Published in final edited form as:

J Pediatr Orthop. 2011 March ; 31(2): 138–143. doi:10.1097/BPO.0b013e3182093ddd.

Rapid Re-Mineralization of the Distal Radius Following Forearm Fracture in Children

Ellen B. Fung, PhD RD¹, Marcie L. Humphrey, RN MSN², Ginny Gildengorin, PhD³, Natalie Goldstein, BS⁴, and Scott A. Hoffinger, MD²

¹Department of Hematology, Children's Hospital & Research Center, Oakland, CA 94609

²Department of Orthopedics Children's Hospital & Research Center, Oakland, CA 94609

³Pediatric Clinical Research Center Children's Hospital & Research Center, Oakland, CA 94609

⁴Dana-Farber Cancer Institute, Boston, MA

Abstract

Background—Bone mineral content (BMC) and density (BMD) have been shown to diminish following fracture and immobilization in adults. Distal radius fractures (DRFx) are common in children, and unlike adults, there is a low incidence of re-fracture. The primary aim of this study was to assess the change in radial BMC and BMD following upper extremity fracture and casting in healthy pediatric patients.

Methods—Subjects were recruited at the time of DRFx casting. The non-fractured (non-Fx) distal radius was initially scanned by dual energy x-ray absorptiometry (baseline), and then both arms were scanned at the time of cast removal (CastOff), as well as 4, 8, 12, 24 and 52 weeks post cast removal.

Results—Twenty-one subjects were enrolled (13 Male, 13 Caucasian, 10.4±2.5 yrs) with an average length of casting of 38 ± 11 days. Eighteen subjects (86%) completed all protocol requirements. At CastOff, there was no significant difference in total BMC or BMD between the fractured and non-Fx arms. From CastOff to 24 weeks, the overall change in BMC and BMD for the non-Fx arm was +4.2% and +0.2%, respectively; while for the Fx arm, the change was +8.3% and +3.4%, respectively. By 24 weeks, the difference in the overall change in BMD between the Fx and non-Fx arms was statistically significant (greater than instrumental error and $p < 0.05$). However, by 52 weeks, these differences were no longer significant. The increased mineralization was unrelated to age, gender, arm dominance or calcium intake.

Conclusions—This data shows that there is rapid re-mineralization following a simple forearm fracture in children, with a transient elevation in BMD in the fractured arm after casting. This novel finding suggests that bone may be stronger around the site of fracture and could significantly change how we counsel young patients recovering from forearm fracture. Future

Corresponding Author: Ellen Fung, PhD RD Assistant Research Scientist, Children's Hospital & Research Center, Oakland HEDCO Health Science Center 5700 Martin Luther King Jr Way Oakland, CA 94609 Phone: 510-428-3885 x4939; Fax: 510-450-5877 efung@mail.cho.org.

None of the authors received financial support for this study.

Level of Evidence: Case Series: Therapeutic Studies – Investigating the Results of Treatment, Level IV.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

research should focus on children immobilized for varying lengths of time, as well as those with repeat fractures, employing volumetric techniques of bone geometry and strength assessment.

Keywords

DXA; bone mineral content; bone mineral density; forearm fracture; children

Introduction

Epidemiological studies have shown that fracture incidence is bimodal, with peaks occurring in youth in addition to the elderly.¹ Before the age of 20, the most common site of fracture is the forearm, resulting from high impact, sports related injuries.^{2,3} It has been theorized that fracture incidence is elevated during adolescence due to the lag in bone mineralization following skeletal growth.⁴ Above the age of 50, fragility type fractures of the spine and hip are most commonly observed, primarily the result of decreased bone mass.⁵ In these adults, re-fracture is a relatively common complication of a fracture.⁶ In 1999, a study found a re-fracture rate of 13.2% in adults aged 45 to 84 years old.⁷ In comparison to adults, there is a relatively low incidence re-fracture in children. Reports from the 1990s suggest only 5% of children who fracture their forearm will re-fracture within 18 months.^{8,9} Similarly, in a 2006 study, only 1 case of forearm re-fracture was observed at the same site in 125 female children with 58 fractures followed prospectively for 8 years, or a rate of 1.7%.¹⁰

Adults may be at an increased risk for re-fracture due to significant bone loss secondary to immobilization. The 2004 Surgeon Generals Report on Bone Health and Osteoporosis listed prolonged inactivity or immobility as one of the behaviors that affects bone mineral acquisition in pediatrics, and as a risk factor in developing osteoporosis in adults.⁵ What is not known about immobility and bone mineral loss is the length of time required for bone loss and if it differs in adult compared to pediatric patients. Studies performed in post-menopausal women treated for distal radius fragility fractures suggest forearm bone mineral density (BMD) may be decreased up to 4 years following cast removal and immobilization.¹¹ Although there are now a number of studies focused on the relationship between reduced BMD and incident fracture risk in pediatric populations,^{12,13} there are few studies addressing BMD before and after immobilization for a fracture.

The objective of this study was to assess bone mineral content (BMC) and BMD using dual energy x-ray absorptiometry (DXA) in pediatric patients following a distal radius fracture, the most common site of fracture in children.¹⁴ BMD assessment upon cast removal of upper extremity fractures in the pediatric population has not been previously studied. Comparing the non-fractured site to the healing/healed site, along with continued measurements during the post-cast-removal phase will provide information regarding the potential difference and/or potential re-mineralization once mobility is restored. If BMD is recovered rapidly following cast removal, these data could significantly change how we counsel our young patients with fracture history.

Materials and Methods

Children were invited to participate in the study if they presented to the Children's Hospital & Research Center, Oakland (CHRCO) Emergency Department or Orthopedic Clinic with an upper extremity fracture between August, 2005 and March, 2007 and were between 5 and 15 years of age. The study was approved by the CHRCO Institutional Review Board and informed written consent was obtained from all legal guardians and assent from subjects > 7 years. Subjects were excluded if they had a previous upper extremity fracture, required surgical reduction for their fracture, had endocrine, bone or growth disorders, or were

receiving oral corticosteroids. Subjects with both dominant and non-dominant forearm fractures were included since differences in BMD by arm dominance had not been observed in children.¹⁵

Initially, subjects were assessed on the day of casting of the fractured arm (Casted). A brief medical history was conducted, including a detailed history of current fracture, arm dominance, brief calcium-focused food frequency assessment, and measurement of weight and height. Additionally, the non-fractured arm was assessed by Dual Energy X-ray Absorptiometry (DXA, Hologic Discovery A, software v 12.3). Given the potential for the casting material to artificially bias the results, the fractured arm was not scanned at the initial visit. Both forearms were scanned at cast removal (CastOff), and 1, 2, 3, 6 and 12 months post cast removal. Scans were performed within ± 2 weeks of each time point with few exceptions. All scans were performed in duplicate by one of two state licensed DXA operators, while one operator analyzed all of the scans (EBF). The average of the 2 scans for each forearm was used in the analysis. Given the short duration of the project, a constant forearm length, determined at CastOff, was used for each analysis. According to DXA methodology, bone mineral content (BMC) is the grams of mineral assessed within a certain region of interest or area (cm^2). Bone mineral density (BMD) is the areal density within this region of interest, or grams of mineral per cm^2 . BMC and BMD of the total region (Ulna + Radius: Total), radius only and the ultra-distal portion (UD) of the forearm scan were abstracted from each analyzed scan (Figure 1). The non-fractured portion of the fractured arm (MID + 1/3) was calculated by subtracting the ultra-distal region of the scan from the total and used in the analysis (Mid-Forearm). Forearm BMD Z-scores of the non-fractured arm were calculated as the difference between the observed value and the age and gender-specific mean value for the reference population divided by the standard deviation of the reference population.¹⁶

Data analysis

Differences in continuous variables (BMC, BMD) between fractured and non-fractured extremities were assessed using Student's t-tests for normally distributed data and Wilcoxin-Mann-Whitney test for non-normally distributed data. Differences in categorical variables were analyzed using Pearson's chi-square. The longitudinal change in BMD or BMC within each forearm relative to the time of cast removal were analyzed by repeated measures analysis of variance. Longitudinal models were used to explore the effect of arm dominance on the rate of fracture healing. Other potential covariates included in the models were age, gender, calcium intake, and length of casting. Statistical analyses were conducted using SAS (version 9.1.3, SAS Institute, Cary NC) and significance defined as $p < 0.05$.

Sample Size

A pilot study of forearm DXA scans was performed in 18 healthy pediatric subjects (5 to 14 years, 13 males) prior to initiation of the current project to assist in sample size estimation. The average difference in BMD between upper extremities (dominant minus non-dominant forearm) was 0.001 g/cm^2 with a standard deviation of 0.013. The average total extremity BMD for both left and right sides was 0.39 g/cm^2 . A 5% change in BMD was considered clinically relevant, which calculates to a theoretical BMD of 0.3705 g/cm^2 for the fractured arm. Therefore the expected average BMD difference in the fractured compared to the non-fractured arms was estimated to be 0.0195 g/cm^2 with a standard deviation of 0.013. With a two-sided alpha of 0.05, and 80 percent power to detect this magnitude of difference it was estimated that 8 subjects would be required to complete the study. In order to allow for interaction by which side was fractured, twice this number was required (16 subjects total), assuming that the probability of fracturing the dominant or non-dominant side is approximately the same.

Results

Twenty-three patients were initially approached who met inclusion criteria and invited to participate. Of these 21 subjects consented and were originally enrolled in the study while 18 completed all protocol-required scans (Table 1). Three subjects did not complete the study: one male subject required surgical reduction post-cast removal; and two subjects (1 female, 1 male) were lost to follow-up at 4 and 8 weeks, respectively.

All subjects were healthy and most had a body mass index within the normal range (Table 1). The majority of the subjects (71%) were right hand dominant and slightly over half of the subjects (52%) fractured their dominant forearm. The sites of fracture were: the distal radius (81%); the ulna (5%); and both the radius and the ulna (14%). The causes of the fracture were: organized sports (36%); the playground 'monkey' bars (27%); and significant falls (36%). None of the fractures occurred from minimal trauma, and therefore are not considered fragility fractures. All of the subjects had forearm BMD Z-scores above -2.0 , the cut-off indicative of low bone mass in pediatric patients.¹⁷

On average there was no significant difference in the total BMC or BMD between the Casting and Cast Off interval in the non-fractured arm (Table 2). Also, there was no significant difference in total BMC or BMD between the fractured and non-fractured arms at the time of cast removal. BMC and BMD for the entire forearm (Figures 2a/2b) increased more rapidly in the fractured compared to the non-fractured arm following immobilization. There was a trend towards an increase in the change in total BMC from cast removal to 24 wks post removal in the non-Fx arm (4.2%) compared with the Fx arm (8.3%, $p=0.05$). The overall rate of change in BMD was significantly higher in the Fx compared to the Non-Fx arm at just 2 months post cast removal. By 24 weeks, the change in BMD from baseline was 0.2% for the non-Fx and 3.4% for the Fx arm ($p=0.04$). Due the high rate of bone turnover observed in this population, the differences observed between the subjects 2 forearms were greater than the least significant change (LSC), or the instrumentational error for the DXA instrument at our site. However, by the end of the study, 12 months, these differences were no longer apparent for either total forearm BMC or BMD.

These observed differences were also apparent in the mid-region of the forearm (Figures 3a/3b), that is the non-fractured region of the fractured forearms. Mid-region BMC was significantly greater in the Fx compared to the Non-Fx arm at just 3 months post cast removal (3.6% vs. 13.6%, $p=0.01$). The differences observed in mid-region BMD were apparent at 3 months, and remained significantly higher at the 12 month time point (Figure 3b).

There were no significant differences observed in the bone area between the fractured and non-fractured sites at any study time points, that is the relative change in bone size were similar within an individual (data not shown). When the data are explored in absolute terms (Table 2) rather than relative change from baseline, the differences in BMC and BMD between the 2 arms are no longer significant at any time point.

Neither length of casting, nor calcium intake was related to bone acquisition following fracture. Arm dominance also had no effect on the rate of re-mineralization. However, after controlling for arm dominance, length of immobilization and initial bone mineral content, we observed a significant effect of age on rate of change in bone mineral content ($p=0.005$). That is, the older the subject, the greater the change in mineralization following a simple upper extremity fracture.

Discussion

This is the first prospective study focused on young patients that has assessed the change in radial bone mineral content (BMC) and density (BMD) following upper extremity fracture and casting. What is clear, and quite unique from previous adult studies, is that there is a rapid re-mineralization of bone following upper extremity fracture. Within the first 3 months following a simple distal radius fracture, the site of fracture is denser than the non-fractured arm. This finding suggests that bone density improves rapidly in children, and perhaps bone is stronger around the site of fracture in young patients. This information could significantly change how we counsel young patients with fracture history, and encourage them to continue to participate in normal childhood activities soon after cast removal.

Distal radius fractures are the most common site of fracture in children. Following a forearm fracture, most children are advised by their physician to refrain from physical activity, especially contact sports, for a period of time. This advice is predicated on the results from fracture recovery in adults, as well as the well known effects of immobilization on reducing bone density. We have shown that both BMC and BMD increases rapidly following a simple forearm fracture in children.

We observed a significant effect of age on the rate of bone re-mineralization following fracture. It is well known that bone mineralization is greatest during and immediately following the adolescent growth spurt.⁴ The average age of subjects in this study was 10 years, thus, many were peri-pubertal and beginning the active period of bone acquisition. Given our subjects age, it seems feasible that we observed an effect of older age on bone acquisition. However, significant differences in bone size were not apparent during the period of observation. This is likely due to the fact that we explored relative changes in the fractured vs. non-fractured arms and both arms were growing in area during the period of observation (one year). Furthermore, it is unlikely that growth alone could explain the differences in BMC and BMD observed, given the non-fractured arm served as the 'control' to the fractured arm. Growth rates are not expected to differ between a dominant and non-dominant arm within an individual child, unless of course a subject were actively participating in a sport where there was a significant load placed on one arm and not the other (e.g Tennis). None of the subjects in this study were participating in sports such as this.

Relatively large standard deviations were observed for the mean values in the absolute change in total BMC and BMD in this sample of subjects presented in Table 2. Typically a large standard deviation in a particular variable suggests increased variability. This is to be expected in bone outcome variables presented in a group of pediatric subjects who differ in gender and age; for example, bone turnover will be quite different in a 9 year old compared to a 14 year old male. Fortunately, the power of the statistics in this study come in the longitudinal changes observed overtime, within a subject. Therefore despite large variability between subjects at one time point, there is much smaller variability in the change of BMD within a subject with time.

Previous studies conducted in adults have observed a significant decrease in BMD following upper and lower extremity fractures^{18,19} or surgery and immobilization for tendon injuries.²⁰ Bone losses as great as 20% were observed, and length of time to recovery of bone loss depended on severity and location of injury.^{18,20} Arm dominance has a significant effect on bone remodeling in adult subjects. Kekilli et al. found that bone loss was greater in an immobilized non-dominant forearm compared to the dominant forearm.²⁰ We, however, did not observe a significant effect of arm dominance on rate of re-mineralization in this sample of children with forearm fractures.

The bone density was assessed by DXA, which is an areal density or a two dimensional image. DXA is the most frequently used tool to assess bone density in children and adults and is considered a proxy measure for bone strength because it does not directly measure bone architecture or strength. The assumption made herein is that bone acquired post fracture in these children is similar to that in the non fractured arm. Given this study focused only on healthy children without prior fracture or history of bone disorders, the assumption is reasonable. In order to determine bone architecture directly, bone histomorphometry studies at the site of fracture would be necessitated. Histomorphometry was far too invasive for a study involving healthy children. Alternatively, new high resolution peripheral computed tomography scanners are available that enable one to determine the thickness of and spacing between trabeculae. Follow-up studies involving HRpQCT would be quite informative, particularly with regard to assessment of bone strength following fracture and immobilization.

One limitation of this study is that a non-weight bearing site, the distal radius, was assessed. Bone acquisition following fracture and immobilization of a weight bearing site may be significantly different. Henderson has shown that immobilization due to spica casting in children with cerebral palsy is the single strongest predictor of future fracture.²¹ It would be very interesting to design a similar study in patients recovering from femoral fracture. Additionally, Baiter and colleagues found that the distal radius is less susceptible to re-fracture compared to the proximal radius.²² Therefore, the results from the present study may not be applicable to all fractures occurring at upper extremities. Additionally, due to our study design, the first scan of the fractured arm occurred following cast removal. Acute changes to bone area around the site of fracture may have been missed. Finally, this study was limited to simple, nonor minimally- displaced distal radius fractures that did not require surgical intervention. It is unknown if similar results would be observed in young patients with fractures requiring open reductions.

In summary, these data show that there is rapid re-mineralization following a simple forearm fracture in children, with a transient elevation in BMD in the fractured arm after casting. This novel finding suggests that bone may be stronger around the site of fracture and could significantly change how we counsel young patients recovering from forearm fracture. Future research should focus on children with more severe fractures, occurring at weight bearing sites and/or those children with repeat fractures, employing volumetric techniques of bone geometry and strength assessment.

Acknowledgments

We wish to thank all of the subjects and their families who so graciously participated in the study as well as the nurses within the orthopedic department for their assistance in subject recruitment. We are indebted to the DXA technicians and staff at the CTSI Clinical Research Center. We extend a special thank you to Anita Bagley for her assistance with the final manuscript preparation.

This publication was supported in part by the following grants: M01 RR01271 and UL1-RR024131 from the National Center for Research Resources.

References

1. Johansen A, Evans RJ, Stone MD, et al. Fracture incidence in England and Wales: a study based on the population of Cardiff. *Injury*. 1997; 28:655–660. [PubMed: 9624346]
2. Landin LA. Epidemiology of children's fractures. *J Pediatr Orthop B*. 1997; 6(2):79–83. [PubMed: 9165435]
3. Cheng JC, Shen WY. Limb fracture pattern in different pediatric age groups: a study of 3,350 children. *J Orthop Trauma*. 1993; 7(1):15–22. [PubMed: 8433194]

4. Bailey DA, McKay HA, Minwald RL, et al. A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: The University of Saskatchewan Bone Mineral Accrual Study. *J Bone Miner Res.* 1999; 14(10):1672–1679. [PubMed: 10491214]
5. U.S. Department of Health and Human Services. Bone Health and Osteoporosis: A report of the surgeon general. U.S. Department of Health and Human Services, Office of the Surgeon General; Rockville, MD: 2004.
6. Cheng JC, Shen WY. Limb fracture pattern in different pediatric age groups: a study of 3,350 children. *J Orthop Trauma.* 1993; 7(1):15–22. [PubMed: 8433194]
7. Robinson CM, Royds M, Abraham A, et al. Refractures in patients at least forty-five years old. A prospective analysis of twenty-two thousand and sixty patients. *J Bone Joint Surg Am.* 2002; 84:1528–1533. [PubMed: 12208908]
8. Bould M, Bannister GC. Refractures of the radius and ulna in children. *Injury.* 1999; 30(9):583–586. [PubMed: 10707224]
9. Schwarz N, Pienaar S, Schwarz AF, et al. Refracture of the forearm in children. *J Bone Joint Surg Br.* 1996; 78(5):740–744. [PubMed: 8836061]
10. Ferrari SL, Chevalley T, Bonjour JP, et al. Childhood fractures are associated with decreased bone mass gain during puberty: An early marker of persistent bone fragility? *J Bone Miner Res.* 2006; 21(4):501–507. [PubMed: 16598368]
11. Ashe MC, Khan KM, Davis JC, et al. Hand dominance and bone response after a distal radial fracture: a peripheral QCT study. *J Clinical Densitometry.* 2007; 10(1):93–101.
12. Goulding A, Grant AM, Williams SM. Bone and body composition of children and adolescents with repeated forearm fractures. *J Bone Miner Res.* 2005; 20(12):2090–6. [PubMed: 16294262]
13. Ma D, Jones G. The association between bone mineral density, metacarpal morphometry, and upper limb fractures in children: A population based case-control study. *J Clin Endocrinol Metab.* 2003; 88(4):1486–1491. [PubMed: 12679427]
14. Janmohammadi N, Keshavarz P, Bahrami M. Epidemiology and Influencing Factors of Refracture. *Journal of Orthopaedics.* 2005; 2(5):e2.
15. Min JY, Min KB, Paek D, et al. Side differences in the bone density of the distal radius and calcaneus in Koreans aged 4–86 years. *Journal Clin Densitom.* 2007; 10(2):184–8.
16. Kalkwarf HJ, Zemel BS, Gilsanz V, et al. The bone mineral density in childhood study: bone mineral content and density according to age, sex and race. *J Clinical Endocrin Metab.* 2007; 92(6):2087–99.
17. Guidelines for Pediatric Patients [International Society for Clinical Densitometry Web Site]. [Accessed May 6,2010]. Available at: <http://www.iscd.org/Visitors/positions/OfficialPositionsText.cfm#PEDIATRIC>.
18. Veitch SW, Findlay SC, Hamer AJ, et al. Changes in bone mass and bone turnover following tibial shaft fracture. *Osteoporos Int.* 2006; 17(3):364–72. [PubMed: 16362144]
19. Nilsson BE, Westlin NE. Long-term observations on the loss of bone mineral following colles' fracture. *Acta Orthop Scand.* 1975; 46(1):61–66. [PubMed: 1136737]
20. Kekilli E, Ertem K, Yologlu S, Ceylan F. Comparisons of the bone mineral density in dominant and nondominant forearm following clean-cut tendon injuries, repair, and passive mobilization. *J Clin Densitom.* 2006; 9(2):198–201. [PubMed: 16785081]
21. Henderson RC. Bone density and other possible predictors of fracture risk in children and adolescents with spastic quadriplegia. *Devel Med Child Neurol.* 1997; 39(4):224–7. [PubMed: 9183259]
22. Baitner AC, Perry A, Lalonde FD, et al. The Healing Forearm Fracture: a matched comparison of forearm refractures. *J Pediatr Orthop.* 2007; 27(7):743–7. [PubMed: 17878777]

Figure 1.

Forearm Fracture Assessment, Images from Dual Energy X-ray Absorptiometry Analysis at time of Cast Removal and 6-months Post-Cast Removal in a 13 year old female with left distal radius fracture. (1a) Left forearm image at time of cast removal, (1b) DXA scan analysis performed at time of cast removal, (1c) DXA scan analysis performed 6 months after cast removal.

Figure 1a: Subject #11 13 y.o. female, Left forearm fracture of the radius at time of cast removal

Figure 1b: Subject #11 Left forearm DXA scan analysis performed at time of cast removal

Figure 1c: Subject #11 Left forearm DXA scan performed analysis 6 months after cast removal

Figure 2A.

Change in Total Bone Mineral Content from Time of Cast Removal to 12 months in Fractured vs. Non-Fractured Arms. Mean $\pm$ SD for n=18 subjects for the Fractured arm (Solid squares, dashed line) and non-fractured arm (Solid Circles, solid line). P-values are from paired Student's T-tests. NonFx: non-fractured arm; Fx: fractured arm; LSC: Least significant change denoted in shaded area on graph; Total Bone mineral content (BMC) defined as BMC of UD + MID + 1/3 regions. Error bars are shown in one direction on graph for simplicity, though standard deviations around each data point are in both directions (+/-).

Figure 2B.

Change in the Total Bone Mineral Density of the Forearm from Time of Cast Removal to 12 Months Fractured vs. Non-Fractured Arms. Mean $\pm$ SD for n=18 subjects for the Fractured arm (Solid Squares, dashed line) and non-fractured arm (Solid Circles, solid line). P-values are from paired Student's T-tests. NonFx: non-fractured arm; Fx: fractured arm; LSC: Least significant change denoted in shaded area on graph; Total Bone mineral density (BMD) defined as BMD of UD + MID + 1/3 regions. Error bars are shown in one direction on graph for simplicity, though standard deviations around each data point are in both directions (+/-).

Figure 3A.

Change in Non-Fractured (“Mid-Region”) Bone Mineral Content from Time of Cast Removal to 12 months in the Fractured vs. Non-Fractured Arms. Mean $\pm$ SD for n=18 subjects for the Fractured arm (Solid Squares, dashed line) and non-fractured arm (Solid Circles, solid line). P-values are from paired Student's T-tests. Mid-Region Bone Mineral Content (BMC) defined as Total BMC – UD region. Error bars are shown in one direction on graph for simplicity, though standard deviations around each data point are in both directions (+/-).

Figure 3B.

Change in Non-Fractured ("Mid-Region") Bone Mineral Density from Time of Cast Removal to 12 Months in the Fractured vs. Non-Fractured Arms. Mean $\pm$ SD for n=18 subjects for the Fractured arm (Squares, dashed line) and non-fractured arm (circles, solid line). P-values are from paired Student's T-tests. Mid-Region Bone Mineral Density (BMD) defined as Total BMD – UD region. Error bars are shown in one direction on graph for simplicity, though standard deviations around each data point are in both directions (+/-).

Table 1

Characteristics of Twenty-One Healthy Pediatric Subjects with Forearm Fracture at Entry into the Study

Gender	Male [13], Female [8]
Age, Years	10.4 $\pm$ 2.5 (Range: 5.8–14.8)
Ethnicity	Caucasian [13] Asian [4] African-American [1] Other [1] Hispanic [2]
Weight, kg	44.1 $\pm$ 15.7 (Range: 19.8–77.7)
Height, cm	144.9 $\pm$ 16.5 (Range: 115–174.4)
Body Mass Index, kg/m²	20.5 $\pm$ 4.8 (Range: 15–32)
Arm Dominance	Right side [15], Left side [6]
Fractured Arm	Right side [9], Left side [12]
Fractured Dominant Arm	[11]; 52.4%
Site of Fracture	Distal Radius [17] Distal Radius + Ulna [3] Distal Ulna [1]
% Reduced Fractures	23.8
Length of Casting, days	37.6 $\pm$ 10.9 (Range: 20–56)
Calcium Intake, mg/day	1041 $\pm$ 466 (Range: 281–1899)
Forearm BMD Z-Score	−0.33 $\pm$ 0.47 (Range: −0.98 – 0.82)

Mean $\pm$ SD (Range); [Number of subjects]BMD: Bone mineral density, g/cm²

Forearm BMD Z-score determined from (Ref 19; Kalkwarf et al, 2007)

Table 2

Absolute Change in Total Forearm Bone Mineral Content and Bone Mineral Density from Baseline to 12 Months in the Fractured vs. Non-Fractured Arm (n=18)

Time point	Total Bone Mineral Content, g		Total Bone Mineral Density, g/cm ²	
	Non-Fractured Radius	Fractured Radius	Non-Fractured Radius	Fractured Radius
Casting	7.06 ± 2.42	--	0.406 ± 0.056	--
Cast-Off	7.22 ± 2.31	7.45 ± 2.23	0.409 ± 0.053	0.415 ± 0.045
1 month	7.18 ± 2.48	7.38 ± 2.50	0.405 ± 0.052	0.415 ± 0.048
2 months	6.83 ± 2.33	7.40 ± 2.38	0.395 ± 0.044	0.417 ± 0.042
3 months	7.36 ± 2.53	7.88 ± 2.51	0.408 ± 0.053	0.428 ± 0.050
6 months	7.61 ± 2.69	8.26 ± 2.56	0.410 ± 0.061	0.431 ± 0.050
12 months	8.05 ± 3.01	8.45 ± 3.07	0.425 ± 0.067	0.436 ± 0.065

Mean ± SD

Time point: Time in months following removal of the cast on the fractured forearm, +/- 2 weeks

Total BMC (g) and BMD (g/cm²) taken from the total of UD, MID and 1/3 regions on each individual DXA scan (see Figure 1)

No significant differences were observed between the fractured and non-fractured arms at any time point.