitable duration of the plaster cast. Failure, or the risk of angulation within the cast, is associated with movement within the cast. The aim of this study was to evaluate the applicability of the Cast Index (CI) and Three-Point Index (TPI) measurements, which indicate the loss of reduction, in pediatric mid-third forearm fractures. The hypothesis of the study was that as edema decreases and deformity of the plaster cast occurs after fracture reduction, TPI and CI should be examined during follow-up, as they indicate shifting due to movement within the plaster cast.

METHODS: This retrospective study included a total of 48 patients, who were treated with closed reduction and long-arm plaster cast for a mid-third forearm diaphyseal fracture at our Emergency Polyclinic between March and September 2014. The mean age of the patients was 8.15±3.19 years (range, 5–14 years). Patients were excluded from the study if they had isolated radial or ulnar fracture, open fractures, concomitant fracture or systemic disease (bone metabolism disease, etc), and <10° fracture angulation in the ulna and radius on the initial radiograph and if they did not followup. TPI and CI values were calculated on anterioposterior (AP) and lateral radiographs in the Picture Archiving Communication Systems.

RESULTS: In the AP plane, compared with TPI values after reduction, statistically significant increases were observed in TPI values 10 days after reduction ($p<0.01$). However, no significant difference was observed between those with and without reduction loss in TPI values in the AP plane ($p>0.05$). Although there was a statistically significant increase in TPI values 15 daysafter reduction compared with the values immediately after reduction, a significant difference between those with and without reduction loss was observed only on lateral TPI.

CONCLUSION: In cases of pediatric forearm diaphyseal fracture, ulnar TPI examined in the lateral plane can be used in monitoring the fracture in a plaster cast applied after the reduction.

Keywords: Forearm fractures; pediatrics; Three-Point Index.

INTRODUCTION

Forearm fractures constitute approximately 40% of all pediatric fractures. Generally, conservative treatment involves theapplication of a plaster cast with the elbow in 90° flexion. [1,2] The success of the treatment depends on the protection of the reduction in the correct position and suitable duration of the plaster cast.[3,4] Failure, in other words the risk of angulation within the cast, is associated with movement within the cast. No correlation has been shown between the failure and fracture type, location of the fracture, and sex of the patient.[5]

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The aim of this study was to evaluate the applicability of the Cast Index (CI) and Three-Point Index (TPI) measurements, which indicate the loss of reduction, in pediatric mid-third forearm fractures. The hypothesis of the study was that as edema and deformity of the plaster cast decreases after fracture reduction, TPI and CI are parameters that should be examined during follow-upbecause they indicate shifting due to movement within the plaster cast.

MATERIALS AND METHODS

This retrospective study included a total of 48 patients, who were treated with closed reduction and long-arm plaster cast for a mid-third forearm diaphyseal fracture at our Emergency Polyclinic between March and September 2014. The mean age of the patients was 8.15±3.19 years (range, 5–14 years).

Patients with an isolated fracture of the radius in four cases, isolated fracture of the ulna in three cases, open fracture in four cases, concomitant fracture in the same upper extremity in two cases, a systemic disease (bone metabolism disease, etc.) in one case, non-displaced fractures (<10° fracture angulation in the ulna and radius on the initial radiograph) in five cases, open reduction and internal fixation applied on the 3rd day in onecase, and no appropriate follow-up in one case.

In the classification of the fracture location, the distance between the distal epiphysis of the radius and the proximal epiphysis was divided into threeequal parts and fractures in the mid-third were accepted as diaphyseal fractures (Fig. 1a).

Following reduction, a long-arm plaster cast extending from the middle of the arm to the metacarpophalangeal joints with the elbow in 90° flexion and the forearm in a neutral position was applied to all patients. Monitoring of the reduction within the plaster cast was made by accepting <10° angulation and >50% contact of the radial and ulnar fracture on AP and lateral radiographs as sufficient (Fig. 1b).[1]

In the control, X-ray was taken 15 days after the reduction of >5° angulation, which was compared with the first X-ray taken after fracture reduction, and lack of contact surface was considered as loss of reduction. In fractures with no contact surface, where an increase of >5° angulation was seen, they were excluded without evaluation of the contact surface. The measurements were calculated on the AP and lateral radiographs in the Picture Archiving Communication Systems (PACS). Fracture classifications and fracture angulations were evaluated by orthopedic specialists.

TPI and CI values were calculated on the AP and lateral radiographs in PACS. On the AP radiograph, with the measurements of the space between the plaster cast and soft tissue on the radial side at the level of the distal epiphyseal line of the radius (a), the space on the ulnar side in the fracture line (b), the space on the radial side at the level of the beginning of the radial tubercle (c), and the total external diameter of the proximal radius at the level of the fracture line (d), the radial TPI was calculated as (a+b+c)/d. On the AP radiograph, with the measurements of the space between the plaster cast and soft tissue on the ulnar side at the level of the distal epiphyseal line of the radius (a), the space on the radial side in the fracture line (b), the space on the ulnar side at the level of the beginning of the radial tubercle, (c) and the total external diameter of the proximal ulna at the level of the fracture line (d), the ulnar TPI was calculated as a+b+c/d. On the lateral radiograph, the radial TPI measurement was obtained taking the (a) and (c) distances from the volar side and the (b) distance from the dorsal side and the ulnar TPI measurement taking the (a) and (c) distances from the dorsal side and the (b) distance from the volar side (Fig. 1c).

CI values were calculated on the AP and lateral radiographs with the measurements of the distance between soft tissues in the radial and ulnar fracture line (q) and the distance between the plaster (w) as q/w. The ulnar CI was calculated according to the measurements made from the ulnar fracture line and radial CI from the measurements in the radial fracture line (Fig. 1d).

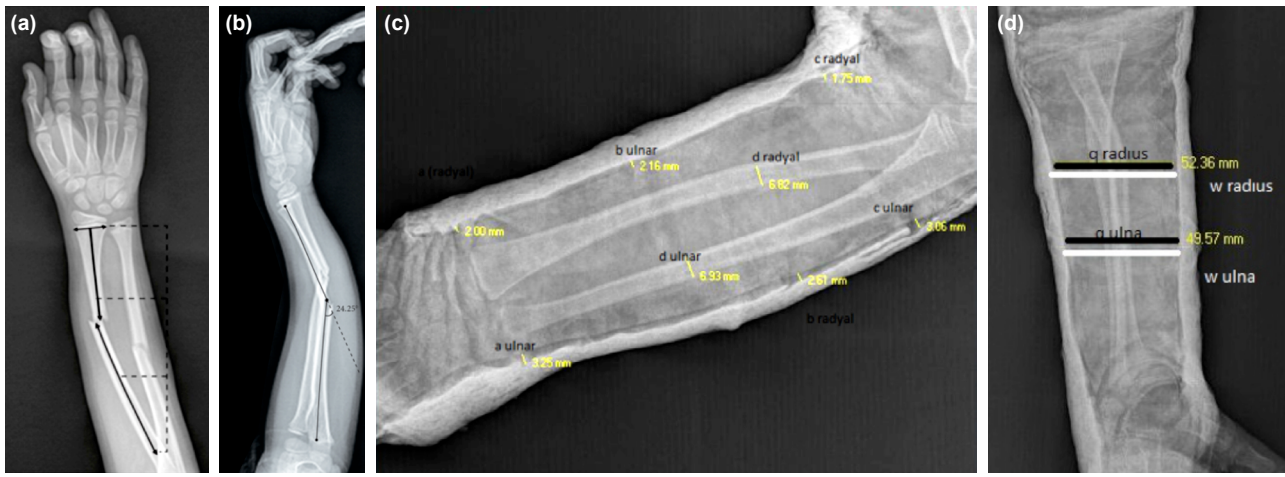

Figure 1. (a) Identification of the fracture location. **(b)** Angulation on lateral radiography. **(c)** TPI calculations. **(d)** CI calculations.

The inter- and intra-observer reliability of TPI measurements was evaluated by two orthopedic specialists repeating the measurements on the same radiographs 20 days after the first measurements.

IBM SPSS 22.0 software was used for the evaluation of the findings obtained in the study. The conformity of the study data to normal distribution was evaluated with the Kolmogorov–Smirnov test, and the data were determined to conform to the normal distribution of the parameters. In addition to descriptive statistical methods (mean, standard deviation), in the comparison of quantitative parameters between two groups, Student's t-test was used. In the comparison of changes observed in the measurements made 15 days after reduction, the paired samples t-test was used. Pearson's correlation analysis was applied in the examination of correlations between the parameters. A p value of <0.05 was accepted as statistically significant. The intraclass correlation coefficient (ICC) was used for the analysis of intra-observer and inter-observer reliability.

RESULTS

The mean age of the patients was 8.15±3.19 years (range, 5–14 years). Of the total 48 cases, the fracture was on the right arm in 24 cases and on the left arm in 24 cases. On initial radiographs, >15° angulation was determined on the lateral radiograph in 32 cases and on the AP radiograph in 27 cases. Reduction loss was observed in the lateral plane in 12 cases, in the AP plane in 5 cases, and in both the AP and lateral planes in 7 cases. When the cases with reduction loss were examined, it was seen that on all the initial radiographs, there was angulation of >15° in at least one of the ulnar or radial fracture lines (Table 1).

In both the ulnar and radial TPI measurements, a statistically significant increase was observed in the TPI measurements on the 15th day compared with the measurements taken after reduction in both the AP and lateral planes (p<0.01) (Table 2).

According to the reduction loss seen on the AP radiographs, no statistically significant difference was determined between the ulnar and radial TPI measurements after reduction and on the 15th day (p>0.05). Also, according to the reduction loss seen on the AP radiographs, no statistically significant difference was determined between the ulnar and radial CI measurements after reduction and on the 15th day (p>0.05) (Table 3).

In the group in which no reduction loss was seen on the AP radiographs, a statistically significant difference was determined between the ulnar and radial TPI measurements after reduction and on the 15th day (p=0.001). Furthermore, in the group in which reduction loss was observed on the AP radiographs, a statistically significant difference was determined between the ulnar and radial TPI measurements after reduction and on the 15th day (p=0.004, p=0.007) (Table 3).

Table 1. Distribution of general characteristics

	Number of patients	
	n	%
Side		
Right	24	50
Left	24	50
>15° angulation on initial AP radiograph		
Absent	21	43.8
Present	27	56.2
>15° angulation on initial lateral radiograph		
Absent	12	25
Present	36	75
Reduction loss		
None	24	50
On lateral radiograph only	12	25
On AP radiograph only	5	10.4
On both AP and lateral radiographs	7	14.6

AP: Anterioposterior.

Table 2. Evaluation of the TPI measurements on the AP and lateral radiographs

	After reduction	15th day	p
	Mean±SD	Mean±SD	
AP			
Radial TPI	1.01±0.44	1.21±0.40	0.001**
Ulnar TPI	1.11±0.39	1.40±0.52	0.001**
Lateral			
Radial TPI	1.08±0.37	1.50±0.49	0.001**
Ulnar TPI	1.09±0.36	1.44±0.47	0.001**

Paired samples t-test **p<0.01. AP: Anterioposterior; TPI: Three Point Index; SD: Standard deviation.

According to the reduction loss seen on the AP radiographs, no statistically significant difference was determined between the ulnar and radial TPI measurements after reduction and on the 15th day (p>0.05) (Table 4).

According to the reduction loss seen on the lateral radiographs, no statistically significant difference was determined between the ulnar and radial TPI and CI measurements after reduction and on the 15th day (p>0.05).

In cases in which reduction loss was seen on the lateral radiographs, ulnar TPI measurements on the 15th day were determined to be significantly higher than those in cases in which no reduction loss was observed (p<0.05). According to observed on lateral radiographs, no statistically significant

Table 3. Evaluation of the TPI and CI measurements according to the reduction loss seen on the AP radiographs

	Reduction loss on AP radiograph		[1]p
	Absent	Present	
	Mean±SD	Mean±SD	
Radial TPI			
After reduction	1.02±0.48	0.97±0.29	0.745
15th day	1.22±0.43	1.19±0.32	0.847
[2]p	0.001**	0.007**	
Ulnar TPI			
After reduction	1.13±0.41	1.02±0.32	0.381
15th day	1.44±0.53	1.29±0.47	0.381
[2]p	0.001**	0.004**	
Radial CI	1.12±0.16	1.15±0.17	0.522
Ulnar CI	1.12±0.15	1.14±0.17	0.635

[1]Student's t-test; [2]Paired samples t-test; **p<0.01. AP: Anterioposterior; TPI: Three Point Index; CI: Cast Index; SD: Standard deviation.

Table 4. Evaluation of the radial and ulnar TPI measurements at 15 days compared to with those immediately after reduction according to the reduction loss seen on the AP radiographs

	Reduction loss on AP radiograph		[1]p
	Absent	Present	
	Mean±SD	Mean±SD	
Radial TPI			
Difference between immediately after reduction and 15th day	0.19±0.32	0.21±0.22	0.825
Ulnar TPI			
Difference between immediately after reduction and 15th day	0.31±0.37	0.27±0.26	0.742

Student t-test. AP: Anterioposterior; TPI: Three Point Index; SD: Standard deviation.

Table 5. Evaluation of TPI and CI measurements according to the reduction loss seen on the lateral radiographs

	Reduction loss on AP radiograph		[1]p
	Absent	Present	
	Mean±SD	Mean±SD	
Radial TPI			
After reduction	1.04±0.39	1.16±0.34	0.269
15th day	1.41±0.47	1.65±0.49	0.110
[2]p	0.001**	0.001**	
Ulnar TPI			
After reduction	1.02±0.36	1.19±0.33	0.118
15th day	1.33±0.37	1.61±0.56	0.043*
[2]p	0.001**	0.002**	
Radial CI	1.11±0.16	1.15±0.16	0.395
Ulnar CI	1.11±0.16	1.15±0.15	0.394

[1]Student's t-test; [2]Paired samples t-test; *p<0.05; **p<0.01. AP: Anterioposterior; TPI: Three Point Index; CI: Cast Index; SD: Standard deviation.

Table 6. Evaluation of the radial and ulnar TPI measurements immediately after reduction and on the 15th day according to the reduction loss seen on the lateral radiographs

	Reduction loss on lateral radiograph		p
	Absent	Present	
	Mean±SD	Mean±SD	
Radial TPI			
Difference between immediately after reduction and 15th day	0.37±0.27	0.48±0.43	0.274
Ulnar TPI			
Difference between immediately after reduction and 15th day	0.31±0.23	0.43±0.50	0.343

Student t-test. AP: Anterioposterior; TPI: Three Point Index; SD: Standard deviation.

difference was determined between radial TPI measurements on the 15th day (p>0.05) (Table 5).

In the group in which no reduction loss was observed on the lateral radiographs, the radial and ulnar TPI measurements on the 15th day were determined to be significantly higher than the measurements after reduction (p=0.001). Furthermore, in the group in which reduction loss was observed on the lateral radiographs, the radial and ulnar TPI measurements on the 15th day were determined to be significantly higher than the measurements after reduction (p=0.001).

According to the reduction loss observed on the lateral radiographs, no statistically significant difference was determined between the ulnar and radial TPI measurements after reduction and on the 15th day (p>0.05) (Table 6).

Table 7. Correlations between TPI and CI measurements

	Radial CI	Ulnar CI
	r	r
AP radial TPI	0.336*	–
Lateral radial TPI	0.233	–
AP ulnar TPI	–	0.285*
Lateral ulnar TPI	–	0.205

Pearson's correlation coefficient *p<0.05. TPI: Three Point Index; CI: Cast Index.

Table 8. Inter-observer reliability of the lateral radial TPI measurements

	Observer 1- Observer 2
	ICC (95% CI)
1st measurement	0.997** (0.992/0.999)
2nd measurement	0.998** (0.994/0.999)

**p<0.01. ICC: Intraclass correlation coefficient; TPI: Three Point Index.

Table 9. Intra-observer reliability for the first and second measurements of the lateral radial TPI

	1st measurement-2nd measurement
	ICC (95% CI)
Observer 1	0.997 (0.992/0.999)
Observer 2	0.999 (0.996/0.999)

**p<0.01. ICC: Intraclass correlation coefficient; TPI: Three Point Index.

On the AP radiographs, a statistically significant correlation was determined in the same direction between the radial CI and radial TPI measurements ($p<0.05$) at the level of 33.6%. As the radial CI measurements increased, so did the radial TPI measurements. On the AP radiographs, a statistically significant correlation was determined in the same direction between the ulnar CI and ulnar TPI measurements ($p<0.05$) at the level of 28.5%. As the ulnar CI measurements increased, so did the ulnar TPI measurements. While the ulnar and radial TPI and CI measurements were seen to be in parallel on the AP radiographs, TPI and CI measurements on the lateral radiographs were not consistent (Table 7).

When the lateral radial TPI measurements were examined, statistical reliability was determined between the two observers ($p<0.01$) (Table 8).

When the lateral radial TPI measurements of Observer 1 were examined, statistical reliability was determined between the first and second measurements ($p<0.01$). When the lateral radial TPI measurements of Observer 2 were examined, statistical reliability was determined between the first and second measurements ($p<0.01$) (Table 9).

The inter- and intra-observer ICC reliability of the TPI measurements was observed to be high (95% CI) (Tables 8 and 9).

DISCUSSION

In the follow-up of pediatric forearm fractures with closed reduction and plaster cast, several factors affect reduction loss.[6] Initial fracture angulation occurring at the time of trauma is one of the most important factors affecting reduction loss.[6] This angulation can give an idea of the severity of the trauma and whether or not the periosteum is torn. In the current study, all the cases with reduction loss were seen to have >15° angulation in the fracture line on the initial radiograph taken after the trauma (before reduction). Severe soft tissue trauma may cause excessive swelling, which loosens the plaster cast, and this may result in an increased risk of reduction loss. Anatomic reduction and fixation of the reduction in completely displaced fractures are rarely successful.[4,7,8] In the current study, an increase was determined in both the TPI and CI measurements on the 15th day, which supports the hypothesis that as soft tissue edema decreases, the plaster cast is loosened.

In general, reduction loss is accepted as >10° angulation toward the dorsal or volar side, >5° radial or ulnar angulation, or >3 mm translation. There are also physicians who accept reduction loss as 2-mm translation in addition to 5° volar or dorsal angulation.[9] In the current study, reduction loss was evaluated as an increase of >5° in fracture angulation or no surface contact. We believe that translation should be measured as a ratio in forearm fractures. As increases in fracture angulation of <5° can show variations in individual measurements, increases in fracture angulation of >5° were evaluated in this study.

Mazzini et al.[10] showed that reduction loss was common in their series involving 161 cases of distal radial metaphyseal fractures. They advocated that reducing the post-reduction translation was the most important predictor of preventing reduction loss.

In the follow-up of distal radius fractures with plaster casting, the CI, Padding Index, Gap Index, and TPI have been described. The TPI is an extremely valuable measurement withrespect to predicting the re-displacement of distal radius fractures.[11] In the current study, it was aimed to identify the possibility of reduction loss in pediatric forearm fractures using TPI. The findings of the study show that ulnar TPI in the lateral plane can be used for this purpose. That TPI measurements in the AP plane in particular were higher in those with reduction loss than in those without reduction loss can be considered to be due to less soft issue in the AP plane and

that the ligamentous structures between the radius and ulna are seen in the AP plane.[12]

Iltar et al.[13] showed that in 71 fractures (93%), TPI correctly predicted that there would be re-manipulation with 84% sensitivity, 97% specificity, 89% positive predictive value, and 95% negative predictive value. There were three false-negative and two false-positive results. In both the false-negative results, banana-type elbow molding was applied. These results suggest that lateral radiography is more valuable in forearm fractures that were truly casted.

Children were divided into three groups according to age: 1st group: <5 years, 2nd group: 5–10 years, and 3rd group:>10 years. When the sensitivity and specificity of CI was high to predict the re-manipulation of displaced distal forearm fractures in children of all age groups, the cut-off point for intraoperative CI was 0.84. Elevated CI (≥0.84) in post-manipulation radiographs showed the increased risk of displacement, especially in fractures in patients aged <5 and >10 years. In our study, the ulnar and radial TPI and CI measurements were seen to be compatible on AP radiographs, but the TPI and CI measurements on the lateral radiographs were not consistent.[14]

In those with reduction loss, the ulnar TPI measured in the lateral plane was high and the measurability of the ulnar TPI in the lateral plane was found to be statistically significant. However, the ulnar TPI results in the lateral plane were not calculated with cut-off values because of the low number of cases. In addition, the high (1.33±0.37) value of the ulnar TPI in the lateral plane in cases with no reduction loss on the 15th day can be considered to be the reason for the cut-off values not having been calculated.

The most important limitation of this study is that it was retrospective and there were few cases determined with reduction lossduring the follow-up period. A prospective study with a greater number of cases of pediatric forearm fractures would be able to calculate TPI or CI with cut-off values. Additionally, the study could be evaluated with a control group by changing the plaster cast within 10 days, those with reduced TPI.

Several authors have emphasized that quality and weakness of the plaster cast are among the risk factors for reduction loss.[5,8,15–18] Alemdaroğlu et al.[19] reported that TPI is more sensitive and specific than other radiological indexes. On the basis of the opinion of Alemdaroğlu et al. that TPI is more sensitive, the current study focused more on TPI. Based on the results of this study, it was concluded that in cases of pediatric forearm diaphyseal fracture, in the monitoring of the fracture within a plaster cast applied after the first reduction, ulnar TPI examined in the lateral plane can be used on the 15th day. In conclusion, in pediatric forearm diaphyseal fractures, which have achieved sufficient reduction, several factors can be held to be as important as the quality of the plaster cast in the effect on reduction loss.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Çocuk önkol orta 1/3 kırıklarının konservatif tedavisi sırasında redüksiyon kaybının saptanmasında "Three Point Index"in kullanılabilirliği

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AMAÇ: Önkol kırıkları çocuk kırıklarının yaklaşık %40'ını oluşturur. Genel olarak dirsek 90° fleksiyonda alçılama yapılarak konservatif olarak tedavi edilir. Tedavinin başarısı redüksiyonun doğru pozisyonda korunmasına ve alçılamayı zamanında sonlandırmaya bağlıdır. Başarısızlık, yani alçı içerisinde açılanma oluşma riski, alçı içindeki harekete bağlıdır. Bu çalışmanın amacı, redüksiyon kaybını işaret eden "Cast Index" (CI) ve "Three Point Index" (TPI) ölçümünün çocukların önkol orta 1/3 kırıklarında uygulanabilirliğinin araştırılmasıdır. Hipotezimiz kırık redüksiyonu sonrası ödemin azalması ve alçının deforme olması nedeniyle, alçı içerisinde harekete bağlı kaymayı işaret eden TPI ve CI'inin takipler sırasında bakılması gereken parametreler olduğudur.

GEREÇ VE YÖNTEM: Çalışma geriye dönük olarak planlandı. 2014 yılı Mart–Eylül ayları arasında acil polikliniğimizde 1/3 orta önkol diyafiz kırığı kapalı redüksiyon ve uzun kol alçı tespiti ile tedavi edilen 48 olgu çalışmaya dahil edildi. Hastaların yaşları beş ile 14 (8.15±3.19) arasında değişmekte idi. Sadece radiusu veya sadece ulnası kırık olanlar, açık kırıklar, ek kırığı ya da sistemik hastalığı (kemik metabolizma hastalığı, vb) olanlar, geliş grafisinde ulna ve radiusta 10°'den az kırık açılanması olanlar ve uygun takibi yapılamayan hastalar çalışmadan çıkarıldı. "Picture Archiving Communication Systems" (PACS) üzerinde anteroposterior (AP) ve lateral grafilerde TPI ve CI hesaplandı.

BULGULAR: Anteroposterior planda redüksiyon sonrası yapılan TPI ölçümlerine göre, redüksiyondan 10 gün sonra yapılan TPI ölçümlerinde saptanan artışlar istatistiksel olarak anlamlı idi ($p<0.01$). Ancak AP planda redüksiyon kaybı olanlar ile olmayanların redüksiyon sonrası TPI ölçümleri arasında istatistiksel olarak anlamlı farklılık bulunmadı ($p>0.05$). Redüksiyon kaybı olanlar ile olmayanların AP planda CI ölçümleri arasında da istatistiksel olarak anlamlı farklılık yoktu ($p>0.05$).

TARTIŞMA: Redüksiyondan 15. günde ölçülen TPI değerlerinde redüksiyon sonrası TPI değerlerine göre anlamlı artış olmasına rağmen, redüksiyon kaybı olanlar ile olmayanlar arasında anlamlı fark sadece lateral TPI'de gösterildi.

Anahtar sözcükler: Çocuk; önkol kırıkları; Three Point Index.

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