Journal of Orthopaedic Science and Research

ATHENAEUM SCIENTIFIC PUBLISHERS

Research Article

Spine3d: Evaluation of Deformity in Patients with Idiopathic Scoliosis: A Case Series

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Citation: Daniele M, et al. Spine3d: Evaluation of Deformity in Patients with Idiopathic Scoliosis: A Case Series. J Ortho Sci Res. 2024;5(3):1-8. https://doi.org/10.46889/JOSR.2024.

Received Date: 11-11-2024

Accepted Date: 25-11-2024

Published Date: 02-12-2024

Abstract

Idiopathic scoliosis is a complex orthopedic condition marked by a lateral spinal curvature, typically affecting children and adolescents. The Cobb angle is a key metric for evaluating scoliosis severity through X-rays, but its measurement can suffer from variability due to imaging quality, positioning and physician experience, with an acceptable range of variation up to 5 degrees. LiDAR technology offers advantages over traditional methods, as it eliminates ionizing radiation and provides precise three-dimensional representations of the body. This study aims to assess the accuracy and reproducibility of Spine3D, a LiDAR-based tool, in measuring the Cobb angle in idiopathic scoliosis patients.

This study, conducted at Sant'Andrea University Hospital in Rome from September 2022 to September 2024, focused on adolescents (ages 10-18) with idiopathic scoliosis, excluding those with secondary curves or relevant health issues. Informed consent was obtained and body metrics were recorded. The Spine3D system, utilizing infrared technology for non-invasive spine assessment, measured alignment and generated detailed reports on parameters such as the Cobb angle and spinal curvature. Out of 29 participants, 26 were analyzed, showing an average Cobb angle of 29.9 degrees. Results indicated measurements of shoulder asymmetry, pelvic tilt, kyphotic and lordotic angles, with no significant statistical variations observed.

The measurement of the Cobb angle using Spine3D has demonstrated excellent reliability and efficiency. It is therefore suggested to promote the use of this method in clinical practice, alongside radiographic monitoring. Further studies will be needed to evaluate the spinal curvatures measured using Spine3D and traditional radiology.

Keywords: Idiopathic Scoliosis; Radiographic Monitoring; Spine; X-ray

Introduction

Idiopathic scoliosis is one of the most complex orthopedic conditions, characterized by a lateral curvature of the spine without a defined cause. It predominantly affects children and adolescents, but its presence can be noticed at any stage of growth [1]. The Cobb angle is one of the most commonly used methods to quantify the severity of scoliosis on X-rays, providing an essential standardized parameter for the assessment and management of spinal curvature [2]. However, the measurement of the Cobb angle is not without limitations. One of the main issues is inter- and intra-observer variability, which can affect measurement accuracy [3,4]. Factors such as the quality of the radiographic image, patient positioning and the physician's experience can contribute to differences in measurements, generally accepted up to 5 degrees of variation.

LiDAR (Light Detection and Ranging) technology is a remote sensing method that uses laser light to measure relative distances and produce accurate three-dimensional representations of objects or surfaces [5]. In the evaluation of scoliosis, LiDAR offers significant potential advancements over traditional methods, such as X-rays, both in terms of safety, given the absence of ionizing radiation and for its precision in representing the body's three-dimensional structure. In this context, Spine3D (Sensor Medica, Guidonia Montecelio, Italy) emerges as an innovative tool for evaluating the spine and its rotation [6].

The process of assessing scoliosis with LiDAR involves emitting laser pulses from a scanning device. These pulses reflect off the surfaces of the patient's body and return to the sensor. By analyzing the time taken for the pulses to return, the LiDAR system calculates the distance with high precision, thus constructing a three-dimensional map of the analyzed surface. These data can be used to determine the shape of the spine and other critical anatomical aspects in the diagnosis of scoliosis.

The aim of this study is to evaluate the accuracy and reproducibility of Spine3D in the measurement of the Cobb angle in patients with idiopatic scoliosis.

Methodology

This study was conducted at the Sant'Andrea University Hospital in Rome, within the Orthopedics and Traumatology Department, from September 2022 to September 2024. Patients included were those with idiopathic scoliosis aged between 10 and 18 years, with a Cobb angle between 10° and 45°. Patients with a secondary scoliotic curve, a history of vertebral fractures or the presence of cardiovascular or metabolic diseases such as obesity were excluded.

Parents or legal guardians and adolescents provided their informed consent both verbally and in writing. All procedures were in accordance with the Declaration of Helsinki (1975) as revised in 2013 [7]. Body mass was measured barefoot and in light clothing, standing upright in the center of the scale platform (Seca, Hamburg, Germany) with hands at the sides. Height was measured using a Harpenden stadiometer (Holtain Ltd., Cross-Well, UK) with a fixed vertical backboard and an adjustable head piece. The measurement was conducted with subjects in an upright position, without shoes and the head in the horizontal plane. Two measurements were taken for each parameter and a third was conducted if there was a discrepancy of 500 g and 0.5 cm between the initial measurements. The anthropometric parameters were then based on the average of the two closest measurements.

The Body Mass Index (BMI) of the patients was also assessed, calculated as BMI = weight in kilograms / (height in meters x height in meters).

SPINE3D

The Spine3D® (Fig. 1) is an innovative and non-invasive three-dimensional optoelectronic detection system (Kinect) that allows for accurate assessment of vertebrae alignment. The Spine3D system consists of a single vertical aluminum panel measuring 165 × 63 × 76 cm, a 27" touchscreen monitor with a resolution of 1920 x 1080 @60Hz (2.1-megapixel Full HD) in a 16:9 vertical orientation, with dimensions LxH: 597.6 x 336.15 mm, 23.5 x 13.2".

The system uses infrared cameras called "Time of Flight" (ToF) that allow the measurement of light reflection (camera-subject-camera) without the need for a dark room. It features an RGB camera with a resolution of 1600 x 1200 pixels, a frame rate of 15 fps and a field of view of H-70° V-50°. There is also a Depth camera with a resolution of 640 × 480 pixels, a frame rate of 15 fps and a field of view of H-60° V-45°.

The internal software, using a class I infrared light beam, captures the image of the back and records the difference between the projected and acquired image, which is displayed on a panel. The data obtained from surface irregularities, automatically identified by the instrument such as the prominent vertebra, right and left shoulder and left and right lumbar dimple, are mathematically analyzed to map the spine's morphology with a three-dimensional rendering (resolution of 1 mm). All measurements were conducted in the afternoon in the same clinical office, with a constant temperature of 21°C. Participants stood barefoot on the stabilometric platform, in a quiet and upright position, with their back exposed and facing the Spine 3D, positioned approximately 110 cm away from the subjects. Measurements were taken by two different operators at a 5-minute interval.

Once the patient was correctly positioned, the exam was initiated and from that moment the patient had to remain still for 10 seconds and wait for the acquisition to be completed.

The Spine3D system identifies the following anatomical landmarks (Fig. 2):

- VP (Vertebra Prominent) = identifies the prominent vertebra, representing C7
- SL (Left Shoulder) and SR (Right Shoulder) = identify the left shoulder acromion and right shoulder acromion, respectively
- DL (Left Dimple) and DR (Right Dimple) = identify the left and right lumbar dimples, respectively, representing the posterior iliac crests of the pelvis
- SP (Sacral Prominent) = identifies the sacral prominence, representing S2-S3

Once the acquisition is complete, the software will automatically generate a patient report that includes all the values and indices of the spine. The measurements considered in this study are: the kyphotic angle, lordotic angle, shoulder disparity, pelvic tilt and the curvature angle of the spine (Fig. 3,4).

Figure 1: Spine3D.

Figure 2: Registration of anatomical landmarks during image acquisition: VP, SL, SR, DL, DR, SP.

Figure 3: Measurements performed by Spine3D in the sagittal projection of the spine.

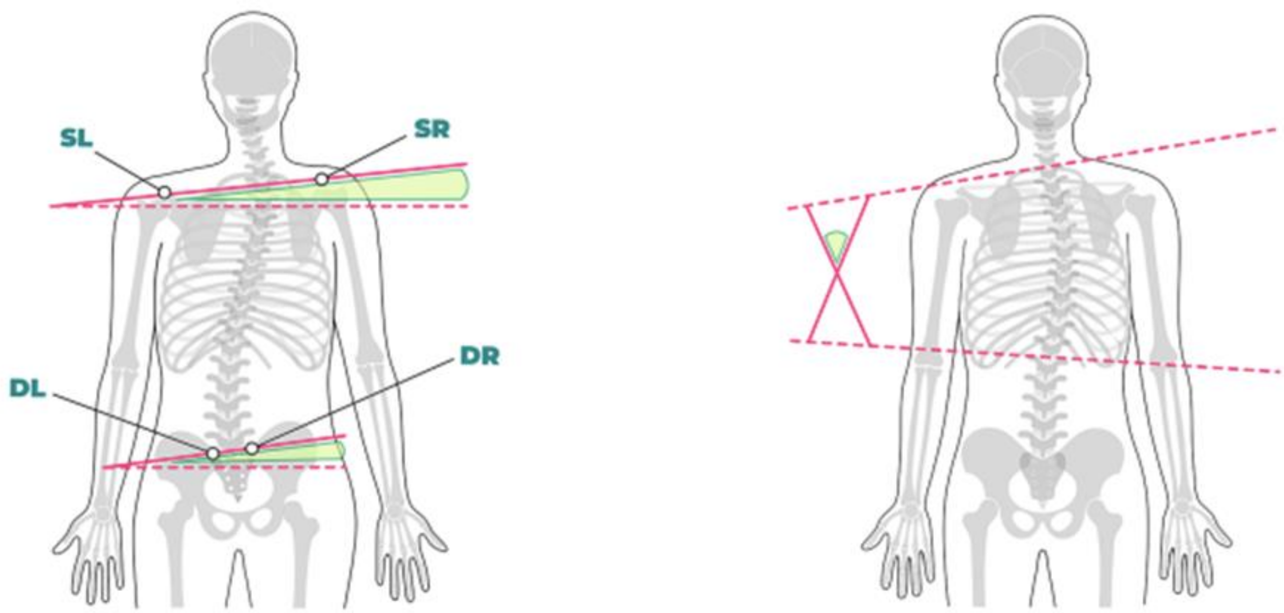

Figure 4: Measurements performed by Spine3D in the coronal projection of the spine.

Kyphotic Angle (KA) is defined as the angle formed by the tangents to the surface at the Cervico-Thoracic Inversion point (ICT) and the Thoraco-Lumbar Inversion point (ITL). It is expressed in degrees. Lordotic Angle (LA) is defined as the angle formed by the tangents to the surface at the Thoraco-Lumbar Inversion point (ITL) and the lumbo-sacral inversion point (ILS). It is expressed in degrees.

The shoulder asymmetry is assessed by the distance between the horizontal axis passing through the left acromion (SL) and the horizontal axis passing through the right acromion (SR). It is expressed in millimeters (mm). The pelvic tilt is assessed by the distance between the horizontal axis passing through the left Dimple (DL) and the horizontal axis passing through the right Dimple (DR). It is expressed in millimeters (mm).

The curvature angle is defined as the angle formed by the two tangents passing above the upper end vertebral body and below the lower end vertebral body. It is expressed in degrees.

Statistical Analysis

All data were expressed as mean, followed by ± Standard Deviation (SD), with the range of measurements in parentheses. Differences in the two measurements of the Cobb angle using Spine3D were considered. The frequency and cumulative percentage distribution of the intra-observer differences were recorded. Statistical analyses were performed using SPSS 13.0 software (SPSS Inc., Chicago, IL).

Results

The study included 29 adolescents with idiopathic scoliosis; 2 were excluded due to behavioral disorders and one did not complete the follow-up. The sample therefore consisted of 26 adolescents, whose demographic data are presented in Table 1.

Patients (n)	26
Male (n) **Female (n)**	15 11
Age (anni)	13.7 ± 2.2 (10-18)
Height (m)	1.56 ± 0.1 (1.41-1.79)
Weight (Kg)	47.8 ± 8.9 (32-70)
BMI	19.4 ± 1.9 (16-25)

Table 1: Demographics data.

The average Cobb angle measured was 29.9 degrees (range, 17-58 degrees) using Spine3D. The average Cobb angles measured, the Standard Deviation (SD) between the two measurements and the 95% confidence interval for the difference between the two measurements are summarized in Table 2.

	Measurement 1	**Measurement 2**
Cobb Angle, mean	30.1	29.8
Cobb Angle, SD	1.1	1.4
SD of difference between 2 measurements	1.1	1.2
95% confidence interval for the difference (±) between 2 measurements	2.1	2.3

Table 2: Summary of data for the Spine3D measurement.

All other measurements are outlined in Table 3 and none proved to be statistically significant.

	Spine3D Measurements
Shoulder asimmetry (mm)	6.1 ± 1.2 (1-9)
Pelvic tilt (mm)	2.4 ± 1.3 (1-9)
Kyphotic angle (degree)	28.3 ± 2.7 (12-37)
Lordotic angle (degree)	38.41 ± 3.2 (32-44)

Table 3: The Spine3D measurement is expressed as the average of the two different measurements.

Discussion

The study highlights that Spine3D is a valid and reproducible method for the evaluation in patient with idiopathic scoliosis. Although a low-dose solution has been recently developed (EOS Imaging System, EOS Imaging, Paris, France), the ability to utilize radiation-free methods to monitor scoliosis and its progression would be advantageous [8-10]. Numerous systems based on dorsal surface topography have been developed as non-invasive alternatives to traditional radiography (such as the Moiré projection, laser scanning, electromagnetic topography, ultrasound imaging and rasterstereography [8-26]. Based on the reconstruction of the body's back surface, these systems provide an indirect measurement of spinal deformities. Since they do not characterize the internal shape of the spine, such techniques cannot inherently diagnose the degree of scoliosis. However, the use of Artificial Intelligence (AI) has allowed the inclusion of numerous subjects to predict the anatomical conformation of the spine. Additionally, they can potentially be exploited as cost-effective and quick methods for the initial screening of spinal deformities.

Encouraging results have been reported in terms of reliability (the repetition of a measure) and validity (the measure accurately corresponding to reality).

This study represents the first utilization in the literature of a LiDAR method in idiopathic scoliosis, with certainly encouraging results. However, it has some limitations: the sample size is small, due to the strict inclusion criteria. More severe curvatures are often associated with the patient's inability to perform the test while standing and are frequently linked to secondary conditions. Additionally, the study does not consider other radiographic parameters, which could not be compared with Spine3D. Moreover, monitoring of scoliosis curvature was not performed on the patients, as this would have required additional follow-up time.

Conclusion

In conclusion, the measurement of the Cobb angle using Spine3D has demonstrated excellent reliability and efficiency. It is therefore suggested to promote the use of this method in clinical practice, alongside radiographic monitoring. Further studies will be needed to evaluate the spinal curvatures measured using Spine3D and traditional radiology.

Conflict of Interests

The authors declare that they have no conflict of interest in this paper.

Funding

None

Authors' Contributions

All authors contributed equally in this paper.

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