Vitamin D Supplementation Protocol in Elective Arthrodesis of the Foot: A Retrospective Review of Outcome in Consecutive Cases

Troy J. Boffeli DPM, FACFAS, Catlea M. Gorman, DPM
Regions Hospital / HealthPartners Institute for Education and Research - Saint Paul, MN

Regions Hospital®
Foot & Ankle Surgical Residency Program
HealthPartners®

STATEMENT OF PURPOSE

Vitamin D plays a crucial role in maintaining bone health with potential impact on healing after osteotomy, arthrodesis and fracture. However, there is minimal literature regarding the impact of deficiency or supplementation in patients undergoing elective foot and ankle surgery. Consensus is lacking regarding optimal bone health assessment and management of low vitamin D in the perioperative setting. The patient population at our center in St. Paul, MN is at high risk for vitamin D deficiency because of its northern latitude (44.9°N). This retrospective review demonstrates surgical outcomes in consecutive patients undergoing elective foot arthrodesis with a standardized perioperative protocol for sub-optimal vitamin D levels.

LITERATURE REVIEW

Vitamin D is essential in bone health maintenance and plays a vital role in in the absorption of dietary calcium and phosphorous to maintain bone mineral density. Both in vivo and in vitro studies have shown that at the cellular level it is involved with every stage of fracture healing, however the exact cellular role in human fracture healing is unclear [1]. Gorter et al. also concluded in a systematic review that studies looking at the clinical effects of vitamin D deficiency and supplementation on fracture healing are limited. There has been much support to show that adequate vitamin D levels reduce the incidence of fragility fractures in osteoporotic patients. There has also been an association between vitamin D deficiency and delayed union or non-union of fractures [1-2].

There are certain factors that put an individual at higher risk of developing vitamin D deficiency as well as non-union; these include obesity, liver disease, kidney disease, malnourishment, smoking and advanced age. Living in northern latitude climates and darker pigmented skin are also risk factors, since vitamin D can be synthesized in the skin when exposed to sunlight. Living in a climate above 30 or 35 degrees northern latitude from the November to February months has been shown to produce little to no vitamin D3 [3-4]. Furthermore, the ability to synthesize vitamin D decreases with age [5].

The measurement of 25(OH)D is the lab value that is recommended to measure a person's vitamin D level. Comparison of 25(OH)D values between health centers can be difficult due to variability seen amongst laboratories [6]. There is also inconsistency regarding what is considered suboptimal levels of vitamin D, however most are in agreement that a vitamin D level less than 30-32 ng/mL is considered low [6]. The Endocrine Society categorizes vitamin D status into sufficient, insufficient, and deficient levels. Sufficient levels are 30-80 ng/ml; insufficient levels are 21-29 ng/ml; and deficient levels are <20 ng/ml. Treatment recommendations utilizing supplementation with vitamin D2 or D3 are based on individual vitamin D status. Currently vitamin D screening is reserved for high risk individuals and is not routinely performed for the general population. Childs et al demonstrated the cost-effectiveness of vitamin D supplementation in fracture care when comparing to the cost of treatment of a non-union.

It is estimated that over a billion people worldwide are deficient in vitamin D [3]. Despite how common vitamin D deficiency is, there is no consensus regarding vitamin D testing and supplementation, especially in the perioperative setting. Current recommendations for treatment of vitamin D deficient patients include 50,000 IU D2 weekly for 8-12 weeks followed by or in addition to a maintenance therapy of 1000-2000 IU daily with another 8-12 week course if repeat 25(OH)D is less <30 ng/ml [3,7]. Regardless of prescription therapy, a maintenance dose of 800-2,000 IU daily is indicated to avoid recurrent deficiency, with an average maintenance dose of 2,000 IU daily shown to be below the safe upper limit of daily dosing. Vitamin D toxicity from supplementation alone is extremely rare [7]. Daily maintenance doses from 1,000-4,000 IU have been described, and while there is variability among individuals, it has been shown that 1,000 IU vitamin D3 daily can increase circulating 25(OH)D by 10ng/mL [6]. There is disagreement in the literature regarding the effectiveness of vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol) with some data describing vitamin D3 as having a greater affinity for circulating vitamin D binding protein and therefore making it more effective. Unfortunately, high dose prescription strength vitamin D is only available in vitamin D2 [6].

The foot and ankle literature regarding the role of vitamin D and bone healing is scarce and is focused primarily on fracture healing. Bogunovic et al. performed a retrospective review of 723 orthopedic patients scheduled for surgery and reported that 43% were vitamin D insufficient, of which 40% had deficient levels. Of the 192 foot and ankle patients, 34% had inadequate vitamin D levels, of which 32% were vitamin D deficient. Brinker et al. reported 25/37 (68%) patients who developed non-union had a previously undiagnosed vitamin D deficiency. Smith et al. assessed the prevalence of vitamin D deficiency in 75 patients with low energy fractures of the foot or ankle, of which 47% of the patients in the study had insufficient vitamin D and 13% had deficiency in vitamin D. Vitamin D levels were noted to be significantly lower in the fracture patients compared to the non-fracture cohort. They also reported that smoking, obesity, and other high risk medical conditions for hypovitaminosis were significantly associated with vitamin D insufficiency.

To our knowledge, the only study regarding vitamin D and arthrodesis in the foot is by Michelson et al. in 2015. They assessed vitamin D levels in 81 patients undergoing elective midfoot, hindfoot or ankle arthrodesis in a location with latitude of 44.5°N. Preoperative vitamin D levels were obtained and surgery was not delayed for low vitamin D levels. 66.7% of the patients had vitamin D levels less than 30 ng/mL (insufficient) with 27% of the patients having a vitamin D level less than 20 ng/mL (deficient). Patients with vitamin D levels less than 30 ng/mL were treated with prescription dose vitamin D2 in addition to a daily maintenance dose of D3. They reported an overall fusion rate of 85%.

METHODOLOGY

A level 4 retrospective review of consecutive patients was performed from March – October 2017. Consecutive cases were identified through Current Procedural Terminology (CPT) codes for 1st metatarsophalangeal joint (MPJ) fusion, Lapidus fusion, and subtalar joint (STJ) fusion. All procedures were performed by one surgeon (TJB). A preoperative 25(OH)D level is routinely ordered for arthrodesis surgery. Surgery was not delayed if vitamin D was insufficient or deficient. Inclusion criteria consisted of adult patients (≥ 18 years old) who underwent primary elective 1st MPJ, Lapidus, and/or STJ fusion, a 25(OH)D level drawn within 6 months of surgery, 6 week postoperative radiographs for 1st MPJ fusions and 10 week postoperative radiographs for STJ and Lapidus fusion available in EMR, and completion of bone health questionnaire **(Figure 1)**. Exclusion criteria consisted of patients who underwent primary arthrodesis for trauma or charcot arthropathy, patients under the age of 18, a 25(OH)D level drawn greater than 6 months prior to surgery, and patients who did not complete a bone health questionnaire. 33 patients were identified by CPT code who met inclusion criteria. Patients with sufficient vitamin D level (30-80 ng/ml) were not treated. Those with insufficiency (20-29 ng/ml) were treated with 2,000 IU vitamin D3 daily. Those with vitamin D deficiency (< 20 ng/ml) were treated with prescription dose 50,000 IU vitamin D2 weekly for 12 weeks, in addition to 2,000 IU vitamin D3 daily. If delayed union was noted in a vitamin D deficient patient by 10 weeks postop, a repeat 25(OH)D lab was drawn and if the level remained deficient the patient would undergo another 12 week course of 50,000 IU vitamin D2 weekly in addition to the 2,000 IU vitamin D3 daily **(Table 1)**. If the repeat lab was in the insufficient range, the patient would continue with daily 2,000 IU vitamin D3. Age, union rates, and comorbidities were also assessed in those 33 patients **(Figure 1)**.

Figure 1. Bone Health Assessment Involved Preoperative Patient Questionnaire and Chart Review

Patient Questionnaire:

1. Have you ever been diagnosed with:
   - Osteoporosis/Osteopenia Yes No
   - Vitamin D Deficiency Yes No
   - Celiac Disease Yes No
   - Thyroid Disease Yes No
   - Parathyroid Disease Yes No
   - Kidney Disease Yes No
   - Liver Disease Yes No
2. Have you ever had your Vitamin D level checked? Yes No If yes, what were the results?
3. Have you ever had a DEXA scan? Yes No If yes, what were the results?
4. Do you currently take:
   - Daily Multivitamin? Yes No
   - Calcium supplements? Yes No
   - Vitamin D supplements? Yes No
   - Steroid medication? Yes No
   - Anti-seizure medication? Yes No
5. Race (Please Circle One):

American Indian or Alaskan Native
Black or African American
White
Native Hawaiian or Pacific Islander
Asian
Other

6. If you are a woman, are you post-menopausal? Yes No

Chart Review

- Gender
- Age
- Ethnicity/Race
- Past 25(OH)D labs
- Current medications
- Past medical history significant for vitamin D deficiency risk factors

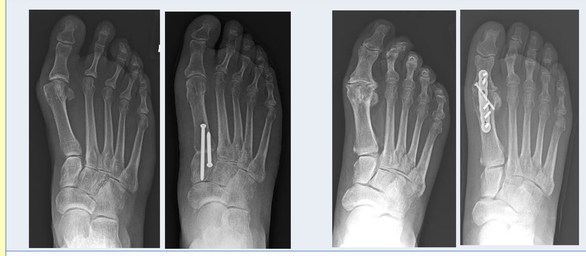
Table 1. Vitamin D Supplementation Protocol with Patient Distribution

Vitamin D Status	Serum 25(OH)D Value	Treatment Protocol	Patients (N = 33)
Sufficient	>30 ng/ml	Not Treated	18
Insufficient	20-29 ng/ml	2000 IU vitamin D3 daily	10
Deficient	<20 ng/ml	50,000 IU vitamin D2 weekly x 12 weeks plus 2000 IU vitamin D3 daily	5

PROCEDURES

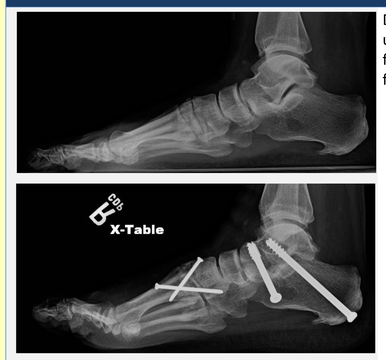
Patients undergoing subtalar, 1st MPJ, and Lapidus arthrodesis were tested preoperatively and concomitantly treated for low vitamin D without delay in surgical treatment. Joint prep for each cohort group was performed using the same technique, involving removal of articular cartilage using a flexible osteotome, followed by curettage. The subchondral plates were thinned and contoured with a rotary burr to expose bleeding bone. The joint surfaces were then fenestrated with a 2.0 drill to draw autograft into the fusion site and promote healing. See **Figure 2 and 3** for our standard fixation constructs for 1st MPJ, Lapidus, and STJ arthrodesis. Postoperatively, patients undergoing 1st MPJ fusion were allowed to stand and transfer in a below knee fracture boot while those undergoing Lapidus and STJ fusion were made non-weight bearing for 6 weeks followed by progressive weight bearing in a removable cast boot for 4 weeks.

Figure 2. Fixation Constructs for Lapidus and 1st MPJ Fusion



Lapidus fusion cases involved crossing solid screw fixation. Combined compression screw and locked plate fixation was used in 1st MPJ fusion cases.

Figure 3. Fixation Construct for Subtalar Joint Fusion



Divergent screw fixation was used in cases involving STJ fusion. Lateral view of Lapidus fusion fixation is also shown.

RESULTS

There were 33 patients (39 fusions) including eight males and 25 females. 17/25 females were post-menopausal. Average age was 58.2 years (range 19-79). There were six STJ fusions, nine 1st MPJ fusions, and 23 Lapidus fusions. 18/33 (55%) patients had sufficient vitamin D levels. 15/18 (83%) of those with sufficient vitamin D had associated risk factors for vitamin D deficiency. 15/33 (44%) patients had a 25(OH)D level < 30 ng/ml with 10/15 (67%) categorized as vitamin D insufficient. 5/33 (15%) patients had vitamin D deficiency. All of the patients with vitamin D deficiency had risk factors for inadequate vitamin D levels and all of them underwent 12 weeks of prescription strength vitamin D2 in addition to daily vitamin D3. None of them required a second course of treatment. 10/33 (30.3%) patients had vitamin D insufficiency and were treated with daily vitamin D2 maintenance dose based on our protocol. 8/10 (80%) patients who were vitamin D insufficient had risk factors associated with inadequate vitamin D levels. 12/33 (36%) patients had been previously diagnosed with either vitamin D deficiency (6/12) or insufficiency (6/12). 4/15 (27%) patients who had a 25(OH)D level < 30 ng/ml had been previously diagnosed with vitamin D insufficiency or deficiency. 4/33 patients had a prior diagnosis of osteopenia confirmed by DEXA scan and 3/33 patients had a prior diagnosis of osteoporosis confirmed by DEXA scan. 10/33 (30.3%) patients confirmed taking calcium supplementation prior to their preoperative appointment. Calcium supplement dose varied from 200-1,000 mg daily. 18/33 (55%) patients confirmed taking vitamin D supplementation prior to their preoperative appointment with daily supplementation ranging from 400-4,000 IU daily. The average BMI for patients was 29.85 (range 21.47-43.07). 14/33 qualified as obese (BMI ≥ 30), 8/33 were overweight (BMI 24-29.9), and 11/33 were in the range of healthy weight (18.5-24.9). 7/15 (47%) patients who either were deficient or insufficient in vitamin D had a BMI ≥ 30 (obese). 4/33 patients described themselves as current smokers with 2/4 found to be vitamin D insufficient and the other 2/4 vitamin D deficient. One patient had undergone multiple joint medial column fusion that required revision surgery at the talonavicular fusion site secondary to non-compliance with non-weight bearing instructions. This patient had a 25(OH)D of 26 ng/ml and had been on 2,000 IU vitamin D3. The 25(OH)D was repeated and was 50 ng/ml. She was continued on the 2,000 IU vitamin D3 based on our protocol and went on to heal her revision fusion. 38/39 (97%) fusions were successful and did not require revision surgery.

Prevalence of Vitamin D Deficiency Risk Factors (N = 33 patients)	
Post-menopausal	17
Obesity	14
Smoking	4
Dark skin pigmentation	5
History of osteoporosis	3
History of osteopenia	4
History of vitamin D deficiency	6
Hypothyroidism	4
Liver disease	1
Ulcerative colitis	2

ANALYSIS & DISCUSSION

Multiple studies have advocated for monitoring of 25(OH)D and supplementation in the setting of fracture healing and in prevention of fragility fractures in at risk populations [5,6,9,-11], however only one study has demonstrated the role of vitamin D in the setting of elective foot and ankle arthrodesis. That study reported 66.7% of the patients to have hypovitaminosis D and an overall fusion rate of 85%. The author's concluded that routine testing and supplementation should be considered preoperatively for all surgical patients [10].

Our study had 44% of patients with hypovitaminosis D, of which 15% qualified as deficient in vitamin D. These results are similar to those reported by Bogunovic et al. That same study found that obese patients who underwent surgery for foot or ankle injuries were 4 times more likely to have inadequate vitamin D levels. Vitamin D is a fat soluble vitamin stored in the body's fat and patients with a BMI > 30 kg/m2 are at higher risk of deficiency as the body fat tends to sequester the vitamin D. It has also been reported that obese patients who receive oral 50,000 IU vitamin D2 are only able to raise circulating vitamin D levels by half of what is normally seen in a non-obese individual [3]. 47% of patients in our study who were either deficient or insufficient in vitamin D were obese.

Our study consisted entirely of an elective patient population as opposed to studies that focused on patients who had sustained fractures who seemingly could have been at higher risk for sub-optimal vitamin D levels. However, we found that a high percentage of our elective surgery patients had risk factors for hypovitaminosis D but only 44% actually had inadequate levels, highlighting the importance of testing. We also found that only 4/15 patients who had a 25(OH)D level < 30 ng/ml had been previously diagnosed with vitamin D insufficiency or deficiency, meaning that 73% of these patients had a new diagnosis of vitamin D insufficiency or deficiency. If we had selectively treated patients who had risk factors based on bone health questionnaire alone, we would have potentially over or under treated certain patients.

Limitations of this study include the relatively small number of patients in the study, although all were consecutive which decreases exclusion bias. Also, all procedures were performed by a single surgeon, which could also be seen as a benefit, as this removes the inter-surgeon variability with patient selection and procedure technique. Another limitation was having a disproportionately large number of white patients (28/33), which could have led to the prevalence of hypovitaminosis D among darker skin-toned patients to possibly be underreported. Although we did find that 4/5 patients with darker pigmented skin had hypovitaminosis D. Overall, one of the goals of this study was to bring raise awareness among foot and ankle surgeons and demonstrate our protocol regarding vitamin D testing and supplementation. Utilization of a standardized preoperative bone health assessment is intended to avoid identification of low vitamin D levels after poor healing has been identified. Our supplementation protocol allows elective arthrodesis patients to be concomitantly treated for low vitamin D while healing from surgery rather than waiting for levels to normalize. This review did not identify a compromised union rate which supports the effectiveness of this protocol.

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