

The Effect of Angulated Radius Fractures in Forearm Rotation: A Computer Based Model

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Abstract

Background: Forearm fractures amongst children are quite a common presentation. The accuracy of correct alignment in forearm bones is important as it determines the degree of forearm rotation (pronation-supination). However in children due to the potential for continuous growth, a degree of angulation is acceptable. The aim of this study was to determine the effect of angulation of forearm fracture on forearm rotation using computer stimulation. **Methods:** Using a 3D computer modelling software (Wildfire Pro Engineer 4.0, Creo by PTC, Needham, MA), an accurate to scale model of the radius and ulna was replicated from a 7 year old forearm. A realistic representation of pronation/supination of the forearm was applied and a fracture at the junction of proximal one third and distal two third was created. A rotational simulation was created and ended when maximum pronation and supination was reached. Maximum pronation and supination was reached when either no more rotation could occur due to a misalignment of the radius and ulna or there was a collision of the bones. The simulation was repeated in increments of angulation of 2° up to 26°. The angulations that resulted in a combined range of motion (50° pronation and 80° supination) less than 130° were recorded as unacceptable and the others were as acceptable. **Findings:** The study showed that radius angulation fracture of >16° in the proximal third of the radius would result in an unacceptable reduction of pronation-supination to less than 130°. **Conclusion:** Patients with more >16° of radius angulation in a distal third shaft fracture of the radius may result in clinical reduction in forearm rotation.

Keywords

Forearm Fracture, Pronation-Supination, Paediatric Fractures

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1. Introduction

Fractures of the forearm in children are quite common accounting for 25% to 50% of all childhood fractures, with the most affected age group being 5 to 14 years of age (26%) [1]-[3]. Due to the anatomical arrangement of the forearm bones, if one bone is angulated, it is very likely that some pronation-supination would be lost [4] [5]. Maintenance of a normal forearm rotation is dependent on both bones being fully intact and anatomically aligned [6].

In adults, perfect realignment is necessary for return of full pronation and supination movement [3] [5]. However, in children with growth potential, the younger the child is, the lesser angulation of fracture is and the better the result is because of more years available for the bones to remodel and restore normal forearm rotation [7]-[10].

Previous studies have suggested that in children $<20^\circ$ of angulation is acceptable until the child reaches the age of 10 where the amount of acceptability rapidly reduces to $<10^\circ$ on average after this age [4]. However, the threshold varies, argue that any angulation in a child above the age of 8 requires surgery as it significantly affects pronation and supination losses unacceptable for daily tasks [9].

We aim to establish the relationship of degree of angulation to loss of pronation-supination movement in the forearm using a computer model.

2. Experimental Procedure

Using the 3D modelling software 'Wildfire Pro Engineer 4.0' [Creo by PTC, Needham, MA] and with the help of a 7 year old male child the forearm as was replicated. **Figure 1** shows the model of the forearm created on Wildfire Pro Engineer. The red circle indicates the mid shaft oblique fracture created onto the radius for our study. **Figure 2** shows the forearm of the anatomical skeleton model. The black lines represent the exact section to which model was drawn at the radio humeral joint as alignment is affected the greatest after a fracture. This intersection was chosen as the point of analysis because of the slight translation of the radius during pronation and supination, as well as the misalignment that occurs; it is a crucial point to spot the collision of the two bones. **Figure 3** shows the section closely.

Using Wildfire pro engineer the radius and ulna was modelled separately and then constrained to an elbow and wrist to represent the pronation and supination of the forearm realistically. The biomechanics of the forearm consists of the ulna, which is relatively straight, acting as an axis around which the "bowed" radius rotates. The radius is permitted to axially at the proximal end, but stays fixated at the distal end [11].

A typical oblique fracture of the radius was stimulated at the junction between the proximal third and distal two thirds of the radius. This was done because of the prevalence of this type of fracture and its significant effect on forearm rotation [3].

The model was first stimulated in the neutral position (**Figure 4**) then the pronation and supination recorded at fracture angles of $0^\circ - 26^\circ$ in 2° steps. Rotation was simulated and ended when either no more rotation could occur due to a misalignment of the radius and ulnar, or there was a collision of the bones. When the simulation stopped the exact pronation and supination angle was recorded.

The angulations that resulted in a combined range of motion less than 130° (50° pronation and 80° supination) were recorded as unacceptable and the others were recorded as acceptable [12].

3. Results

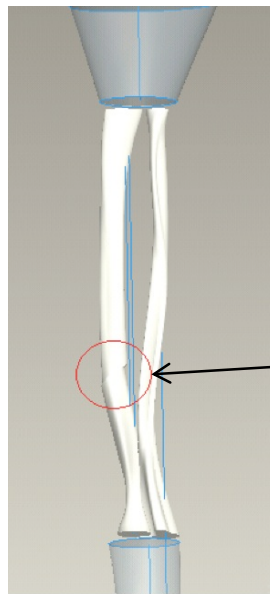
Our results showed that a radial angulation fracture of $>16^\circ$ would result in an unacceptable reduction of pronation/supination of below 130° . This means that all angulations at 16° and below are considered as an "acceptable amount of angulation" for the bones to be realigned and healed through natural growth.

From **Figure 4** it can be seen that between 16° and 18° the ROM suddenly drops from 139° to 103° (26% reduction in range of motion), at 36° fall in ROM and 27° below the acceptable threshold.

From 0° of angulation to 16° the ROM is falling at an average of 3.8° per degree of angulation. From 18° onwards the average rate increases to 6.6° per degree of angulation.

Supination suffered more loss during the angulation process than pronation. At 26° of angulation, pronation had fallen by 56° compared to 71° for supination.

Although full ROM fell below the acceptable threshold at 16° , supination fell below the acceptable threshold at 14° , by 1° [79].



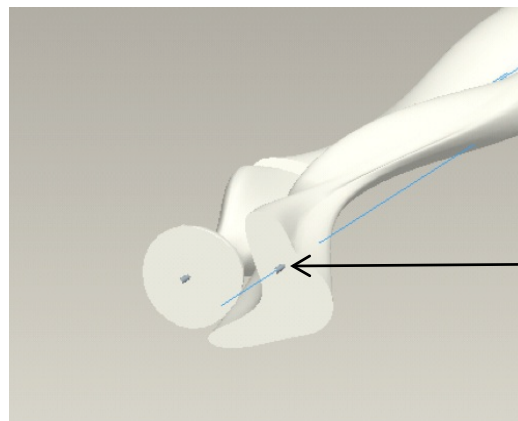
Shows the 3D model of the forearm created on Wildfire Pro Engineer. The red circle indicates the mid shaft oblique fracture

Figure 1. A real model of a radius and ulnar indicated points of intersection.



Shows the forearm of the anatomical skeleton model. The black lines represent the exact section to which the model was drawn

Figure 2. A top down view of the 3D modelled radius and ulnar.



Shows the 3D modelled cross section closely at the radio-humeral joint

Figure 3. 3D modelled cross section of the radio humeral joint.

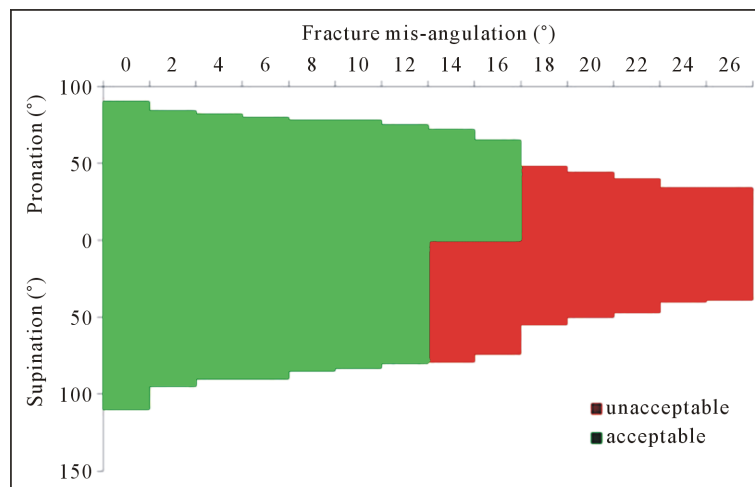


Figure 4. Results from the simulation.

4. Discussion

Pronation and supination are very important motions because they allow daily tasks and activities to be undertaken with ease, such as feeding oneself and performing personal hygiene, as well as many others [13]. The motion depends upon the radius and ulna being fully intact and aligned in its axis, and any damage to these most likely results in the loss of range of motion restricting ability to perform these daily tasks [6] [14].

Our study shows how angulation of radial fractures affects the forearm pronation and supination in incremental angulation of by just 2°; pronation and supination go from 90° and 110° respectively to 84 and 95 respectively. That is a 21° loss of motion from a 2° increase in angulation, stressing the importance of the correct management of these fractures (Figure 4).

Compared to the previous studies, our results are quite conservative in the sense that generally our result of acceptable angulation (16°) is lower. Our results showed a 55° loss of range of motion at 15° of angulation, and Hogstrom *et al.* said that his patients only noticed a loss of function when they had >50° range of motion loss, which showed our results reflected the suggestions by both studies [11]. Our findings also correlated with Daruwalla who said that >10° angulation on the midshaft on a child >10 years old was unacceptable [4]. From our results for a 7 year old child, a 10° angulation results in a 39° loss of range of motion.

Our results have shown that angulation of approximately 16° is the limit to which a proximal radius fracture can be accepted, based on the findings that 130° range of motion is considered normal. Hogstrom *et al.* found that even patients with a decrease in the range of pronation-supination motion of 50° had not noticed their dysfunction [11]. This supports the suggestion that 130° range of motion is considered acceptable.

Patrick finds that in children <15° - 20° of angulation is acceptable and that a loss of 20° - 30° rotation does not impair function and that loss of supination is more problematic than loss of pronation. He also states that children <9 years of age can remodel up to 15° of angulation, and 45° of malrotation. He then suggests that other factors other than angulation can result in restriction of motion, such as the size and of the interosseous membrane [15]. Daruwalla recommended that over 10° midshaft angulation in children over 10 years old was unacceptable [4]. Similarly, Vittas, D. published that deformity above 13 degrees would not remodel in patients above the age of 10 years [16]. Fuller and McCullough argued that open surgery was required for midshaft fractures of >8 year old patients [9].

Although it can be said that our results, albeit relatively conservative, are fairly similar to the findings of previous studies, it should be stressed that there are other factors that determine the amount of pronation/supination available after a fracture and hence can be seen as a limitation of this study.

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