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Original Research Article

Surgical outcome of adolescent idiopathic scoliosis who are Vitamin D deficient

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Abstract

Introduction: Patients with adolescent idiopathic scoliosis (AIS) have a higher prevalence of Vitamin D deficiency compared with healthy peers.
Hypothesis: Vitamin D deficiency in AIS patients do not have good functional outcome after posterior instrumented corrective spinal fusion.
Materials and Methods: A prospective consecutive study of sixty-two (62) children who underwent surgery for AIS had preoperative measurement of Vitamin D levels (ng/mL). All were followed-up for a mean duration of 2 years after surgery. Data was collected for back pain, socioeconomic status, curve magnitude, age and gender. Patients were categorized based on vitamin D level: deficient (<20 ng/mL), insufficient (20 to 29 ng/mL), or sufficient (≥30 ng/mL). The correlation between vitamin D levels and Scoliosis Research Society (SRS) -22 scores was analyzed using multivariate analysis and pair-wise comparisons using Tukey method.
Results: Sixty-two (62) AIS patients (47F: 15M) were studied who underwent posterior instrumented spine fusion. Mean age at time of surgery was 15.24 ± 4.5 years. Major coronal curves had a mean of 68.08 ±12 degrees preoperatively and 12.19 ± 4.2 degrees postoperatively. In this study, 35 (56.45 %) of patients were vitamin D deficient, 23 (37.09 %) were insufficient, and 4 (6.45 %) were sufficient. Although there was no correlation between Vitamin D level and Pain, Mental Health, or Satisfaction domains (p >0.05), Vitamin D-deficient patients were found to be younger than 18 years of age (p <0.001) and had lower SRS-22 function (p =0.010), Self-image (p =0.049), and total scores (p =0.007).
Conclusion: AIS patients with Vitamin D deficiency (<20 ng/mL) are more likely to be younger age at time of surgery, and report lower function, self-image, and total SRS-22 scores postoperatively.

Keywords: Adolescent Idiopathic Scoliosis, Posterior lumbar fusion, Vitamin D Deficiency

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1. Introduction

Adolescent idiopathic scoliosis (AIS) is a complex tri-dimensional deformity, characterized by rotation of the vertebrae and lateral deviation of the spine. Untreated scoliotic curves can progress and cause significant deformities, back pain, cardio-pulmonary limitations, and psychosocial disturbances, such as low self-esteem. Vitamin D plays an important role in maintaining a healthy mineralized skeleton.[1] Hypovitaminosis D adversely affects calcium metabolism, osteoblastic activity, matrix ossification, bone remodeling, and bone density. Vitamin D deficiency and osteopenia were prevalent among AIS patients[2] and were positively correlated with the Cobb angle. It was reported that vitamin D levels were lower in patients with AIS.[2] Another study of AIS patients in Hong Kong found that calcium and Vitamin D supplementation reduced progression of major curve angle.[3] The aim of our study was to determine the functional outcome after corrective spinal fusion in AIS patients with Vitamin D deficiency.

2. Materials and Methods

This prospective cohort study was done in a single tertiary care center with dedicated pediatric spinal unit. Data were collected on all consecutive patients who had idiopathic scoliosis on preoperative MRI, undergoing corrective surgery for AIS from January 2017 to August 2024. Any patients with

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pathological and congenital scoliosis as evidenced by pre-operative MRI were excluded.

Baseline data on age, gender, history of back pain and socioeconomic status as per Modified Kuppuswamy[4] classification was collected. Type of scoliosis was noted based on Lenke classification[5] system. Preoperative measurement of Vitamin D levels (serum 25-hydroxyvitamin D in ng/mL) of all the patients was done who underwent surgical correction. Patients were categorized based on vitamin D level: deficient (<20 ng/mL), insufficient (20 to 29 ng/mL), or sufficient (≥30 ng/mL).[6] Preoperative and postoperative follow-up Cobb angles were measured and changes in the angle were recorded. SRS-22 questionnaire[7] comprising of five domains: function, pain, self-image, mental health and satisfaction with management were recorded pre and postoperatively. All 22 items and each domain (activity, pain, self-image, mental health, and satisfaction) are scored on a 1–5 scale, with higher scores indicating a better outcome.

AIS was managed surgically by posterior instrumented spine fusion and patients were followed up postoperatively for a mean duration of 2 years. The collected data was entered into an Excel spreadsheet and subsequently analyzed using SPSS (ver 23) statistical software. Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as mean ± SD or median (inter-quartile range). To compare proportions between two groups, the correlation between vitamin D levels and SRS-22 scores was analyzed using multivariate analysis and pair-wise comparisons using Tukey's method, depending on the distribution pattern of the observations for different variables. A p-value of <0.05 was considered statistically significant.

3. Results

A total of 62 patients were enrolled who underwent posterior instrumented spine fusion. 75.8% of the cohort was female and the average age at the time of surgery was 15.24 ± 4.5 years (range 9 –30). 5 out of 62 cases complained of back pain at presentation with no significant association with Vitamin D levels.

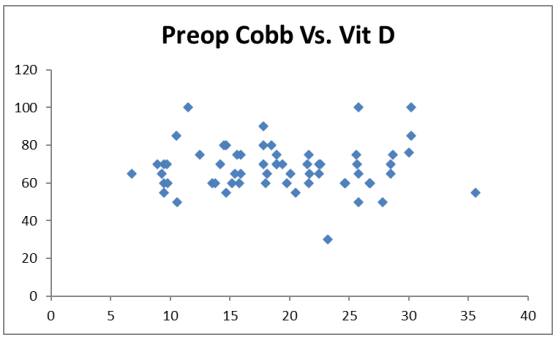

Figure 1: Scatter plot showing correlation between Vitamin D level and major curve at first presentation [r= 0.021, P= 0.649]

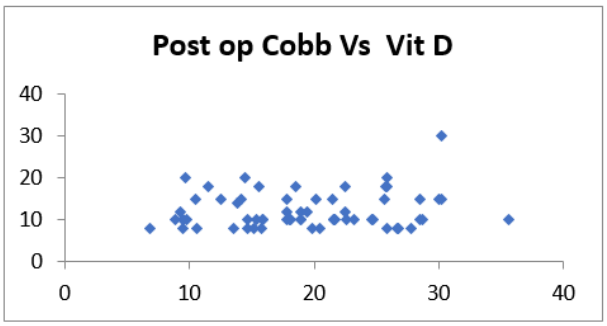

Figure 2: Scatter plot showing significant improvement in Cobb angle after surgical fusion

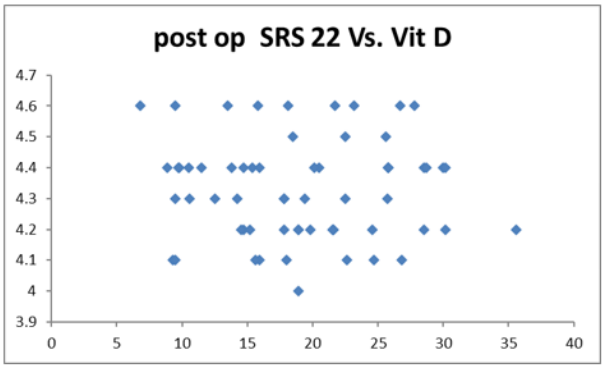

Figure 3: Correlation between post op total SRS22 scores and Vitamin D levels

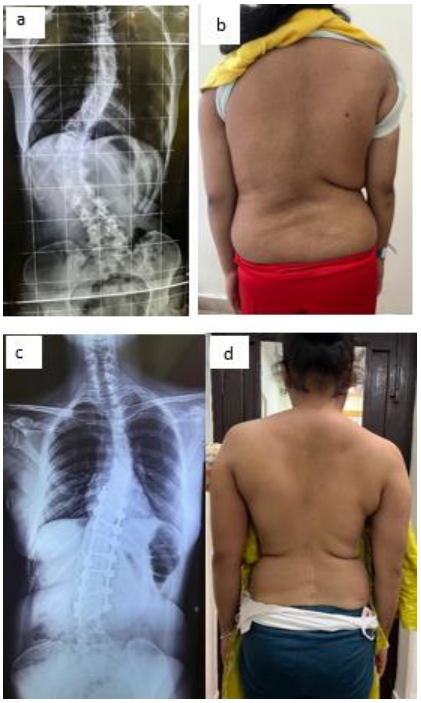

Figure 4: a: Preoperative X-ray AP view showing the Left Thoracolumbar Scoliosis (Cobb 70°); **b:** Preoperative Clinical photo showing the curvature; **c:** 2 year post op X-ray AP view showing corrected Thoracolumbar spinal curvature; **d:** 2 year post op clinical photo showing well corrected spine.

At the preoperative appointment, 35 (56.45%) of patients were vitamin D deficient, 23 (37.09%) were insufficient, and 4 (6.45%) were sufficient, with mean age of 13.34 ± 4.59, 15.3 ± 4.58 and 16.17 ± 5.72 years respectively [**Table 1**]. All Vitamin D deficient patients were found to be less than 18 years of age. The level of Vitamin D in the group of patients was, on average, 19.194 ng/mL ± 6.696. The mean 25-hydroxyvitamin D levels were 14.32 ± 6.73 nmol/L for the deficient group, 19.32 ± 6.74 nmol/L for the insufficient group, and 20.17 ± 7.34 nmol/L for the sufficient group. The preoperative assessment also showed that the average major coronal curve (Cobb angle) was 68.08 ± 12.69 degrees (Range 30- 100, SD 12.69). However, there was weak correlation between the severity of Vitamin D deficiency and the preoperative standing Cobb angle [**Figure 1**], suggesting that Vitamin D levels did not directly influence the magnitude of spinal curvature before surgery [**Table 1**]. Analysis of the Vitamin D level in correlation with sex showed a predominantly lower level for the male group (on average, 17.32 ng/mL) compared to the female group (on average, 19.79 ng/mL) being statistically significant (p = 0.034), [**Table 2**]. Additionally, preoperative SRS scores across various domains such as function, pain, self-image, mental health, and satisfaction did not differ across Vitamin D groups, implying that patients' quality of life was not significantly impacted by their Vitamin D status before surgery [**Table 3**].

Post-operatively, the improvement in the major curve was significant, with an average reduction to 12.19 ± 4.2 degrees and a p-value of 0.021, indicating the success of the surgical intervention [**Figure 2**]. We found vitamin D deficiency to negatively impact post-operative outcomes in specific SRS-22 domains [**Table 4**]. No statistically significant correlations were found between vitamin D levels and post-operative SRS-22 scores in mental health, pain, and satisfaction, indicating that these aspects were not influenced by vitamin D status. As noted in the post-operative follow- up visit, Vitamin D deficient group had significantly lower scores in function (p = 0.010), self-image (p = 0.049), and total scores (p = 0.007) [**Table 5**], suggesting that lower vitamin D levels may be associated with poorer post-surgical recovery in these areas. The scatter plot reflects the same although in a non-uniform distribution (**Figure 3**). Preoperative Vitamin D deficiency did not effect the post-operative outcome in AIS patients as suggested by SRS 22 scores [**Figure 4**a-d].

Figure 4 a-d A 16 years old female with Thoracolumbar left sides scoliosis (AIS) with a Cobb angle of 70°. She had preoperative Vitamin D level as 16.9pg/ml. Preoperative SRS 22 score was 3.9 and the two year post-operative SRS 22 scores was 4.2.

Table 1: Vitamin D deficiency levels by number of patients, age, mean Vitamin D level, mean SRS-22 pain score, and mean Cobb angle.

25-Hydroxyvitamin D Level (nmol/L)	No. of Patients (%)	Age in years	Mean (SD) 25-Hydroxyvitamin D Level (nmol/L)	Mean SRS-22 Pain Score Domain (1–5) pre op	Mean Cobb Angle pre op
Deficient (<20 ng/mL)	35 (56.45%)	13.34 ± 4.59	14.32 (6.73)	4.16 (0.02)	69.14° (11.62)
Insufficient (20 to 29 ng/mL)	23 (37.10%)	15.3 ± 4.58	19.32 (6.74)	4.13 (0.29)	68.17° (12.39)
Sufficient (≥30 ng/mL)	4 (6.45%)	16.17 ± 5.72	20.17 (7.34)	4.08 (0.30)	67.08° (10.62)

Table 2: Comparison between the Vitamin D level and the patient's gender.

25-Hydroxyvitamin D Level	Female	Male
Total	47	15
Average	19.79	17.32
SD	6.96	6.73
Median	18.9	17.4
Min	6.8	9.5
Max	35.6	24.6
*P-Value (P)**	0.034	
95% CI	(15.24 - 21.37)	(14.95 - 20.09)

Table 3: Preoperative SRS 22 scores

SRS 22 Parameters	SRS 22 scores with different Vitamin D groups				p value
	Overall	Deficient	Insufficient	Sufficient	
SRS 22 Total Score	3.87 ± 0.18	3.86 ± 0.31	3.86 ± 0.23	3.9 ± 0.33	0.410
SRS 22 Self image	3.13 ± 0.39	3.09 ± 0.09	3.16 ± 0.37	2.93 ± 0.20	0.07
SRS 22 Function	4.24 ± 0.35	4.24 ± 0.42	4.23 ± 0.56	4.16 ± 0.13	0.811

SRS 22 Mental	3.95 ± 0.37	3.99 ± 0.33	3.90 ± 0.33	4.07 ± 0.18	0.06
SRS 22 Pain	4.12 ± 0.30	4.16 ± 0.02	4.13 ± 0.29	4.08 ± 0.30	0.20
SRS 22 Satisfaction	4.31 ± 0.89	4.37 ± 0.07	4.36 ± 0.21	4.27 ± 0.29	0.31

Table 4: Correlation between Vitamin D levels and postoperative SRS22 scores

Domains of SRS22 scores	SRS 22 scores with different Vitamin D groups				p value
	Overall	Deficient	Insufficient	Sufficient	
SRS 22 Total Score	4.31 ± 0.16	4.13 ± 0.33	4.33 ± 0.33	4.3 ± 0.16	0.025
SRS 22 Self image	4.04 ± 0.38	3.97 ± 0.01	4.09 ± 0.02	4.06 ± 0.28	0.015
SRS 22 Function	4.34 ± 0.37	4.29 ± 0.41	4.33 ± 0.83	4.20 ± 0.31	0.0328
SRS 22 Mental	4.71 ± 0.99	4.63 ± 0.23	4.75 ± 0.02	4.69 ± 0.39	0.741
SRS 22 Pain	4.14 ± 0.33	4.17 ± 0.38	4.16 ± 0.40	4.05 ± 0.22	0.12
SRS 22 Satisfaction	4.75 ± 0.72	4.74 ± 0.31	4.78 ± 0.09	5.36 ± 0.04	0.06

Table 5: Comparison of pre and post op mean total SRS-22 scores of Vitamin D deficient patients.

Parameter	Pre op mean total SRS 22 score	Post op mean total SRS 22 score	p value
SRS 22 Total Score	3.86 ± 0.31	4.13 ± 0.33	0.007
SRS 22 Self image	3.09 ± 0.09	3.97 ± 0.01	0.049
SRS 22 Function	4.24 ± 0.42	4.29 ± 0.41	0.010
SRS 22 Mental	3.99 ± 0.33	4.63 ± 0.23	0.719
SRS 22 Pain	4.16 ± 0.02	4.17 ± 0.38	0.182
SRS 22 Satisfaction	4.37 ± 0.07	4.74 ± 0.31	0.063

4. Discussion

AIS is a multifactorial disease influenced by genetic factors, hormones, neuromuscular diseases, environmental and lifestyle factors.[8] It affects 0.47–11.1 % of the general population.[9] Vitamin D acts as a hormone with multiple functions in the human body. After being synthesized in the skin or ingested in the form of animal or plant products, it is metabolized in the liver and kidneys. The end product of this pathway performs vital roles in maintaining the structure and function of the musculoskeletal tissues. Recent genome-wide association studies (GWAS) revealed a novel locus named wingless-related integration site 16 (WNT16) in the WNT signaling pathway, acts as a key biological pathway that regulates bone homeostasis and serum 25-(OH) Vitamin-D levels.[10,11] Recent evidence suggests a material impact of Vitamin D on bone mineral density and on the development of deformities, such as AIS.[12] It correlates positively with hip bone mineral density (BMD) and negatively with Cobb angle, thereby plays a fundamental role in the process of postural balance. Lowered vertebral BMD is associated with a higher Cobb angle and increased risk for curve progression.[13-15] Its role in pathogenesis of AIS is an active area of interest with a growing amount of research.

Scoliosis severity is quantified using the Cobb angle and is classified as mild (≤ 20°), moderate (21° to 40°), severe (41 to 55°) or very severe (≥56°). Approximately 10% of scoliosis patients have progressive curves and 0.1 to 0.3% of them require surgical treatment.[16-18] We found a weak negative correlation [r=0.021, P= 0.649] between Vitamin D level and major curve at first presentation [**Figure 1**]. A study on patients of AIS showed that the Cobb angle was negatively correlated with 25-OH-D level (r = - 0.147, p=0.026). Though statistically significant, it showed weak relationships between variables.[19] Vitamin D deficiency has been described as having adverse effects on the general well-being of an individual.[20]

We hypothesized that Vitamin D deficiency in AIS patients do not have good functional outcome after spinal fusion. Our study with the cohort of 62 patients of AIS showed a high prevalence of Vitamin D deficiency (56.45%). This was consistent with previous research showing a prevalence of 81% (52% insufficient and 29% deficient) in AIS patients prior to spine fusion surgery.[21] One recent study from UK suggested that 53.7% patients had mild deficiency 20.4% patients had severe deficiency.[22]

Previous studies conferred the relationship between Vitamin D and average household income could be due to dietary habits,[23] sunlight exposure[24] and darker skin pigmentation[25] which was found in our study as well. The socioeconomic analysis of this study highlights the link between Vitamin D deficiency and factors influenced by socioeconomic status (SES) in AIS patients. Lower-income families often have poor dietary habits, reduced sunlight exposure, and limited health-care access, all contributing to Vitamin D deficiency. Darker skin pigmentation, more common in lower SES groups, further exacerbates this issue. These deficiencies negatively impact functional outcomes after spinal fusion surgery in AIS patients. Addressing these

disparities through improved nutrition, health-care access, and public health initiatives could enhance post-surgical recovery and overall outcomes for socioeconomically disadvantaged patients. Furthermore, levels of Vitamin D binding protein, which accounts for total Vitamin D, shows variation in different ethnicities and varies with the nutrition status of the child, rendering free Vitamin D level a more reliable factor.

Our study found a statistically significant correlation between Vitamin D deficiency and poor outcome after spinal fusion. The post-operative SRS 22 total score, self-image and function scores in Vitamin D deficient patients have significant positive correlation with low Vitamin D levels indicating that Vitamin D deficient patients have lower scores in these parameters [**Table 4**]. Further studies in both Taiwan and the United States have found that AIS was associated with an increased risk of depression, potentially due to increased pain and insomnia.[26-28] In a study with adults undergoing elective spine fusion, Vitamin D deficiency was a risk factor for longer time for spinal fusion (12 vs. 6 months, $p = 0.001$) and an independent predictor for non-union when adjusted for other variables.[29] Successful spinal fusion is integral to the success of surgery for AIS, and symptomatic pseudoarthrosis can arise in up to 5% of patients treated for AIS, causing persistent pain, failure of implants, and recurrence of deformity.[30-31] Follow-up period of 2 years after spinal fusion to study the functional outcomes was one of the strengths of this study which showed significant improvement in curve angles. Previous studies on spinal fusion rates in patients with AIS, have highlighted the importance of Vitamin D in bone health and promoting spinal fusion rates.[32-33] Several studies including ours have highlighted Vitamin D deficiency as a potential cause for curve progression in patients with AIS, and it has been postulated that treating the Vitamin D deficiency with supplementation may significantly improve bone health and potentially reduce the risk of curve progression.

Smaller sample size and single center-oriented study being the limitations of this study affecting the interpretation and application of the results. All patients included in this study were undergoing surgical intervention meaning all patients had reached a curve magnitude warranting surgical intervention. No patients were treated preoperatively with Vitamin D supplementation. We cannot conclude the effects of Vitamin D supplementation on curve progression or any complications such as back pain after surgery.

5. Conclusion

This study confirms large proportion (56.5%) of patients in AIS as Vitamin D deficient. AIS patients with vitamin D deficiency (<20 ng/mL) are more likely to be younger age at time of surgery and tend to report lower function, self-image, and total SRS-22 scores postoperatively. Thus, preoperative evaluation for Vitamin D levels is of paramount importance in case of AIS patients for better preoperative outcomes. We should be routinely investigating and optimizing Vitamin D levels in patients with AIS preoperatively.

6. Conflict of Interest

None.

7. Source of Funding

None.

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