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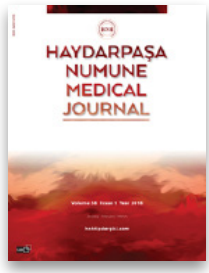

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ORIGINAL ARTICLE

Use of a Smartphone Application for Fracture Angulation Measurement

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Abstract

Introduction: After reduction and casting of pediatric long bone fractures, angulation of the fractured segments are measured, in order to determine if the reduction is acceptable. This study aimed to assess the reliability of a smartphone application (iPinPoint) for the measurement of pediatric forearm diaphyseal fracture angulations with reference to picture archive and communication systems (PACS) software measurements.

Methods: Anteroposterior and lateral forearm radiographs of 30 patients were retrospectively analyzed. Four observers measured the radius fracture angulations using the tools in the PACS software and a smartphone application. The inter- and intraobserver reliabilty were measured using intraclass correlation coefficients (ICC).

Results: Very good interobserver reliability was seen among the four observers measuring the angulations on anteroposterior and lateral radiographs using the PACS software (ICC 0.962 and 0.974, respectively) and iPinPoint (ICC 0.933 and 0.959, respectively). Intraobserver reliability was also very good for both techniques for all observers (ICC >0.9 for all observers).

Discussion and Conclusion: Both techniques are reliable in measuring fracture angulations. The iPinPoint application may represent a useful alternative to digital PACS measurements when measuring tools are not available.

Keywords: Fracture angulation; interobserver reliability; intraobserver reliability; smartphone.

Measurement of fracture angulation is a routine practice after closed reduction and casting of pediatric long bone fractures. Loss of correction during follow-up is also evaluated measuring the angulation, translation and rotation of the fractured segments. Manual measurements of fracture angulations using a goniometer have largely been replaced by digital measurements which are performed using the digital tools within the picture archive and communication systems (PACS). However, patients may come with hard copy radiographs or PACS angle measurement tools may not be available. For these cases angle measuring smartphone applications may represent a useful alternative to digital PACS or manual goniometer measurements.

Reliability of smartphone applications has previously been assessed for Cobb angle measurements in scolioisis and kyphosis, as well as hallux valgus angle measurements [1-6]. However, to the best of our knowledge, no study has investigated the accuracy and reproducibility of a smartphone application in measuring fracture angulations. The aim of this study was to assess the reliability of a smartphone application (iPinPoint) for the measurement of pediatric forearm diaphyseal fracture angulations with reference to digital PACS measurements. Pediatric forearm diaphyseal

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fractures were chosen for measurements because they are one of the most common fractures in pediatric population that are treated with closed reduction and casting, and need close monitoring during follow-up due to possible reduction loss [7, 8].

Materials and Methods

Radiographic Measurements

Conventional anteroposterior (AP) and lateral radiographs of 30 consecutive pediatric patients with diaphyseal forearm fractures that were admitted to our emergency orthopaedic department between June and December 2017 were extracted from PACS records and retrospectively analyzed. Since the data used in our study were obtained retrospectively from patient files, ethics committee approval was not requested. All radiographs were forearm radiographs taken with the x-ray beam centered on the midshaft at a source-to-image distance of 100 cm, with wrist and elbow joints visible on the radiograph. For each patient one AP and one lateral post-reduction radiograph was selected randomly from one, two or three week follow-up radiographs. In order to preserve the uniformity of the measurement technique and to decrease possible measurement errors due to superimposition in lateral radiographs, only radius fracture angulations were measured. Four observers, two orthopaedic surgeons and two radiologists, measured the fracture angulations in AP and lateral radiographs using the software in PACS of our institution and the smartphone application iPinPoint, version 2.1 (i-SmartSolutions, 2010-2017). Radiographs were presented to each observer in a random order and the complete set of radiographs were measured by each observer using both tecniques, by drawing lines parallel to the long axis of fractured segments. In both techniques the Cobb angle measurement tool was used to measure the angles between the lines. In order to measure the intraobserver variability, this process was conducted again after two weeks using the same set of radiographs in a different order, to minimize the recall of prior measurements.

The smartphone measurements were performed using an Apple iPhone model 6S (Apple Inc., Cupertino, CA). The iPinPoint application was downloaded free from the Apple iTunes store. It is an application that uses the built-in camera of the smartphone for angular measurement. First, a photograph was taken, pointing straight to the monitor showing the forearm radiograph. In order to minimize parallax errors, the smartphone was kept parallel to the monitor. The Cobb angle measurement tool within the application was used to measure the magnitude of the angles

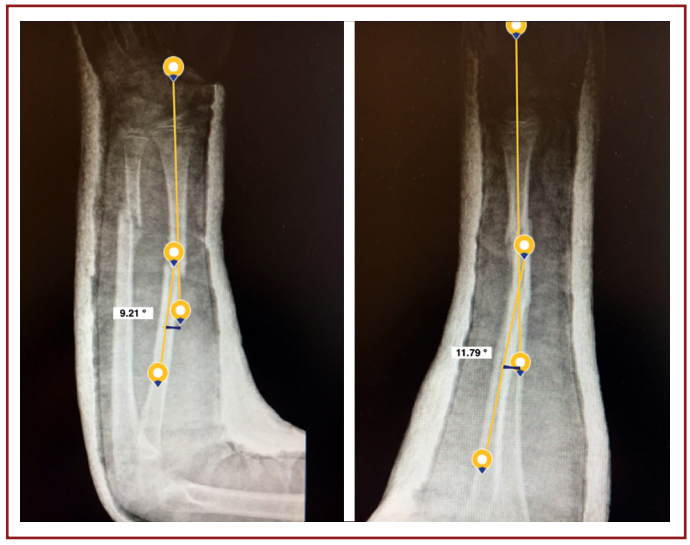

Figure 1. Measurement of radial fracture angulation in AP and lateral radiographs by iPinPoint application.

similar to PACS measurement technique (Fig. 1). Before the first set of measurements, each observer received a training period, which consisted of measuring ten different forearm radiographs with the smartphone, in order to get used to the application.

Statistical Analysis

All statistical analyses were conducted using SPSS for Windows (Version 21.0; IBM Corp., Armonk, NY, USA). The interobserver and intraobserver reliability was estimated using intraclass correlation coefficients (ICCs) for the four observers. Poor reliability was considered present with values of 0 to 0.20, fair reliability with values of 0.21 to 0.40, moderate reliability with values of 0.41 to 0.60, good reliability with values of 0.61 to 0.80, and very good reliability with values of 0.81 to 1.0[9]. A p value of <0.05 was considered as statistically significiant.

Results

Mean age of the patients at the time of injury was 7.5 years (range 4-10). Nine of the patients were female and 21 of them were male. Mean fracture angulations on AP radiographs measured by all observers were 6.1 and 6.0 degrees for PACS and smartphone measurements respectively. Mean angulations on lateral radiographs were 10.5 and 10.3 for PACS and smartphone measurements respectively.

ICCs for inter- and intraobserver reliability are given in Table 1 and Table 2 respectively. Very good interobserver agreement was seen with both methods for AP and lateral plane measurements. Intraobserver reliability was also verygood for both techniques for all observers. ICCs for inter- and intraobserver reliability were significant at the 0.01 level.

Table 1. Interobserver reliability of PACS and smartphone measurements

	PAC Measurements		Smartphone Measurements	
	ICC	p	ICC	p
Anteroposterior	0.962	<0.01	0.933	<0.01
Lateral	0.974	<0.01	0.959	<0.01

Table 2. Intraobserver reliability of measurements of all observers

	PACS Measurements		Smartphone Measurements	
	ICC	p	ICC	p
Observer 1				
Anteroposterior	0.981	<0.01	0.977	<0.01
Lateral	0.992	<0.01	0.987	<0.01
Observer 2				
Anteroposterior	0.972	<0.01	0.963	<0.01
Lateral	0.985	<0.01	0.968	<0.01
Observer 3				
Anteroposterior	0.975	<0.01	0.971	<0.01
Lateral	0.984	<0.01	0.979	<0.01
Observer 4				
Anteroposterior	0.942	<0.01	0.953	<0.01
Lateral	0.967	<0.01	0.979	<0.01

Discussion

Diaphyseal fractures of the radius and ulna are the third most common fractures in the pediatric population[7, 8]. These fractures are treated mostly nonoperatively. However, close monitoring during follow-up is mandatory, since reduction loss may occur, especially in unstable fracture types. This is also true for other pediatric long bone fractures that are treated nonoperatively[10]. After reduction and casting of a long bone fracture, angulation of the fractured segments is measured, in order to determine if the reduction is acceptable. This procedure is repeated at each visit during follow-up. Different measuring options are available according to the format of the image.

Measurements on nondigital radiographs are usually performed using a goniometer. However with replacement of hard copy radiographs by digital images and use of PACS softwares, digital measurements are more widely used nowadays. Good correlation to manual measurements and improved measurement precision have been shown for digital measurements of hallux valgus and Cobb angles. Moreover, improved inter- and intraobserver agreement compared to manual measurements were found in some studies[11-12]. Integration of mobile technology into daily life introduced another option to clinical practice for radiographic angle measurements: the smartphone applications. They can be used to measure angles both on hard copy and digital images.

Several studies have been performed to assess the reliability of smartphone applications in measuring hallux valgus and Cobb angles, by comparing them with manual or digital measurements[1-6]. Shaw et al.[1] and Qiao et al.[2] compared goniometer and smartphone measurements of Cobb angles in scoliosis, and found smartphone measurements to be equivalent to manual measurements in terms of reliability and efficiency. The time consumed for smartphone measurements was significantly shorter in their study. Ege et al.[4] and Walter et al.[5] compared smartphone and PACS measurements of hallux valgus angles, and found that smartphone applications are as reliable as PACS softwares. The applications used in these studies were accelerometer based, which utilize the position sensor of the device. The iPinPoint application, which was used in our study makes the measurements on photographs. This application was used for the first time in the study of Mattos E Dinato et al[6]. They found iPinPoint more reliable than an accelerometer based application in measuring hallux valgus angles with reference to goniometer measurements.

In this study we tried to assess the inter- and intraobserver reliability of a smartphone application (iPinPoint) in measuring the fracture angulations, which was not performed before, to our knowledge. Our hypothesis was that smartphone measurement of fracture angulations has a comparable reliability to PACS measurements, which has been shown to be a reliable technique. In our study intraclass correlation coefficientts of both PACS and iPinPoint measurements farly exceeded the threshold of 0.6 which was recommended by Chin et al.[13] for a reliable measurement. This result confirmed our hypothesis. We tested the application on radius fracture angulations, but we think that it can also be used for other long bone fractures, where same measuring principles are used.

This study has several limitations. Measurements on photographs taken with smartphones are prone to parallax errors. Special care should be given to position the plane of the smartphone screen parallel to the computer screen. However we did not observe statistically significant differences due to this effect. Another limitation is that our reference measurement technique is also prone to variations, but PACS measurements are generally accepted as reliable. We also did not compare the time consumed for both

measurement techniques. However subjectively both techniques were very fast, especially after having the training period and getting used to the application for the smartphone technique.

Measuring radiographic angles with smartphone applications has several advantages. It is a practical method which eliminates the need to carry additional equipment (a goniometer) when hard copy radiographs are available. It can also be used to measure digital radiographs when angle measuring tools are not present whithin the software.

In conclusion, the smartphone application iPinPoint can be used as a reliable tool for measuring fracture angulations. As many surgeons carry a smartphone, use of this practical application may solve problems when angle measuring PACS tools or manual measurement equipments are not available.

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Conflict of Interest: None declared.

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