Obtaining Vitamin D Levels in Children With Fractures Improves Supplementation Compliance

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Background: Obtaining ideal serum 25-vitamin D (25VitD) levels (> 30 ng/mL) is imperative in childhood to achieve peak bone mass. Supplementation compliance in children recommended to take vitamin D postfracture was evaluated. The questions we sought to answer were: Is there (1) a compliance difference between patients with known versus unknown 25VitD levels; (2) an association between compliance and age; and (3) an association between fracture severity and initial 25VitD level.

Methods: One physician analyzed compliance in 1818 fracture patients 2 to 18 years (42% female) with known (48%) and unknown 25VitD. Patient/caregiver's self-reported adherence to supplementation as "yes" (4 d/wk minimum) or "no" defined compliance. Compliance relating to fracture severity via Abbreviated Injury Scale (AIS), 25VitD level, and age, was analyzed.

Results: Patients with 25VitD levels were more compliant than patients without (61%, n = 532/872; 21%, n = 206/946; $P < 0.001$). In total, 83% (n = 104/125) of AIS 3 patients were compliant, compared with 49% (n = 628/1292) of AIS 1/2 patients ($P < 0.001$). Compliance increased with age (odds ratio: 1.09, 95% confidence interval: 1.061-1.120, $P < 0.001$).

Conclusions: Compliance increased when 25VitD levels were obtained, improving with fracture severity. Clinicians should order 25VitD levels on fracture patients to improve supplementation compliance.

Level of Evidence: This is a level IV prognostic study which aims to investigate the effects of various patient characteristics on compliance.

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Ethical Review Committee Statement: The study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki and in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA).

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Patient adherence to medicinal regimens and lifestyle adjustments is of concern to physicians, researchers, and public health officials. Approximately 40% to 70% of patients do not correctly adhere to treatments.[1] Parents and children may not understand the necessity of taking a supplement regularly. Improving patient compliance is not only of importance for better patient outcomes, but would also be beneficial to improving outcome data and economic efficiency of the health care system.[1] There is a void in the literature and no other studies to date that have examined pediatric vitamin D supplementation compliance and how it relates to serum testing, fracture severity, age, body mass index (BMI), and sex.

The American Academy of Pediatrics (AAP) only advocates checking 25-vitamin D (25VitD) levels in "at risk" children but not in the general healthy population. Included in the "at risk" population are premature infants, dark-skinned infants and children, children who reside in areas of limited sun exposure (> 37.5 degrees latitude), obese patients, and those on medications known to compromise 25VitD concentrations.[2] This means that unless a physician orders a test for a specific reason such as fracture, spondylolysis, or scoliosis, children who do not have these risk factors would not get their 25VitD levels checked. In a previous study, pediatric fracture patients in the multiethnic Morris-Essex counties of New Jersey community had comparable 25VitD demographics to a nonfracture control population. Of concern, 65% of healthy pediatric fracture patients in this group had deficient or low (< 30 ng/mL) 25VitD level, which was shown to impact fracture severity.[3] The majority of patients in this population are considered healthy and would never have been identified by the "at risk" list.[3]

There is concerning evidence even as it relates to children who are identified as being at risk for 25VitD deficiency. According to a recent study by Gorter,[4] only 1 in 22 children with a dark skin type over the age of 4 had been receiving supplementation, indicating poor implementation of guidelines for children at risk for 25VitD deficiency.

Vitamin D plays an important role in the regulation of calcium and skeletal homeostasis, and is thus essential

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TABLE 1. Demographics by 25VitD Grouping

	Optimally Sufficient (40 < 25VitD)	Sufficient (30 < 25VitD ≤ 40)	Insufficient (20 < 25VitD ≤ 30)	Deficient (25VitD ≤ 20)	Severely Deficient (25VitD ≤ 12)	No 25VitD level
Sex						
Female (n)	44	75	149	87	17	413
Male (n)	76	136	199	106	14	533
Total (N = 903) (%)	13.4	23.5	38.5	21.2	3.4	
BMI						
Mean (SD)	17.851 (2.891)	19.640 (4.142)	20.309 (4.801)	21.732 (5.893)	20.523 (5.260)	19.257 (6.181)
Age						
Mean (SD)	9.642 (3.823)	10.195 (3.864)	10.509 (3.606)	11.031 (3.584)	10.742 (4.227)	9.025 (4.106)
AIS						
1, 2 (nonsurgical) (n)	111	194	298	152	26	929
3 (surgical) (n)	9	16	48	39	5	14
Compliant						
Yes (n)	79	102	220	131	5	206
No (n)	31	85	98	45	20	428

Severely deficient is considered separately as a subset as deficient because management is different between these groups. Supplementation is more aggressive in those considered severely deficient versus deficient.

AIS indicates Abbreviated Injury Scale; BMI, body mass index; 25VitD, 25-vitamin D.

for bone mineralization and maintenance of bone quality. Bone mineralization is part of hard callus formation and bone remodeling, 2 important stages in the fracture healing process. Therefore, it is highly likely that vitamin D is vital to at least these 2 important stages of fracture healing.[5] Two clinical studies found vitamin D and calcium supplementation to positively affect the fracture site via increased bone mineral density or increased callus area.[5] Another study examining the effects of vitamin D supplementation on the rate of fracture reported a reduced risk of 26% for hip fractures and 23% for nonvertebral fractures.[6]

This study was designed to evaluate supplementation compliance in children with 25VitD deficiency being treated for a fracture. A recent study found that 1 in 3 children with a fracture can be 25VitD deficient.[4] Although the 25VitD level has been shown in at least one study to not directly result in increased rate of fractures, fracture severity is related to the degree of 25VitD deficiency.[3]

The objective was to identify compliance patterns in healthy children with fractures who were recommended to get a 25VitD level checked and counseled to start taking vitamin D supplementation with calcium. The clinical goal of supplementation counseling in this study was to maintain compliance at least during the period of fracture healing (~2 mo). Specifically, the questions asked were, is there (1) a difference in compliance between patients with a known 25VitD level versus patients who did not know their 25VitD level; (2) is there an association between supplementation compliance and age, BMI, and sex; and (3) is there an association between supplementation compliance and fracture severity or initial 25VitD level.

METHODS

This is an IRB-approved retrospective analysis of supplementation compliance in 1818 fracture patients (42% female) aged 2 to 18 years [mean (SD): 9.7 (4)] from a single physician community-based practice (Table 1). All fracture patients were included from August 2015 through February 2018. All fracture types in all patients with fractures were included. All patients were offered the same serum testing. Of the 1818 patients, 872 (48%) had a 25VitD level obtained within 3 weeks from presentation. Patients self-selected into groups (those with a 25VitD level and those who chose not to get testing). There was no blinding to these groups. Compliance duration was collected for those who took no supplement before presentation and started taking a supplement during fracture treatment (465 patients; 25.58% overall cohort percentage). Compliance patterns were addressed to see if fracture severity, 25VitD level, age, BMI, and sex-affected supplementation compliance. Patients were instructed to take vitamin D supplementation with calcium based on 25VitD levels following the senior author's (B.M.) supplementation protocol.[7] If the 25VitD level was found to be normal, no additional supplementation was suggested. However, there was always a bone health discussion with the patient and parent reviewing how supplementation needs change over time. Supplementation protocol recommendations were based on literature sources including "Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline" and "The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know."[8,9]

In this study, mode of supplementation and preferred supplementation was left open for the parent and patient to decide. Options included gummy/candy medications, drops or pills. At each office visit, compliance was assessed by asking patients about daily supplementation use and this information was documented (patients had a minimum 4-wk follow-up appointment).

Compliance was defined as "sustaining a pattern of compliance" meaning that patients started or were already

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taking and continued to take vitamin D supplements after initial encounter. Compliance was reported as parent's or patient's self-reported adherence to recommended supplementation protocol. We recognize that there is a spectrum to compliance. To be considered compliant was defined as taking vitamins a minimum of 4 days per week during the period of fracture treatment. Patients were encouraged to take daily supplementation even beyond the treatment period. Extended compliance was defined as continued compliance beyond the period of fracture healing documented in patient's chart when they returned for other reasons.

Repeat 25VitD level was requested 2 to 6 months after initial assessment. Fracture severity was categorized using the Abbreviated Injury Scale (AIS) which is a validated injury assessment scale.[10] All patients who required surgery after injury were identified as AIS 3. AIS 1 and AIS 2 injuries were grouped together while AIS 3 was identified separately. AIS severity was compared with 25VitD levels.

Two-sample t tests, χ^2 test of independence, univariate and binary logistic regression analyses were performed to identify associations between baseline 25VitD level and demographics including age, BMI, and sex. AIS fracture severity, and patient compliance. Descriptive statistics were calculated using mean (SD) and percent. The age and BMI of the patients was normally distributed and analyzed as such. Initial 25VitD levels were categorized into 5 groupings using the following cut-off values: >40, 30 to 40, 20 to 30, <20, <12 ng/mL; P-value of ≤ 0.05 was taken as significant.

RESULTS

Of 1818 patients, the compliance duration was an average of 2 months with a SD of 8.14 months in 465 patients (period of fracture care). From these patients, extended compliance was seen in 54 patients (12%) with an average duration of 14 months and a SD of 6.67 months.

The proportion of patients who had their 25VitD levels recorded and were compliant (61%) was higher than the proportion of patients who did not have their 25VitD levels recorded and were compliant (21.8%, $P < 0.001$) (Table 2).

TABLE 2. Compliance Patterns

N = 1818	25VitD Level Recorded [N = 872 (48%)] [n (%)]	25VitD Level Not Recorded [N = 946 (52%)] [n (%)]
Compliant	532 (61)	206 (21.8)
Noncompliant	259 (29.7)	428 (45.2)
Lost to follow-up	81 (9.3)	312 (33)

25VitD indicates 25-vitamin D.

In total, 872 patients had both a BMI and baseline 25VitD level recorded. BMI and 25VitD were negatively correlated ($r = -0.217$, $P < 0.001$). BMI was not associated with compliance. There was no statistical association between sex and compliance ($\chi^2 = 0.354$, $P = 0.552$). Age at time of fracture was found to be associated with patient compliance. For every 1-year increase in age, a patient was 9% more likely to be compliant (odds ratio: 1.09, 95% confidence interval: 1.0609-1.1198, deviance r^2 (adj) = 2%, $P < 0.001$). The mean age of compliant patients was 10.19 (3.77 y) years old, older than the age of noncompliant patients of 8.84 (4.07 y) years ($P < 0.001$).

Repeat 25VitD levels improved for both compliant and noncompliant patients, but less so for those who were noncompliant. For noncompliant patients, the mean improvement in 25VitD level was 15.11 units with a SD of 26.34 units. For compliant patients, the mean improvement in 25VitD level was 23.85 units with a SD of 30.21 units. The difference in 25VitD level improvement between compliant and noncompliant patients was not statistically significant, however the trend was in the right direction in that compliant patients saw greater improvement. Even in patients who were compliant, improvements in 25VitD levels were not always seen due to malabsorption and unknown factors that prevent improvement.

Patients with AIS 3 fractures were more compliant than those with AIS 1, 2 fractures (83% vs. 49%; $P < 0.001$). There was no statistically significant association between compliance and initial 25VitD level ($P = 0.138$).

DISCUSSION

Without appropriate 25VitD levels (>30 ng/mL) and calcium intake (700 to 1300 mg/d depending on age), peak bone mass cannot be optimized.[8,9] Over the long term, this could potentially increase future osteoporosis risk, especially for female patients. 25VitD level is a factor related to bone acquisition and peak bone mass, since this facilitates calcium absorption. 80% to 90% of peak bone mass is acquired by age 25.[11] The senior author has shown that lower 25VitD levels are associated with more severe (requiring surgery) fractures.[3] This suggests that if pediatric patients maintain a higher 25VitD level, they may be protected against more severe fractures. Those with a 25VitD level <12 ng/mL show a 55× increased risk of having a surgical fracture, those with a 25VitD level <20 ng/mL show a 6.7× increased risk, and those with a 25VitD level 20 to 30 ng/mL show a 2.8× increased risk.[3] This study found vitamin D supplementation compliance to be significantly related to obtaining a 25VitD level, fracture severity, and older patients in this pediatric population.

This study had limitations. In general, it is difficult to assess and improve compliance in the pediatric population. One of the limitations of this study is that compliance was self-reported by parents and children, so it is difficult to accurately quantify duration of compliance. Another limitation is that the study is from a single institution and a single clinician. However, all patients were counseled by the same clinician, ensuring consistency in recommendations. The findings are reasonable, useful, and applicable to other populations. This is a community-based study with 25VitD

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demographics similar to the findings reported in a 2009 NHANES study.[12]

Patients who had their 25VitD levels drawn, irrespective of the results, were more compliant than those without an initial evaluation of 25VitD who simply took a supplement based on the concept of improving bone health. It should be strongly acknowledged that no statistical significance was found to make the case that a lower laboratory finding led to better compliance. What this study found is that the act of having the level drawn may be sufficient to improve compliance. However, this finding is merely a correlation and may just represent the nature of rule followers versus rule breakers. This finding may also represent the possibility that those with the socioeconomic means to get a 25VitD laboratory finding, which may not be affordable or covered by insurance for all, are the same people who will have the socioeconomic means for the supplements. In the literature, the charge for a 25VitD blood test is $507.[7] In our institution, the cost of the laboratory test is $12; thus, the findings of this study would seem to support that it is reasonable to request a 25VitD evaluation. Despite pushback from insurance companies with regard to cost, having a 25VitD level obtained appears to improve supplementation compliance following a fracture.

Compliance was found to improve with patient age indicating that it may be valuable to empower older patients to take responsibility for themselves. This is interesting since one might assume that parental control of younger patients might make them more responsible. There was no statistical association between initial 25VitD level, sex, or BMI with compliance.

Patients with surgical (AIS 3) fractures were found to be more compliant than patients with less severe (AIS 1, 2) fractures. Perhaps the gravity of undergoing surgery reinforces the importance of bone health. It is also possible that increased contact between surgeon and patients, due to the severity of fractures of those undergoing surgery, may have positively affected supplementation compliance. In this study, there is no association between supplementation compliance and initial 25VitD level; however, it is interesting to examine compliance in another treatment scenario.

An interview-based study questioned 1015 adult women who filled a bisphosphonate prescription to determine motives for noncompliance.[13] Compliance was binary and described as $\geq$140 days of usage over a 7-month prescription period. McHorney and colleagues hypothesized that potential side effects would be the primary obstacle to medical compliance. The main differences between the compliant and noncompliant groups were that adherers were more likely to report a diagnosis of osteoporosis, rather than osteopenia (a "preosteoporosis" state) or normal bone mineral density (70% vs. 61%) and that adherers were more likely to report noticeable height loss (58% vs. 45%).[13] Both a formal diagnosis and noticeable height loss make osteoporosis more striking. The results from this study suggest that the female participants were more likely to comply with their bisphosphonate regimen when the disease became more salient. With this in mind while examining compliance incentives, it is reasonable to suggest that there may be a relationship between baseline 25VitD levels and compliance if patients can recognize 25VitD results as a measure of bone health and potential fracture risk. A more severe deficiency, a more severe and salient condition (surgical fracture), could trigger better patient compliance.

Future studies should address obstacles to compliance. Recent studies illustrate why maximizing supplementation compliance should be a priority for orthopaedists. According to recent literature, 85% of slipped capital femoral epiphysis patients were 25VitD deficient with a 25VitD level <21 ng/mL. Patients healed faster the higher the 25VitD level.[14] In total, 78% of patients with stage 3 and 4 osteochondritis dissecans lesions were found to be 25VitD deficient (< 20 ng/mL). It was concluded that vitamin D supplementation could prevent development of advanced osteochondritis dissecans stages.[15] Another study sought to assess the effects of vitamin D supplementation on curve progression in adolescent idiopathic scoliosis. Results showed that only 16% of curves progressed with high-dose supplementation, compared with 48% in placebo.[16]

It is imperative to develop strategies for improving compliance to supplementation, both for vitamin D and calcium, in order to maximize peak bone mass and then maintain optimal bone health over time. The senior author recommends universal screening for all fracture patients because without serum levels appropriate supplementation cannot be definitively advised. Although there may be discomfort associated with a blood draw, the benefit of scientifically addressing an individual's bone health as part of fracture care outweighs the potential discomfort. In those who choose not to have serum levels checked, recommendations are given based on weight. However, weight-based dosing does not appropriately supplement those who are deficient and require high doses of supplementation. Engaging pediatricians to screen all children and counsel with regard to supplementation would reinforce and improve compliance.

Future studies should also include a longer follow-up period. The goal of supplementation counseling in this study was to maintain compliance during the period of fracture healing. The hope is that patients continue to be compliant beyond the last recorded follow-up visit, as the importance of bone health was impressed upon them during office visits. A 25VitD level is recommended for fracture patients to improve supplementation compliance and provide guidelines for appropriate supplementation. 25VitD levels will normalize within 8 weeks of appropriate supplementation.[8] The goal of this paper was to follow patients and assess compliance during fracture treatment. However, we do not recommend stopping supplementation after serum levels have improved and/or fracture care is complete. Routine supplementation will help establish positive long-term behaviors that are important to prevent future fractures, maximize peak bone mass, and maintain bone health.

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