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Research Article

Spine3d and Its Reliability in Evalution of Deformity in Patients with Idiopathic Scoliolic

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Abstract

Idiopathic scoliosis is a complicated orthopedic disorder marked by a side-to-side curvature of the spine, the cause of which is unknown and it predominantly affects children and adolescents. The Cobb angle is the conventional technique for evaluating the severity of scoliosis through X-rays; however, it has limitations, including inter and intra-observer variability that can compromise measurement accuracy. LiDAR (Light Detection and Ranging) technology presents a promising radiation-free alternative by generating accurate three-dimensional models of the body's anatomy through the use of laser pulses to measure distances.

The aim of this study is to assess the accuracy and reproducibility of the Spine3D system as compared to traditional radiographs.

Conducted at Sant'Andrea University Hospital in Rome from September 2022 to 2024, the study involved patients aged 10 to 18 diagnosed with idiopathic scoliosis. Participants' weight, height and body mass index (BMI) were recorded and a detailed evaluation was conducted using the Spine3D system, which employs infrared cameras to assess spinal alignment and X-rays.

The study included 26 adolescents, showing no significant difference between Cobb angles measured via X-rays (30.1 degrees) and Spine3D (29.9 degrees). Intra-observer reliability was high for both methods, with Spine3D demonstrating superior consistency. Differences were observed in measurements such as lordotic angles, attributed to variations in postural stance.

The Spine3D system for measuring the Cobb angle proved to be reliable and efficient, suggesting it could be integrated into clinical practice alongside radiographic monitoring. Future studies are necessary to further explore the clinical application of Spine3D in tracking spinal curvature throughout treatment.

Keywords: Idiopathic Scoliosis; Spine3D; X-rays; LIDAR

Introduction

Idiopathic scoliosis is among the most intricate orthopedic disorders, marked by a sideways curvature of the spine that lacks an identifiable cause. It mainly impacts children and teenagers, although it can manifest at any growth stage [1]. The Cobb angle is a frequently employed technique for assessing the severity of scoliosis through X-rays, serving as a crucial standardized measure for evaluating and managing spinal curvature [2]. However, measuring the Cobb angle has its drawbacks, particularly inter- and intra-observer variability which may compromise measurement precision. Many factors could affect measurements up to 5 degrees [3,4].

LiDAR (Light Detection and Ranging) technology is a remote sensing method that uses laser light to measure distances, enabling the creation of precise three-dimensional models of objects or surfaces [5]. In scoliosis assessment, LiDAR presents significant improvements over conventional methods like X-rays, notably in safety, as it does not involve ionizing radiation and in its ability to accurately depict the body's three-dimensional anatomy. In this regard, Spine3D (Sensor Medica, Guidonia Montecelio, Italy) is an innovative device designed for spine evaluation and rotation analysis [6].

Employing LiDAR for scoliosis assessment involves sending laser pulses from a scanning unit. These pulses reflect off the surfaces of the patient's body and return to the sensor. By measuring the time taken for the pulses to return, the LiDAR system can accurately calculate distances, resulting in a three-dimensional model of the analyzed surface.

The aim of this study is to measure the Cobb angle using Spine3D, comparing it with X-rays. The study hypothesis is that the LiDAR methodology of Spine3D can be considered a reliable method in the assessment of idiopathic scoliosis.

Methodology

This study was conducted at Sant'Andrea University Hospital in Rome, within the Orthopedics and Traumatology Department, from September 2022 to September 2024. It included patients aged 10 to 18 years diagnosed with idiopathic scoliosis, with Cobb angles between 10° and 45°. Excluded were individuals with secondary scoliosis, a history of vertebral fractures or pre-existing cardiovascular or metabolic disorders such as obesity. Informed consent was obtained both verbally and in writing from parents or legal guardians and the adolescents [7].

Body weight was recorded with participants barefoot and in light clothing, standing upright on a Seca scale platform (Hamburg, Germany) with arms at their sides. Height was measured using a Harpenden stadiometer (Holtain Ltd., Cross-Well, UK), ensuring subjects stood upright and without shoes, with their heads positioned horizontally. Two measurements were taken for each parameter, with a third taken if there was a discrepancy of 500 g in weight or 0.5 cm in height. The final anthropometric parameters were calculated by averaging the two closest measurements. The Body Mass Index (BMI) was also determined using the formula: BMI = weight in kilograms / (height in meters x height in meters).

SPINE3D

The Spine3D® system (Fig. 1) is a cutting-edge, non-invasive three-dimensional optoelectronic detection tool (Kinect) designed for precise evaluation of vertebral alignment. It features a single vertical aluminum panel measuring 165 × 63 × 76 cm and is equipped with a 27" touchscreen monitor that offers a 1920 x 1080 resolution at 60 Hz (2.1 megapixel Full HD) in a vertical 16:9 orientation, with dimensions of 597.6 x 336.15 mm (23.5 x 13.2").

Utilizing infrared "Time of Flight" (ToF) cameras, the system measures light reflection without requiring a dark environment. An RGB camera with a resolution of 1600x1200 pixels operates at 15 frames per second (fps) with a horizontal field of view of 70° and a vertical field of view of 50°. Additionally, there is a depth camera operating at 640 × 480 pixels and 15 fps, with a horizontal field of view of 60° and a vertical field of view of 45°.

The internal software employs a class I infrared light beam to capture an image of the back and assess the difference between the projected and received images, which is displayed on the monitor. The device identifies anatomical surface irregularities, such as prominent vertebrae, shoulders and lumbar dimples and mathematically analyzes this data to create a three-dimensional model of the spine with a resolution of 1 mm.

Measurements were conducted in the afternoon within a consistent clinical environment at a temperature of 21°C. Participants stood barefoot on a stabilometric platform in a quiet, upright position with their backs exposed, facing the Spine3D system, positioned roughly 110 cm away. Two operators performed measurements with a 5-minute interval between them.

Once the participant was properly positioned, the examination began, requiring the individual to remain still for 10 seconds for image acquisition to finish. The Spine3D system identifies various anatomical landmarks during this process (Fig. 2):
VP (Vertebra Prominent)**: Identifies the prominent vertebra, which is C7.

SL (Left Shoulder) and SR (Right Shoulder): Indicate the left and right shoulder acromions, respectively.
DL (Left Dimple) and DR (Right Dimple): Refer to the left and right lumbar dimples, respectively, which represent the posterior iliac crests of the pelvis.
SP (Sacral Prominent): Marks the sacral prominence, representing S2.

Upon of the acquisition, the software automatically generates a comprehensive report for the patient, detailing all relevant spine values and indices. The measurements included in this study are: Kyphotic angle, Lordotic angle, Shoulder disparity, Pelvic tilt, Curvature angle of the spine.

These parameters are illustrated in Fig. 3,4.

Kyphotic Angle (KA): This angle is determined by the tangents to the surface at the cervico-thoracic inversion point (ICT) and the thoraco-lumbar inversion point (ITL). It is measured in degrees.
Lordotic Angle (LA): This angle is defined by the tangents to the surface at the thoraco-lumbar inversion point (ITL) and the lumbo-sacral inversion point (ILS). It is also expressed in degrees.

Shoulder asymmetry is evaluated by measuring the distance between the horizontal axis that passes through the left acromion (SL) and the horizontal axis that passes through the right acromion (SR). This measurement is expressed in millimeters (mm). Pelvic tilt is assessed by the distance between the horizontal axis that passes through the left dimple (DL) and the horizontal axis that passes through the right dimple (DR), also expressed in millimeters (mm). The curvature angle is defined as the angle formed by the two tangents that extend above the upper end vertebral body and below the lower end vertebral body. This angle is expressed in degrees.

Radiographic Evaluation
All patients underwent a full-spine radiographic examination under load in Anteroposterior (AP) and Lateral-Lateral (LL) views. The AP radiographic exam was performed with the patient supine, in an upright position, with arms slightly open along the trunk and frequent, shallow breathing during the radiograph capture. The incident beam is perpendicular and directed at the level of L3, approximately 1-2 cm above the navel.

The LL radiographic exam was also conducted with the patient upright, arms wrapped around the head and knees slightly bent to maintain the position. The centering is performed with the perpendicular incident beam directed at the iliac crest.
The radiographic measurements considered in the study include: lumbar lordotic angle, thoracic kyphotic angle, coracoid height, pelvic tilt and Cobb angle.

The Lumbar Lordotic Angle (LLA) is the angle measured on lateral radiographs, formed by the intersection of the line tangent to the upper portion of the first lumbar vertebra and the line passing through the upper edge of the sacral vertebra. The measurement is normally between 51° and 53° (Fig. 5).

The kyphosis angle is formed between the upper limit of T1 and the lower limit of T12 and can vary between 20-25° and 40-45° (Fig. 6). The difference in coracoid height indicates shoulder asymmetry and is measured as the height difference between the horizontal lines passing through the upper margin of each coracoid process. It is expressed in millimeters (mm) (Fig. 7). Pelvic tilt is assessed by measuring the height difference of the iliac crests and is determined as the height difference between the horizontal lines passing through the upper margin of each iliac crest. It is expressed in millimeters (mm) (Fig.8).

The Cobb measurement method (2), recommended by the Terminology Committee of the Scoliosis Research Society, consists of three steps: (1) locate the upper end vertebra; (2) locate the lower end vertebra; (3) draw lines perpendicular to the upper surface of the upper end vertebra and the lower surface of the lower end vertebra. The angle of deviation of these perpendicular lines from a straight line is the curve angle. If the vertebral endplates are obscured, the pedicles can be used instead. The end vertebra of the curve is the one most tilted towards the concavity of the curve to be measured (Fig. 9).

All measurements were performed by two orthopedic surgeons (DM and SG), by uploading the images to Horos® (Horos project), an open source program that transforms the computer into a DICOM workstation for processing and visualizing medical images. Measurements were conducted twice for all patients by both orthopedics and the average was considered for statistical calculations.

Figure 1: Spine3D.

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

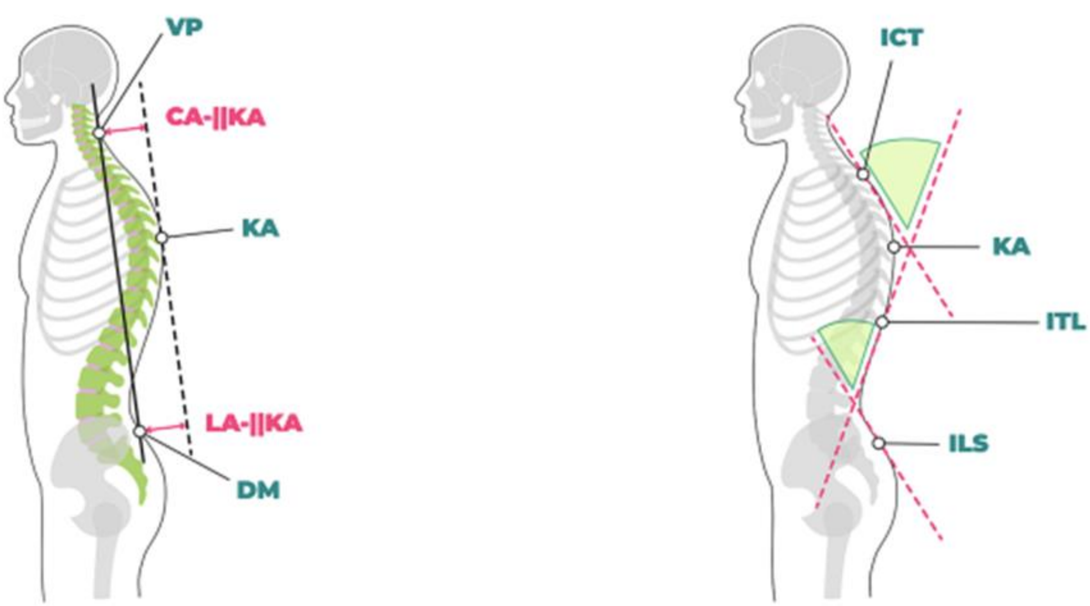

Figure 3: Measurements performed by Spine3D in the sagittal projection of the spine.

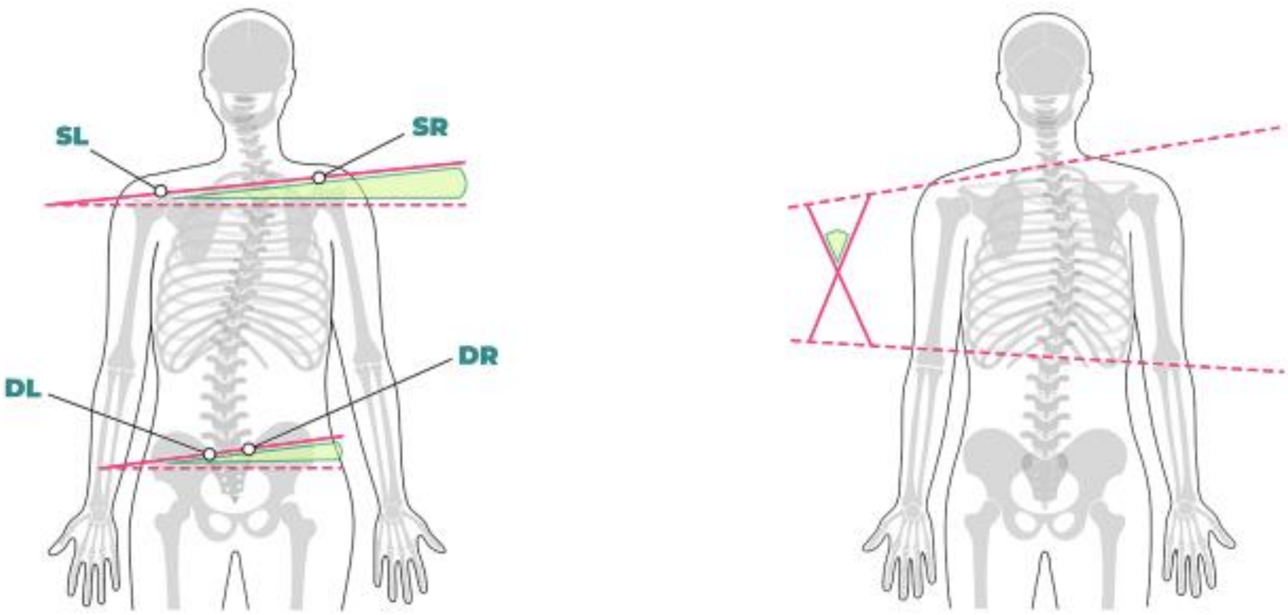

Figure 4: Measurements performed by Spine3D in the coronal projection of the spine.

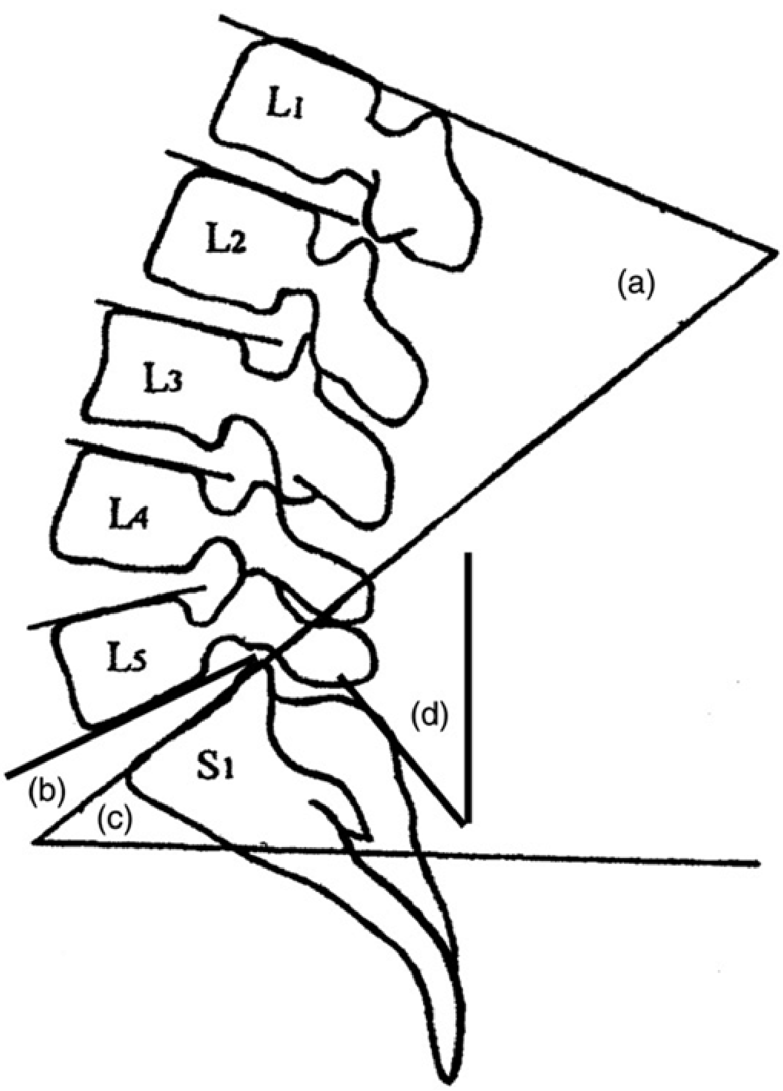

Figure 5: Radiographic measurement of the lumbar lordotic angle.

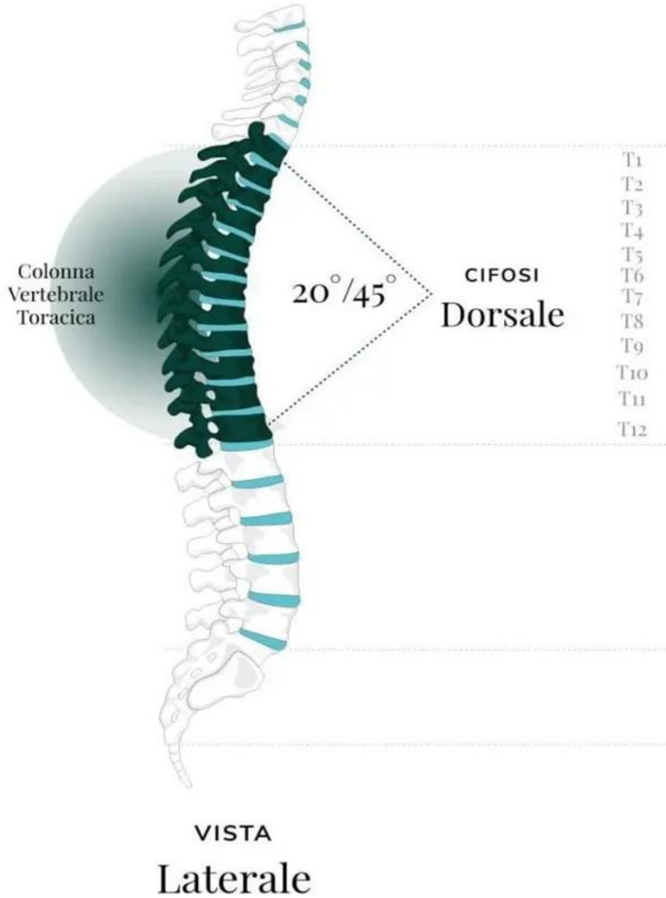

Figure 6: Radiographic measurement of the thoracic kyphosis angle.

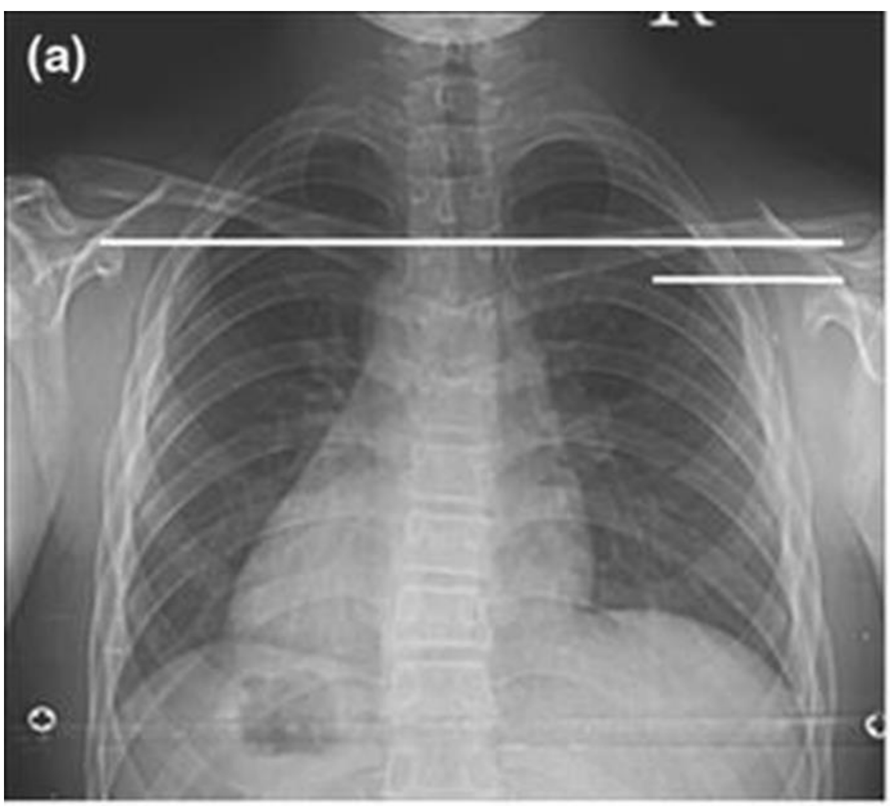

Figure 7: Radiographic measurement of shoulder asymmetry.

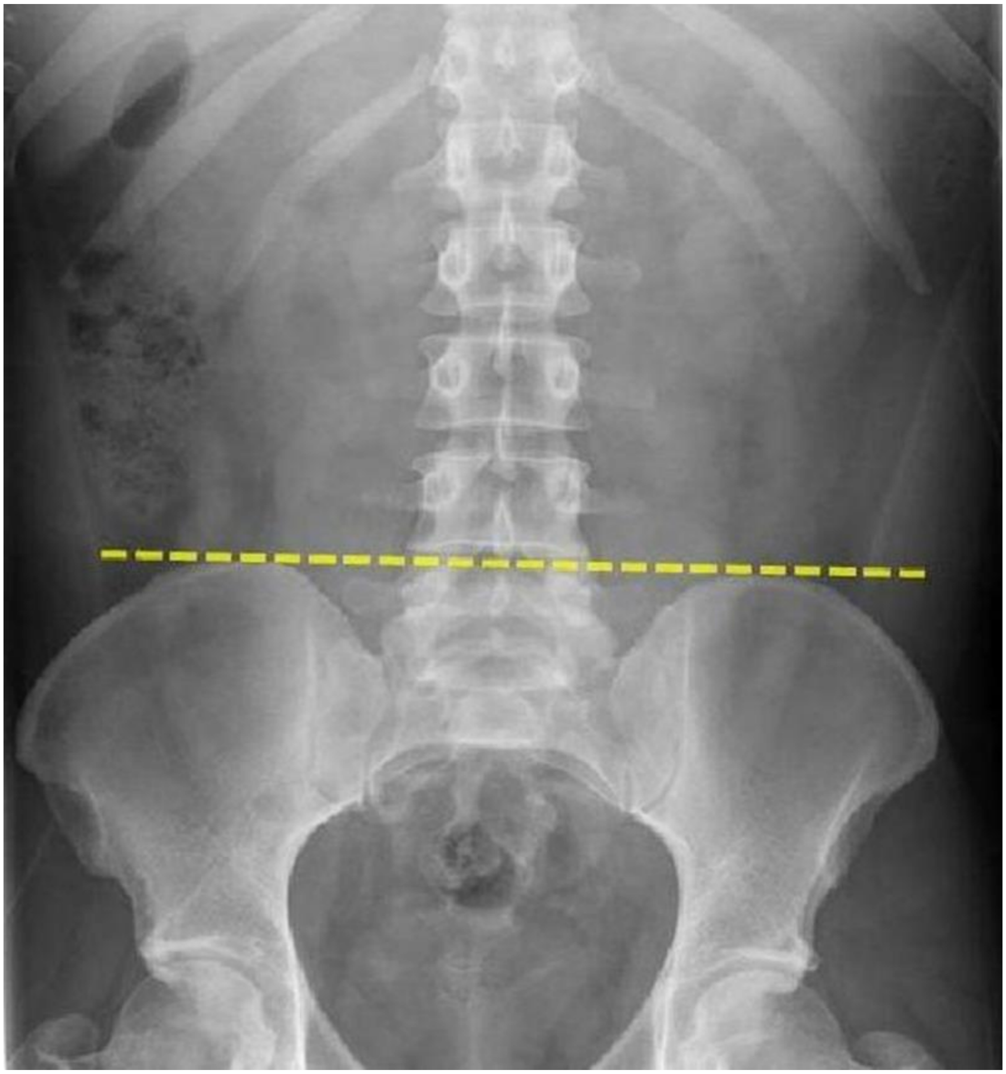

Figure 8: Radiographic measurement of pelvic tilt.

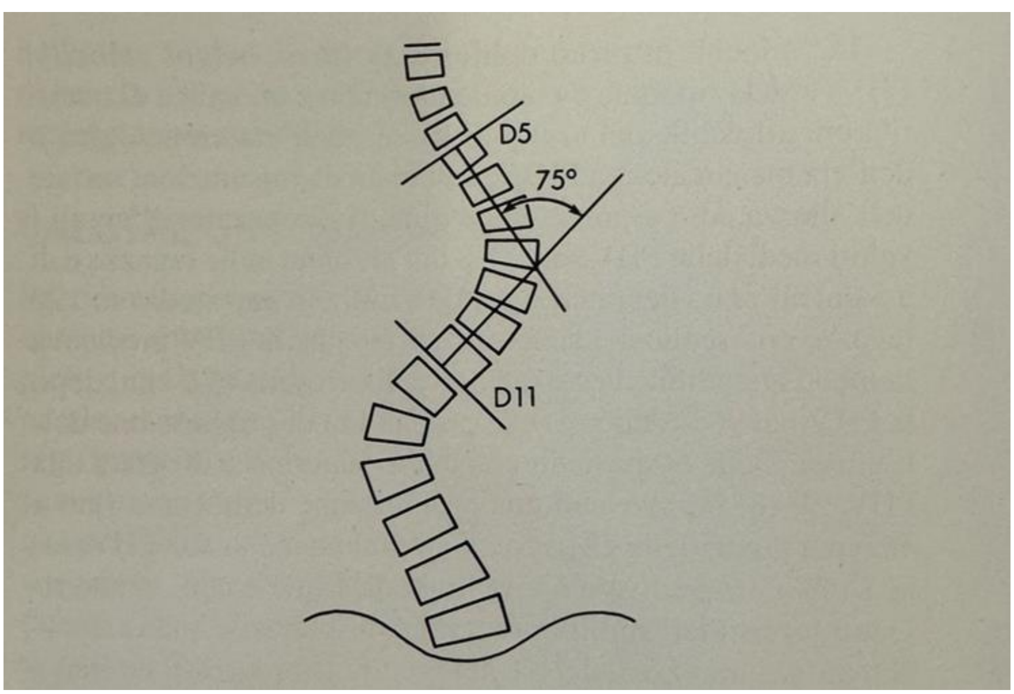

Figure 9: Radiographic measurement of Cobb Angle.

Statistical Analysis

All data were expressed as mean, followed by ± Standard Deviation (SD), with the range of measurements in parentheses. Intra-observer differences in the two measurements of the Cobb angle on the radiographs and the two measurements using Spine3D were considered. The frequency and cumulative percentage distribution of the intra-observer differences were recorded. The Intraclass Correlation Coefficient (ICC) was used to analyze the reliability of the measurements. ICC values can range from 0 to 1, with a higher value indicating greater reliability. An ICC below 0.40 is considered poor, 0.40 to 0.59 fair, 0.60 to 0.74 good and 0.75 to 1.00 excellent. A paired t-test was used to compare results between the two measurement methods. A result is considered statistically significant with a p-value < 0.05. Statistical analyses were performed using SPSS 13.0 software (SPSS Inc., Chicago, IL).

Results

The study initially included 29 adolescents diagnosed with idiopathic scoliosis; however, 2 were excluded due to behavioral disorders and 1 did not complete the follow-up. Consequently, the final sample consisted of 26 adolescents, with their demographic data detailed in Table 1.

Patients (n)	26
Male (n) **Female (n)**	15 11
Age (y)	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 on the X-rays was 30.1 degrees (range, 18-56 degrees) and 29.9 degrees (range, 17-58 degrees) when measured with Spine3D. This measurement is not statistically significant (P=0.89). The average Cobb angles measured in each method, the Standard Deviation (SD) between the two measurements and the 95% confidence interval for the difference between the two measurements are summarized in Tables 2 and 3.

	Observer 1	**Observer 2**
Cobb Angle, mean	30.6	29.7
Cobb Angle, SD	2.2	2.1
SD of difference between 2 measurements	1.6	1.5
95% confidence interval for the difference (±) between 2 measurements	3.1	3.3

Table 2: Summary of data for the manual measurement.

	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 3: Summary of data for the Spine3D measurement.

The overall intra-observer variability was 0.955 and the overall inter-observer variability was 0.936 for the X-ray measurements, while the intra-observer variability was 0.985 and the inter-observer variability was 0.956 for Spine3D. Both intra-observer and inter-observer ICCs were excellent in both types of measurements and between the two observers (Table 4). Both the intra-observer ICC and the inter-observer ICC were better in the Spine3D measurements compared to the manual measurement.

	X-rays Measurements		Spine3D	
	Mean	**Range**	**Mean**	**Range**
Intra-observer1	0.960	0.931-0.975	0.991	0.981-0.995
Intra-observer2	0.972	0.952-0.982	0.985	0.978-0.991
Mean intra-observer	0.955	0.941-0.964	0.985	0.982-0.986
Inter-Observer	0.936	0.932-0.955	0.956	0.947-0.983

Table 4: ICC indicates intraclass correlation coefficients.

All other measurements are outlined in Table 5 and none proved to be statistically significant.

	Manual Measurements	Spine3D Measurements	t-test
Shoulder asimmetry (mm)	6.3 ± 1.1 (1-10)	6.1 ± 1.2 (1-9)	P=0.13
Pelvic tilt (mm)	2.3 ± 1.2 (1-8)	2.4 ± 1.3 (1-9)	P=0.28
Kyphotic angle (degree)	26 ± 3.4 (10-41)	28.3 ± 2.7 (12-37)	P=0.08
Lordotic angle (degree)	49.1 ± 2.8 (36-54)	38.41 ± 3.2 (32-44)	**P<0.05**

Table 5: The manual measurement is expressed as the average of the two measurements from the two operators. 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, comparing it to the digital measurements of the Cobb angle performed on patient X-rays. The hypothesis of the study was that the LiDAR method of Spine3D can be considered a reliable method in the assessment of idiopathic scoliosis and this was confirmed by the results.

While a low-dose imaging solution, like the EOS Imaging System (EOS Imaging, Paris, France), has recently been introduced, utilizing radiation-free methods to monitor scoliosis and its progression remains highly beneficial [8-10]. Several non-invasive systems based on dorsal surface topography have been developed as alternatives to traditional radiography, including: Moiré projection, Laser scanning, Electromagnetic topography, Ultrasound imaging, Rasterstereography [11-25].

These systems, which utilize the reconstruction of the body's back surface, offer indirect measurements of spinal deformities. While they do not directly assess the internal structure of the spine and are unable to definitively diagnose the degree of scoliosis, the integration of Artificial Intelligence (AI) has enabled the analysis of a larger cohort of subjects to predict spinal anatomical conformation. Consequently, these techniques can serve as cost-effective and efficient 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 highlights an overall intra-observer variability of 0.955 and an overall inter-observer variability of 0.936 for X-ray measurements, while the intra-observer variability was 0.985 and the inter-observer variability was 0.956 for Spine3D. Both intra-observer and inter-observer ICCs were excellent for both types of measurements and between the two observers, yet better in Spine3D measurements compared to manual measurement. Standard X-ray measurements using a goniometer inherently show different values. Carman, et al., and Morrissy, et al., found that the inter- and intra-observer variations in Cobb angle measurements average 5-7 degrees [26,27]. However, this study found similar reproducibility values among observers and in their repeat measurements.

The average measurements performed by the operators and by Spine3D on the kyphotic angle, shoulder level difference and pelvic level difference did not show statistically significant differences. However, regarding the lordotic angle, the radiographic measurements showed an average angle of 49.1 ± 2.8, while those performed with Spine3D showed an average angle of 38.41 ± 3.2 [32-54]. This difference was statistically significant. This discrepancy is likely due to the patient's postural stance and the presence of different somatotypes among individuals, which may have led to incorrect identification of the sacral landmarks (DL, DR, SP), thus altering the measurement.

This study represents the first documented comparison between a LiDAR method and standard measurements in idiopathic scoliosis, yielding encouraging results. However, it has certain limitations. The sample size is relatively small due to strict inclusion criteria and patients with more severe curvatures may be unable to stand during testing, often relating to secondary conditions. Additionally, the study did not account for other radiographic parameters that could not be compared with the Spine3D measurements. Furthermore, monitoring scoliosis curvature over time was not conducted, as it would have required additional follow-up.

Conclusion

In conclusion, measuring the Cobb angle with Spine3D has shown remarkable reliability and efficiency. It is recommended to incorporate this method into clinical practice alongside traditional radiographic monitoring. Future research is necessary to assess the effectiveness of Spine3D in the clinical monitoring of spinal curvatures throughout treatment.

Conflict of Interests

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

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None

Authors' Contributions

All authors contributed equally in this paper.

References

1. Kleinberg S. The operative treatment of scoliosis. Arch Surg. 1922;5:631-45.
2. Cobb JR. Outline for the study of scoliosis. In: Edwards JW, editor. AAOS, Instructional Course Lectures. Ann Arbor:The American Academy of Orthopaedic Surgeons; 19485;261-75.
3. Morrissy RT, Goldsmith GS, Hall EC, Kehl D, Cowie GH. Measurement of the Cobb angle on radiographs of patients who have scoliosis. Evaluation of intrinsic error. J Bone Joint Surg Am. 1990;72(3):320-7.
4. Carman DL, Browne RH, Birch JG. Measurement of scoliosis and kyphosis radiographs. Intraobserver and interobserver variation. J Bone Joint Surg Am. 1990;72(3):328-33.
5. Bassani T, Stucovitz E, Galbusera F, Brayda-Bruno M. Is rasterstereography a valid noninvasive method for the screening of juvenile and adolescent idiopathic scoliosis? Eur Spine J. 2019;28(3):526-35.
6. Marin L, Lovecchio N, Pedrotti L, Manzoni F, Febbi M, Albanese I, et al. Acute effects of self-correction on spine deviation and balance in adolescent girls with idiopathic scoliosis. Sensors. 2022;22(5):1883.
7. World Medical Association World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA. 2013;310:2191-4.
8. Dietrich TJ, Pfrrmann CW, Schwab A, Pankalla K, Buck FM. Comparison of radiation dose, workfow, patient comfort and fnancial break-even of standard digital radiography and a novel biplanar low-dose X-ray system for upright full-length lower limb and whole spine radiography. Skelet Radiol. 2013;42(7):959-67.
9. Illes T, Somoskeoy S. The EOS imaging system and its uses in daily orthopaedic practice. Int Orthop. 2012;36(7):1325-31.
10. Somoskeoy S, Tunyogi-Csapo M, Bogyo C, Illes T. Accuracy and reliability of coronal and sagittal spinal curvature data based on patient-specifc three-dimensional models created by the EOS 2D/3D imaging system. Spine J. 2012;12(11):1052-9.
11. Aroeira RM, de Las Casas EB, Pertence AE, Greco M, Tavares JM. Non-invasive methods of computer vision in the posture evaluation of adolescent idiopathic scoliosis. J Bodyw Mov Ther. 2016;20(4):832-43.
12. Prowse A, Pope R, Gerdhem P, Abbott A. Reliability and validity of inexpensive and easily administered anthropometric clinical evaluation methods of postural asymmetry measurement in adolescent idiopathic scoliosis: a systematic review. Eur Spine J. 2016;25(2):450-66.
13. Porto F, Gurgel JL, Russomano T, Farinatti Pde T. Moire topography: characteristics and clinical application. Gait Posture. 2010;32(3):422-4.
14. Willner S. Moire topography for the diagnosis and documentation of scoliosis. Acta Orthop Scand. 1979;50(3):295-302.
15. Hill DL, Berg DC, Raso VJ, Lou E, Durdle NG, Mahood JK, et al. Evaluation of a laser scanner for surface topography. Stud

Health Technol Inf. 2002;88:90-4.
16. Treuillet S, Lucas Y, Crepin G, Peuchot B, Pichaud JC. SYDESCO: a laser-video scanner for 3D scoliosis evaluations. Stud Health Technol Inf. 2002;88:70-3.
17. Knott P, Mardjetko S, Nance D, Dunn M. Electromagnetic topographical technique of curve evaluation for adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2006;31(24):E911-6.
18. Zheng R, Chan AC, Chen W, Hill DL, Le LH, Hedden D, et al. Intra- and inter-rater reliability of coronal curvature measurement for adolescent idiopathic scoliosis using ultrasonic imaging method-a pilot study. Spine Deform. 2015;3(2):151-8.
19. Cheung CW, Zhou GQ, Law SY, Mak TM, Lai KL, Zheng YP. Ultrasound volume projection imaging for assessment of scoliosis. IEEE Trans Med Imaging. 2015;34(8):1760-8.
20. Manca A, Monticone M, Cugusi L, Doria C, Tranquilli-Leali P, Deriu F. Back surface measurements by rasterstereography for adolescent idiopathic scoliosis: from reproducibility to data reduction analyses. Eur Spine J. 2018;27(9):2130-8.
21. Mohokum M, Schulein S, Skwara A. The validity of rasterstereography: a systematic review. Orthop Rev (Pavia) Rasterstereographic measurement of scoliotic deformity. Scoliosis. 2015;9(1):22.
22. Zubovic A, Davies N, Berryman F, Pynsent P, Quraishi N, Lavy C, et al. New method of scoliosis deformity assessment: ISIS2 system. Stud Health Technol Inf. 2008;140:157-60.
23. Liu XC, Thometz JG, Lyon RM, Klein J. Functional classifcation of patients with idiopathic scoliosis assessed by the Quantec system: a discriminant functional analysis to determine patient curve magnitude. Spine (Phila Pa 1976). 2001;26(11):1274-8.
24. Goldberg CJ, Kaliszer M, Moore DP, Fogarty EE, Dowling FE. Surface topography, Cobb angles and cosmetic change in scoliosis. Spine (Phila Pa 1976). 2001;26(4):E55-63.
25. Weisz I, Jeferson RJ, Turner-Smith AR, Houghton GR, Harris JD. ISIS scanning: a useful assessment technique in the management of scoliosis. Spine (Phila Pa 1976). 1988;13(4):405-8.
26. Morrissy RT, Goldsmith GS, Hall EC, Kehl D, Cowie GH. Measurement of the Cobb angle on radiographs of patients who have scoliosis. Evaluation of intrinsic error. J Bone Joint Surg Am. 1990;72(3):320-7.
27. Carman DL, Browne RH, Birch JG. Measurement of scoliosis and kyphosis radiographs. Intraobserver and interobserver variation. J Bone Joint Surg Am. 1990;72(3):328-33.