

Relative Osteopenia After Femoral Implant Removal in Children and Adolescents

L. JOHNSON PATMAN, MD; ELIZABETH A. SZALAY, MD

abstract

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Radiographic osteopenia is regularly observed after implant removal from a fracture or femoral osteotomy but has not been objectively quantified. Hardware removal is generally performed months to years after the index event (fracture or osteotomy) when full activity has been resumed. Objectively demonstrable bone mineral deficiency affects fracture risk. Hardware removal may facilitate the return to normal bone mineral density. Children who had dual-energy X-ray absorptiometry scans following femoral implant removal were retrospectively reviewed to assess the percent of change in bone mineral density and change in Z-scores. The femoral neck and the lateral distal femora were scanned, comparing the operated side with unaffected femur as a control. Sixteen children were included. Patients demonstrated up to 15.4% (average, 4.8%) less bone mineral density in the femoral neck region, up to 43% less (average, 16.5%) in the metabolically active distal metaphyseal region, and up to 18.1% less (average, 6.3%) in the transitional region. No statistical difference was noted in the diaphyseal region. A statistically significant decrease in Z-score was noted when plate and screw constructs (average change, -0.97 SD) as compared with intramedullary nail constructs (average change, -0.33 SD) were used. Children can exhibit statistically significant decreases in bone mineral density in the femoral neck and distal femur following femoral implant removal, with plate and screw constructs demonstrating a greater effect than intramedullary (load sharing) devices. This has implications for return to activity and suggests that implant removal may be important in restoration of bone strength in children.

The authors are from the Department of Orthopaedics and Rehabilitation (LJP), and the Division of Pediatric Orthopaedics (EAS), University of New Mexico School of Medicine, Albuquerque, New Mexico.

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Correspondence should be addressed to: Elizabeth A. Szalay, MD, Division of Pediatric Orthopaedics, University of New Mexico School of Medicine, 1127 University Blvd NE, Albuquerque, NM 87102 (eszalay@salud.unm.edu).

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Bone mineral density (BMD) loss in children and adolescents as a result of orthopedic procedures is well known. Previous studies have reported that adolescents can lose up to 34% of BMD in the first 2 postoperative months after lower-extremity surgery, but it is not known how long it takes to replenish this loss.¹ Radiographic osteopenia is frequently noted after implant removal from the hip and femur but has never been quantified. The timing of implant removal varies but is usually 9 months or more after the index event (ie, fracture or osteotomy). It is unknown how much osteopenia is secondary to the index event and how much is due to stress shielding from the metallic hardware. Regardless, decreased BMD may have implications regarding fracture risk following implant removal and could affect return to play.

Hardware removal is often recommended in children and adolescents due to the possibility of bony overgrowth of the implant that might render subsequent surgery difficult. The need for implant removal is debated, citing the cost and risk of the second surgery compared with its benefit.² However, if a significant decrease in BMD is documented in the femoral implant region, removal of the stress shielding effect of the hardware could have a greater weight in the decision to reoperate.

Noting radiographic osteopenia around implants, such as flexible nails, as much as 1 year after fracture, the authors observed 1 child after implant removal and compared the affected femur with the unaffected side using dual-energy X-ray absorptiometry (DEXA); a BMD difference greater than 1 SD was found. The authors believe that this clinically justified evaluating other children and adolescents after implant removal. The clinical indication for DEXA scanning was implant removal from the hip or proximal femur, with no regard to the presence or absence of radiographic osteopenia. Dual-energy X-ray absorptiometry has been used to quantify

bone response to prosthetic implants in adults,³ but similar studies have not been published in children and adolescents.

This relative osteopenia raised several questions: How much BMD difference can be expected following removal of femoral implants? Does implant type (load bearing vs load sharing) affect the amount of osteopenia? Is there enough BMD loss to affect return to sports and other activities?

MATERIALS AND METHODS

Approval for this study was obtained after review by the Human Research Review Committee of the University of New Mexico Health Sciences Center. A retrospective chart and radiographic review was conducted on children and adolescents who, as part of their clinical course, had femoral implants removed and underwent subsequent DEXA scanning, most commonly of the hip and bilateral distal femora.

Inclusion criteria were healthy, normally ambulatory children and adolescents younger than 18 years who had femoral implants placed and removed unilaterally for the treatment of fracture or osteotomy and had a DEXA scan comparing the affected femur (study side) with the unaffected femur (control side). The DEXA scans were generally performed within a few weeks after implant removal. Participants were excluded if they had a pathologic fracture, tumor, or metabolic bone disease that might affect BMD or if they had an infection, nonunion, or other complication after the index procedure.

A standard hip DEXA scan was performed using a Hologic scanner (Bedford, Massachusetts), and a distal femoral scan was performed using the technique described by Harcke et al.⁴ All scans were interpreted by the primary investigator (E.A.S.), who is certified as a clinical densitometrist by the International Society of Clinical Densitometry. The femoral neck region and the distal femoral metaphysis, distal femoral metaphyseal-diaphyseal

junction, and diaphyseal regions were evaluated and compared with the control side. If the fracture or a fracture callus extended into the DEXA region of interest (eg, femoral neck or distal femoral diaphysis), then that region was not included in statistical analysis.

BMD change in each region was calculated as a percentage by subtracting the BMD in the study limb from that of the control limb and dividing this number by the BMD of the control limb. The change in Z-score, which compares participants with sex- and age-matched means, was calculated using the following formula: $Z\text{-score} = (\text{participant BMD} - \text{mean BMD}) / \text{SD}$.⁵ Participants with intramedullary devices (load sharing) were compared with those with plate and screw constructs (load bearing).

Means and confidence intervals were calculated for all numeric variables. To explore the relationship between BMD and participant, region, and implant type, a general linear model (similar to 3 factor analysis of variance) was fitted to the data. A significant *P* value of .05 and 2-tailed *t* tests were used throughout. The Tukey procedure was used to adjust for multiple comparisons. All calculations were performed on an Intel Pentium-based microcomputer. Statistical calculations were made with Statgraphics Centurion XV version 15.2.06 software (StatPoint, Inc, Herndon, Virginia). Data management was performed using Microsoft Excel 2007 (Microsoft Corporation, Inc, Redmond, Washington).

RESULTS

Between 2003 and 2011, seventeen participants underwent DEXA scanning following implant removal; 1 participant was excluded due to a pathologic fracture through a bone cyst. Implant removal, rather than radiographic osteopenia, was the indication for the DEXA study. Sixteen participants met the inclusion criteria and had adequate medical records available (Table). Nine boys and 7 girls

with an average age of 10 years (range, 6 to 16 years) were included in the study. Average time between placement of the initial implant and subsequent removal was 13.1 months (range, 4.9 to 70.7 months). Constructs included 7 plates and 9 intramedullary nails. Fourteen participants were initially treated for femur fractures, and the remaining 2 had proximal femur osteotomies secondary to developmental dysplasia of the hip treated in infancy. All participants were normally ambulatory prior to the index incident and were fully weight bearing prior to implant removal.

All femoral regions studied except the diaphyseal region showed a statistically significant decrease in BMD. Mean femoral neck region BMD change was -4.8% (range, 18.8% to -15.4%) ($P=.03$). Mean metaphyseal region BMD change was -16.5% (range, 4% to -43%) ($P=.02$). Mean metaphyseal-diaphyseal region BMD change was -6.3% (range, 14.8% to -18.1%) ($P=.03$). The diaphyseal region did not show a statistically significant change in BMD (Figure 1).

All regions except the diaphyseal region also showed a statistically significant decrease in Z-score. Mean femoral neck region change was -0.38 SD (range, 1.1 to -1.2 SD) ($P=.03$). Mean distal femoral metaphysis region change was -1.5 SD (range, 0.3 to -4.4 SD) ($P=.002$). Mean metaphyseal-diaphyseal junction region change was -0.62 SD (range, 0.9 to -2.2 SD) ($P=.03$). The diaphyseal region did not show a statistically significant change in Z-score (Figure 2).

Looking at all data points for the femur as a whole, a significant difference was found in the change in Z-score when comparing intramedullary nail vs plate and screw constructs. The average change in Z-score for intramedullary nail constructs was -0.33 SD (range, -0.72 to 0.03) and the average change with plate and screw constructs was -0.97 SD (range, -1.30 to -0.59) ($P=.03$).

Table		
Patient Data		
Patient No./ Sex/age	Diagnosis	Implant
1/F/11	L proximal femur fracture	SCS
2/M/16	L femur shaft fracture	Rigid IMN
3/M/9	L femur shaft fracture	Flexible IMN
4/F/9	L femur shaft fracture	4.5-mm plate
5/M/7	R femur shaft fracture	Flexible IMN
6/M/13	R femur shaft fracture	Flexible IMN
7/F/6	R femur shaft fracture	Flexible IMN
8/M/9	R femur shaft fracture	4.5-mm plate
9/F/6	L femur shaft fracture	3.5-mm plate
10/F/8	R proximal femur osteotomy	Pronged hip plate
11/F/11	L femur shaft fracture	Flexible IMN
12/M/11	R femur shaft fracture	Flexible IMN
13/M/16	L femur shaft fracture	Rigid IMN
14/F/8	L proximal femur osteotomy	90° blade plate
15/M/9	R femur shaft fracture	3.5-mm plate
16/M/11	L femur subtrochanteric fracture	Rigid IMN

Abbreviations: IMN, intramedullary nail; L, left; R, right; SCS, sliding compression screw

DISCUSSION

This study indicates that children and adolescents exhibit a statistically significant difference in BMD after implant removal, at an average of 13.1 months postoperatively, for fracture or osteotomy of the femur. Relative osteopenia was demonstrated at regions (femoral neck, distal femur, or both) removed from the site of fracture or surgery. All regions evaluated except for the diaphysis showed a significant decrease in BMD and Z-scores, with 1 participant losing 43% of BMD in the distal femoral region. The femoral metaphysis, which is closest to the physis and thus the most metabolically active, showed the most significant

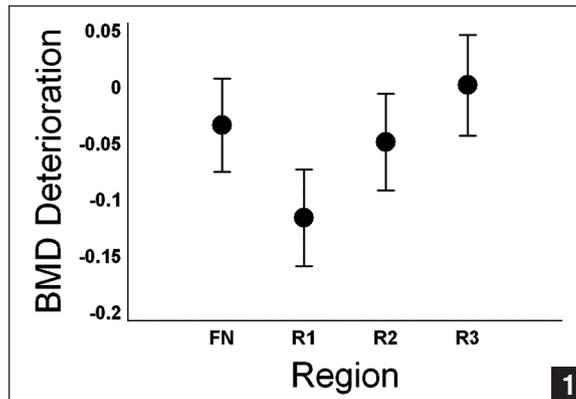


Figure 1: Graph showing bone loss by region as indicated on the lateral distal femur dual-energy X-ray absorptiometry scan, with bone mineral density (BMD) listed in gm/cm². Abbreviations: FN, femoral neck; R1, metaphyseal bone of the distal femur; R2, transitional bone (distal femoral metaphyseal-diaphyseal junction); R3, diaphyseal bone.

change in BMD. The average distal femoral difference between the study and control leg was 16% (range, 3.8% to 43.1%).

The clinical significance of this BMD loss depends on the child's bone health

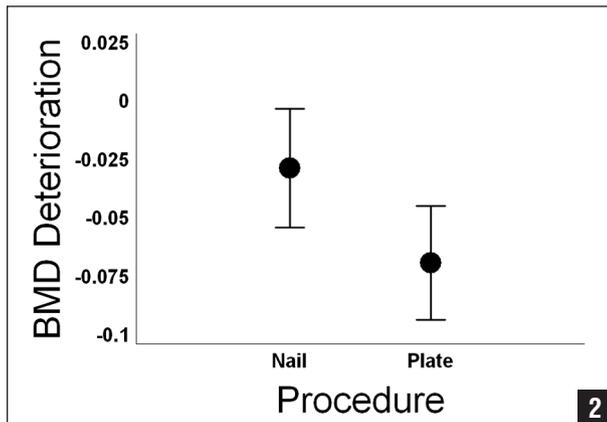


Figure 2: Graph showing bone loss following implant removal comparing the nail implant to the intramedullary nails (n=9) and plate and screw (n=7) constructs. Change in bone mineral density (BMD) is listed as Z-score (which compares participants to age- and sex-matched means). Because of small participant numbers between groups, comparison between constructs based on absolute BMD changes or percentage change were not considered to be statistically applicable.

prior to the index procedure, as well as the activity or athletics to which the bone is then exposed.⁶ An average of 16% of BMD loss may not mean much in a child with antecedent BMD well above age- and sex-matched means, but to a child with preexistent lower BMD, this could be the 16% that matters. Furthermore, depending on the type of sport, this relative osteopenia loss can have different results—a return to swimming may have minimal risks, whereas a return to football or rugby may predispose the child to another fracture.

The change in Z-score was statistically significant in all regions except the femoral diaphysis. The greatest average change (a loss of 1.5 SD) was seen in the distal metaphyseal region. In adults, a T-score change of 1 SD is associated with a doubling of the fracture risk.⁷ In children and adolescents who play collision sports such as football, this may have implications in return to play.

It cannot be determined from these data how much of the loss of BMD is secondary to the index event or to the surgery itself, but the fact that implant type affected the amount of BMD loss suggests that the implant itself has an effect on bone den-

sity. A statistically significant difference was seen in Z-score changes comparing plate and screw constructs (average Z-score change, -0.97 SD) vs intramedullary devices (average Z-score change, -0.33 SD). This suggests that load-sharing devices (ie, intramedullary implants) are less detrimental to BMD than are load-bearing devices (ie, plate and screw constructs).

Other factors influence BMD loss after fracture or osteotomy,

including time to weight bearing after the index surgery. Several surgeons were involved in the current study, resulting in varying postoperative regimens. However, the hardware removal and DEXA scan occurred an average of 13.1 months after the index procedure, when all children had long resumed full ambulatory status.

Limitations of this study include its small sample size, although statistical significance was seen in the comparisons. Although the indication for DEXA scanning was hardware removal and not radiographic osteopenia, the study was non-randomized and retrospective; therefore, selection bias may have been in effect when deciding which patients to study with DEXA scanning. As noted earlier, other factors enter into bone strength that were not considered, including weight bearing and metabolic status (such as Vitamin D levels). Using the contralateral, unoperated femur as a control offers some inherent leveling of individual metabolic status.

Another limitation is the use of BMD or Z-scores as a surrogate endpoint for fracture.⁸ Demonstrably lower BMD is important, primarily with respect to increases in fracture risk. None of the cur-

rent participants experienced a fracture as result of lower BMD in the affected leg, thus the difference observed may not be clinically significant. However, the use of the fracture itself as an outcome requires a large participant pool, making such studies impractical, especially in children and adolescents. Bone mineral density percentage change is best predictive of fracture if the baseline BMD or Z-score is evaluated, which is an unknown value in the current study but is inferred by using the opposite leg as control.

Internal fixation is increasingly used with pediatric lower-extremity fractures. Although an epidemic of fractures occurring after hardware removal has not been observed, the possibility of a significant decrease in BMD at the time of hardware removal should be taken into account with respect to return to activity. The possibility that the hardware itself contributes to this decrease in BMD is an argument for hardware removal. Further study is needed to establish when and if BMD returns to normal levels following hardware removal.

CONCLUSION

Localized BMD deficiency following femoral implant removal is a measurable entity and should be considered during the postoperative course. Potential clinical implications include limiting return to play and consideration of follow-up monitoring with DEXA scanning, especially for children and adolescents returning to collision sports. Stress shielding appears to be greater from plate and screw constructs than from intramedullary devices, but the fact that both had an effect on BMD suggests that routine implant removal should be considered for the developing skeleton. 

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