



ORIGINAL ARTICLE

Does apical vertebra location influence the final outcome of bracing for idiopathic scoliosis?

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ABSTRACT

BACKGROUND: Idiopathic scoliosis represents a complex spinal alteration characterized by lateral curvature and rotation of the spine. Among the numerous factors influencing treatment response, the role of the apical vertebra in idiopathic scoliosis remains a topic of significant interest and debate. The apical vertebra, situated at the apex of the scoliotic curve, holds a pivotal position in determining the overall spinal alignment and, consequently, the efficacy of conservative treatments. Several studies have shown that patients with apical vertebrae located in the thoracic spine are more likely to have progression of their curves than patients with apical vertebrae located in the lumbar spine. Additionally, patients with apical vertebrae located in the upper thoracic spine are more likely to have poorer outcomes than patients with apical vertebrae located in the lower thoracic spine. Therefore, understanding the nuanced relationship between the characteristics of the apical vertebra and treatment outcomes is paramount for tailoring therapeutic strategies and optimizing patient care.

AIM: This study aims to comprehensively analyze the influence of apical vertebra location and rotation on the outcome of conservative treatment of idiopathic scoliosis.

DESIGN: This is an observational controlled cohort study nested in a prospective clinical ongoing database in patients with idiopathic scoliosis.

SETTING: Inpatient and outpatient in Rome.

METHODS: From a consecutive series of patients included in a prospective database, we selected 491 patients with Adolescent Idiopathic Scoliosis with curves of 20-40° (mean: 27.89°±5.15°), Risser grade 0-2 who were treated with a brace at 2 years minimum follow-up (mean: 53.62±49.63 months). X-rays were used to obtain Cobb degrees and torsion of the apical vertebrae (Perdriolle's method). Three outcomes were distinguished according to SRS-SOSORT criteria: correction, stabilization, and progression. The location and rotation of the apex vertebra and the degrees of the curve were analyzed using statistical analysis.

RESULTS: The results of our study showed that, among 491 patients with a definite outcome, the Cobb mean value was 27.89±5.158 SD at baseline and 16.99±15.85 SD at follow-up ($P<0.0001$; $R=0.3228$). Perdriolle was initially 11.9±7.319 and 7.319±7.816 at follow-up ($P<0.0001$, $R=0.4865$). Overall, 411 patients (84%) achieved curve correction, and stabilization was attained in 70 cases (14%). Ten patients (2%) experienced curve progression, and one patient was recommended for surgery because the curve at follow-up was greater than 45°. The analysis of subgroups shows statistically significant differences in the means of L1 and D9, L1 and D8, L1 and D7, L2 and D7, and D12 and D7; the P values are less than 0.05 (Table I). Moreover, a significant correlation was observed between the apex vertebra and the mean Cobb correction ($P<0.0001$) ($R=0.64$).

CONCLUSIONS: Our study demonstrates that the apical vertebra plays a significant role in the outcome of conservative treatment for AIS. Patients with apical vertebrae located in the thoracic spine, particularly in the upper thoracic spine, were more likely to have poorer outcomes compared to patients with apical vertebrae located in the lumbar spine.

CLINICAL REHABILITATION IMPACT: These findings highlight the importance of considering the location of the apical vertebra when determining the prognosis and treatment plan for patients with AIS. Moreover, we can affirm that brace treatment is an effective method for the treatment of AIS, in fact, the majority of patients achieved curve correction and stabilization, with a low incidence of curve progression and surgery.

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KEY WORDS: Scoliosis; Therapeutics; Spine.

Introduction

Adolescent idiopathic scoliosis (AIS) is a prevalent and complex spinal deformity that manifests during adolescence, a critical period of rapid skeletal growth. It is characterized by a three-dimensional deformity, including hypokyphosis, coronal curve, and vertebral rotation.¹ The exact cause of AIS remains unknown, and it is considered a multifactorial condition that likely involves a combination of genetic, environmental, and biomechanical factors. AIS affects approximately 2-3% of adolescents, with a higher incidence in females, suggesting a potential hormonal or genetic influence on its pathogenesis.²⁻⁴ The severity of the condition can range from mild, where no treatment is necessary, to severe cases, where significant curvature can lead to functional impairments and aesthetic concerns.^{5, 6}

AIS is typically identified through clinical evaluation, and diagnosis is confirmed with radiographic imaging. The progression of scoliosis during the growth spurt of adolescence can result in significant deformities, which, if left untreated, may lead to chronic pain, spinal degeneration, and even cardiopulmonary complications due to thoracic cage deformities.⁷

One of the most challenging aspects of managing AIS is predicting which patients will experience curve progression, particularly during periods of rapid skeletal growth. While many patients with mild curves show little to no progression, others experience rapid worsening of their spinal deformity, necessitating intervention.^{8, 9} Early intervention is essential to prevent further curve progression, which can sometimes only be addressed through surgical means, including spinal fusion. However, surgery is typically reserved for cases with severe deformities (*e.g.*, curves greater than 45°), as it carries inherent risks and long-term consequences.^{10, 11}

The mainstay of treatment for AIS remains conservative management, with bracing being the most widely used non-surgical approach. Bracing aims to halt, slow, or, in some cases, reverse the progression of the curve during the adolescent growth spurt. The effectiveness of bracing depends on several factors, including the type and location of the spinal curvature, the patient's age, and the degree of curve progression. Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) has published a consensus paper on brace classification, including the Pash and Lyon braces.¹²

Despite the common use of bracing in treating AIS, considerable variability in treatment outcomes remains, and the factors influencing a patient's response to bracing are

not yet fully understood. A key factor influencing treatment efficacy is the location of the apical vertebra, which is situated at the apex of the curve. The apical vertebra plays a central role in determining the overall alignment and deformity of the spine, and its position within the thoracic or lumbar spine is crucial in determining the success of conservative treatment. Previous studies have shown that patients with thoracic apical vertebrae are more likely to experience curve progression than those with lumbar apical vertebrae.¹³ Moreover, the location of the apical vertebra within the thoracic spine can have significant implications for treatment outcomes, with upper thoracic apical vertebrae generally linked to poorer prognoses than lower thoracic vertebrae.¹³⁻¹⁵

Given the importance of the apical vertebra in scoliosis management, understanding its influence on treatment outcomes is critical for optimizing treatment protocols. Clinicians need to consider not only the magnitude of the curve but also the specific location of the apical vertebra when determining the appropriate course of treatment.

The mechanical behavior of the scoliotic spine informs theoretical assumptions regarding the critical role of apical vertebrae in brace treatment. Intervertebral discs are viscoelastic structures capable of deformation and subsequent recovery. However, the twisting component, which characterizes the scoliotic curve, poses a significant risk. If the disc is subjected to excessive rotation, it may enter a state of hysteresis, which is characterized by a loss of its intrinsic elastic capacity, preventing the disc from returning to its original shape.

The current study aims to comprehensively examine how the location of the apical vertebra affects the outcomes of bracing therapy in patients with AIS. By investigating the relationship between apical vertebra location, curve progression, and bracing response, we aim to provide further insights into how these factors can inform personalized treatment strategies. Understanding this relationship is pivotal for improving patient outcomes, reducing the need for surgery, and enhancing the overall management of adolescent idiopathic scoliosis.

Materials and methods

Study design and methods

From a consecutive series of patients included in a prospective database, we selected 491 female patients with Adolescent Idiopathic Scoliosis (AIS) with curves of 20-40° (mean: 27.89±5.15), Risser grade 0-2. The exclusively female composition of our sample allows for a more ho-

homogeneous analysis of spinal maturity during the pubertal growth spurt. Completion of a minimum 2-year follow-up after brace weaning was a strict inclusion criterion for this study.

This observational, controlled cohort study was nested within a clinical, ongoing database that included 1536 patients with Idiopathic Scoliosis.

Inclusion criteria:

- idiopathic scoliosis;
- curves measuring 20-40°;
- Risser stage 0-2;
- age over ten years;
- X-ray at baseline, end of treatment, and a minimum of two years of follow-up.

Exclusion criteria:

- Cobb angles greater than 40°;
- concurrent musculoskeletal, neurological, or metabolic diseases;
- presence of congenital spine deformities;
- history of spinal surgery.

Bracing protocol

The patients with thoracolumbar and lumbar curves received PASB treatment, while those with thoracic and double significant curves were treated with the Lyon brace.

All patients were prescribed full-time bracing (20-22 hours per day).

To ensure that patients adhere to their treatment, they are always seen by the same physician. Regular check-ups were scheduled every two months until Risser 3, and then every three months thereafter. Parents were always present during these check-ups. The frequent appointments helped us confirm and support adherence by building a positive and open relationship with the patients and their parents.

Treatment compliance was determined through face-to-face interviews during each clinical examination. Their parents confirmed patient responses and indirectly assessed them based on the progression of the spinal curvature. When the spinal curve worsened, a comprehensive evaluation of the patient's behavior was conducted, and greater parental involvement was encouraged.

Endpoints

X-rays were obtained at standardized clinical intervals: baseline (t1), mid-treatment (t2), brace discontinuation at weaning (t3), and a minimum of two-years follow-up after weaning (t4). The t2 radiograph was specifically defined as the in-brace x-ray taken at the midpoint of the duration between t1 and t3.

Our treatment involves clinically following the patient every 3 months by measuring the hump with a humpometer and modifying the brace based on the growth and progression of the hump. A control X-ray is performed every 12 months.

The patients underwent a full-length anteroposterior (AP) radiograph and a standing lateral radiograph. The AP view was used to assess the patient's skeletal age (Risser's sign), the magnitude of the curve (CM, Cobb's method), and the torsion of the apical vertebra (TA: Perdriolle's method).

Measurements were obtained by two independent senior surgeons. The vertebrae were preselected to reduce interobserver bias.

As recommended by the SOSORT and SRS Committee on Bracing and Non-operative Management, outcomes were categorized as follows:

- correction (percentage of patients with $\geq 5^\circ$ curve correction);
- stabilization (percentage of patients with changes in the range of $>-5^\circ$ to $<5^\circ$);
- progression (percentage of patients with $\geq 5^\circ$ progression at maturity);
- percentage of patients with curves exceeding 45° at maturity and those who were recommended for or had undergone surgery.

Statistical analysis

Statistical analysis was performed using GraphPad 9.4.

The Kolmogorov-Smirnov test ascertained the data's normality for all variables.

The primary outcome was the net change in CM and TA from baseline to the 2-year follow-up (t4-t1), which was tested using a Pearson correlation. To assess how the location of the apical vertebra influenced these outcomes, a one-way analysis of variance (ANOVA) was used to compare the mean t4-t1 values among the different apical level groups. Post-hoc comparisons were performed using the Bonferroni correction. As the 2-year follow-up was a mandatory inclusion criterion, the dataset was complete for all 491 patients at t4, and no data imputation was necessary.

Results

A definite outcome was recorded for 491 patients (all female), with a mean age of 11.77 ± 1.83 years at the initial assessment (T1). The Risser sign value was 1.27 (STD 0.81, range 0-2).

Overall, 347 (70%) patients were treated with the PASB

TABLE I.—Average values of parameters evaluated at the beginning of treatment, end of treatment and follow-up.

Parameter	Baseline (t1)	t 2	End of treatment (t3)	Follow-up (t4)	P value T4-T1
Age (years)	11.77±1.883	—	16.44±2.021	20.9±4.13	
Risser	1.273±0.8199	—	—	—	
Menarche	12.38±1.091	—	—	—	
Cobb	27.89±5.159	12.94±7.852	13.97±9.327	16.99±15.85	<0.0001
Perdriolle	11.9±3.74	7.20±4.07	6.47±4.86	7.32±7.81	<0.0001

TABLE II.—Mean values of Cobb and Perdriolle correction depending on the location of the apex vertebrae.

Apical vertebra	N. of values	Mean correction (t4-t1)	SD	SE
Cobb				
T7	9	-7.778	7.48	2.493
T8	61	-10.62	7.766	0.9943
T9	44	-10.91	7.63	1.15
T10	15	-13.8	8.196	2.116
T11	15	-12.87	4.824	1.245
T12	31	-15.48	6.382	1.148
L1	156	-14.47	8.602	0.6887
L2	137	-13.93	7.557	0.6457
L3	23	-13.78	9.11	1.9
Perdriolle				
T7	9	-2.222	3.073	1.024
T8	61	-3.82	3.133	0.4012
T9	44	-3.477	3.968	0.5982
T10	15	-5.467	3.523	0.9096
T11	15	-3.267	1.944	0.5027
T12	31	-5.065	2.658	0.4773
L1	153	-4.974	3.69	0.2983
L2	133	-5.068	3.127	0.2711

brace, while 144 (30%) patients were treated with the Lyon brace. The mean treatment duration was 56.09 ± 24.22 months. The length of follow-up was 53.87 ± 49.45 (range 24-420) months after the end of treatments. Apical vertebra distribution was as follows: T7 (N.=9; 1.8%), T8 (N.=61; 12.4%), T9 (N.=44; 8.9%), T10 (N.=15; 3%), T11 (N.=15; 3%), T12 (N.=31; 6.3%), L1 (N.=156; 31.8%), L2 (N.=137; 27.9%), L3 (N.=23; 4.7%).

The Cobb mean value was $27.89 \pm 5.158^\circ$ at baseline and $16.99 \pm 15.85^\circ$ at follow-up, with a mean correction of t4-t1 of -13.36° ($P<0.0001$; $R=0.3228$). Perdriolle was initially $11.9 \pm 7.319^\circ$ and $7.319 \pm 7.816^\circ$ at follow-up, with a mean correction of t4-t1 of -4.58° ($P<0.0001$, $R=0.4865$) (Table I). According to SOSORT and the SRS Committee on Bracing and Non-operative Management, 411 patients (84%) achieved curve correction, and stabilization was achieved in 70 cases (14%). Ten patients (2%) experienced curve progression; two were recommended for surgery because their curves were over 45° . The Cobb mean correction t4-t1 of the apical vertebral location was reported in the tables (Table II).

The subgroup analysis reveals statistically significant differences in the means of L1 and T9, L1 and T8, L1 and T7, L2 and T7, and T12 and T7, with P values <0.05 (Table III, Figure 1).

Moreover, a significant correlation was observed between the apex vertebra and the mean Cobb correction ($P<0.0001$, $R=0.64$) (Table IV), as well as between rotation at baseline and the mean Cobb correction (Figure 2) ($P<0.0001$) ($R=0.9081$).

Discussion

This study aimed to analyze the impact of apical vertebra location on the outcome of conservative treatment in Adolescent Idiopathic Scoliosis (AIS), specifically with bracing. The findings contribute valuable insights to guide clinicians in optimizing treatment strategies based on the location of the apical vertebra.

Our results confirmed that apical vertebra location is a significant factor influencing the effectiveness of bracing treatment in AIS.

The study demonstrated that the thoracolumbar and lumbar apical vertebrae (such as L1 and L2) were associated with more favorable outcomes regarding curve correction than the thoracic apical vertebrae. Specifically, patients with apical vertebrae in the lumbar spine had a significantly higher mean Cobb angle correction than those with apical vertebrae in the upper thoracic spine (T7, T8, T9).

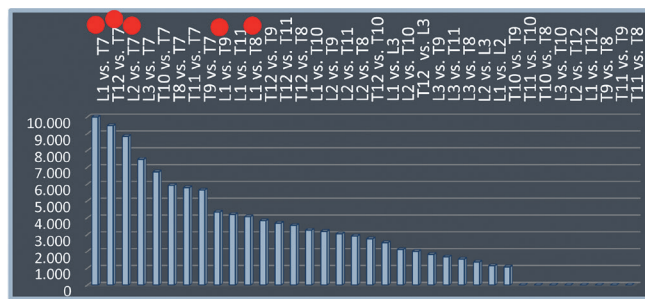


Figure 1.—Mean difference in Cobb correction based on different locations of the apical vertebra.

TABLE III.—Statistically significant differences in the means of L1 and T9, L1 and T8, L1 and T7, L2 and T7, and T12 and T7, with P values of less than 0.05.

Tukey's multiple comparisons test	Mean difference	95% CI	Summary	Adjusted P value
L1 vs. L2	-1.152	-3.489 to 1.186	NS	0.9615
L1 vs. L3	-2.522	-7.166 to 2.121	NS	0.3108
L1 vs. T12	-0.5172	-4.618 to 3.583	NS	>0.9999
L1 vs. T11	-4.2	-9.789 to 1.389	NS	0.2732
L1 vs. T10	-3.267	-8.855 to 3.322	NS	0.6485
L1 vs. T9	-4.345	-7.907 to -0.7834	**	0.0029
L1 vs. T8	-4.067	-7.205 to -0.9292	***	0.0009
L1 vs. T7	-9.997	-17.03 to -2.968	***	0.0001
L2 vs. L3	-1.371	-6.031 to 3.290	NS	>0.9999
L2 vs. T12	0.6345	-3.485 to 4.754	NS	>0.9999
L2 vs. T11	-3.048	-8.651 to 2.555	NS	0.6068
L2 vs. T10	-2.115	-7.718 to 3.488	NS	0.9786
L2 vs. T9	-3.194	-6.777 to 0.3901	NS	0.1505
L2 vs. T8	-2.915	-6.078 to 0.2472	NS	0.1129
L2 vs. T7	-8.845	-15.89 to -1.805	**	0.0017
L3 vs. T12	2.005	-3.437 to 7.444	NS	0.9283
L3 vs. T11	1.677	-8.245 to 4.890	NS	>0.9999
L3 vs. T10	-0.7441	-7.312 to 5.824	NS	>0.9999
L3 vs. T9	-1.823	-6.958 to 3.312	NS	0.9698
L3 vs. T8	-1.545	-6.478 to 3.389	NS	>0.9999
L2 vs. T11	-3.683	-9.048 to 2.582	NS	0.6668
T12 vs. T10	-2.749	-9.014 to 3.516	NS	0.8675
T12 vs. T9	-3.828	-8.170 to 0.8215	NS	0.1705
T12 vs. T8	-3.55	-7.976 to 0.8762	NS	0.2192
T12 vs. T7	-9.48	-17.06 to -1.902	**	0.0018
T11 vs. T10	0.9989	-6.230 to 8.096	NS	>0.9999
T11 vs. T9	-0.1454	-6.149 to 5.858	NS	>0.9999

NS: not significant. Statistically significant differences with P values <0.005 are indicated with asterisks: ** for adjusted P values >0.0010 and *** for adjusted P values ≤0.0010.

TABLE IV.—Correlation between the level of the apex vertebra and the mean Cobb correction.

Spinal segment	Vertebral levels	Pearson's r	Strength of association	P value
Total spine	T7-L3	0.64	Moderate/strong	<0.0001
Lumbar	L1-L3	0.78	Strong	<0.0001
Thoracolumbar	T11-L1	0.61	Moderate/strong	<0.001
Thoracic	T7-T10	0.34	Weak	0.042

These findings align with previous literature, which suggests that patients with lumbar apical vertebrae tend to have more predictable and successful responses to bracing therapy.¹⁶⁻¹⁹

El Hawary *et al.*, in their review, reported better results of conservative treatment in patients with lower levels of vertebral rotations;¹⁷ in a group of 89 patients, Zhang *et al.* illustrated that apical vertebral rotation beyond grade 3 is one of the risk factors for curve progression of more than 5°. ²⁰ Moreover, Aulisa *et al.* showed a correlation between rotation and in-brace correction, confirming that rotation is among the parameters that most influence the deformed spine's reaction to corrective actions.²¹ In fact, in scoliosis, the vertebrae are twisted and locked in an abnormal posi-

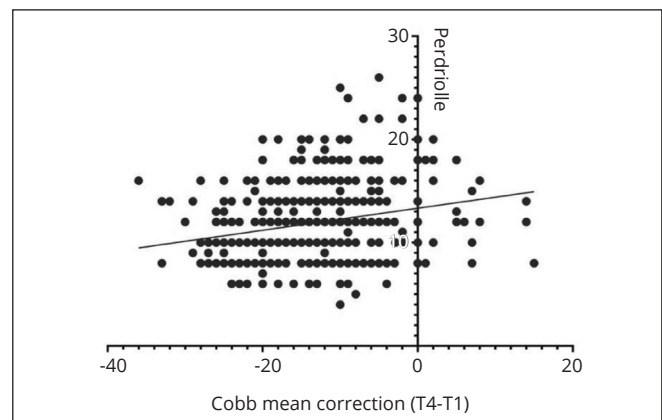


Figure 2.—Correlation between the value of Perdriolle at baseline and the mean Cobb correction (T4-T1).

tion, deforming the discs and increasing the spine's resistance to twisting. This leads to a condition called hysteresis, where the disc becomes stiffer over time and does not fully return to its original shape after being twisted. This stiffness depends on how much the spine is rotated and the disc's original flexibility, which can vary with age and disc

position. In children, discs are more flexible, which can make scoliosis worse over time. However, early and appropriate conservative treatment can halt progression and even correct the deformity. Recovery depends on two main factors: the disc must remain sufficiently flexible (in the elastic-plastic range), and the rotation must be low enough so that, once the twisting force is removed, the spine can return to a more natural position. If the rotation is too high or the disc too stiff, the spine can't fully recover, and only stabilization (not correction) is possible with bracing^{5, 22}

Thompson *et al.* determined how different curve morphologies responded to bracing in a sample of 168 patients. The article showed that, despite similar initial curve magnitudes and full-time bracing, the rate of surgery or curve progression to $\geq 50^\circ$ was significantly greater for main thoracic curves than for main lumbar curves. After combining curve types into the main thoracic and main lumbar, the rate of surgery or curve progression of $\geq 50^\circ$ (combined success) was significantly greater in the leading thoracic group compared to the main lumbar group.²³ The risk of progression of main thoracic curves was also demonstrated by Sun *et al.*²⁴

The subgroup analysis further supports this finding, showing significant differences between the apical vertebrae at L1 and various thoracic vertebrae, such as T7, T8, and T9. This reinforces the importance of identifying the apical vertebra when assessing the prognosis of patients undergoing conservative treatment.

The subgroup analysis of correlation coefficients reveals a clear gradient in brace efficacy. The strong correlation in the lumbar segment ($r=0.78$) underscores the high sensitivity of these vertebrae to corrective forces. In contrast, the weaker correlation in the thoracic segment ($r=0.34$) suggests that the structural constraints of the rib cage impose a mechanical 'ceiling' on correction, where the viscoelastic recovery of the disc is hampered by thoracic stiffness and possible hysteresis.

The observed differences in treatment outcomes highlight the necessity of personalized treatment plans tailored to the individual characteristics of the scoliosis curve, particularly the apical vertebra. Patients with greater baseline rotational deformities showed less correction, emphasizing the need for a comprehensive assessment of the curve's coronal and sagittal aspects when planning treatment. The clinical implications of these findings are considerable. By considering the location of the apical vertebra and its associated rotation, clinicians can refine their treatment approach, selecting the most appropriate bracing techniques and follow-up schedules. These factors should be incorpo-

rated into pre-treatment assessments and serve as important prognostic indicators. Furthermore, our study highlights that treatment adherence, as demonstrated by regular follow-ups and direct parental involvement, is crucial for achieving optimal results. Continuous monitoring enabled timely interventions when curve progression was detected, thereby preventing further deterioration in some cases.

To the best of our knowledge, no study has reported a comparison of results based on the apical vertebra in the same region with those from other regions of the column.

Limitations of the study

A limitation of this study is that our statistical model focused on comparing mean corrections (t4-t1) using a one-way ANOVA, which does not account for potential confounding effects of covariates such as age, menarche, Risser score, or brace type. While the apical vertebra location showed a clear role in the final outcome, future research utilizing multivariate models or mixed-effect models could further clarify the relative weight of these individual clinical factors.

Conclusions

The results of this study confirmed brace treatment as a successful method for treating Adolescent Idiopathic scoliosis. They showed that the apical vertebra plays a significant role in the outcome of conservative treatment. Patients with apical vertebrae in the upper thoracic spine were likelier to have poorer outcomes than those with apical vertebrae in the lumbar spine. Therefore, we should standardize the treatment considering the location of the apical vertebra.

References

1. Cheng JC, Castelein RM, Chu WC, Danielsson AJ, Dobbs MB, Grivas TB, *et al.* Adolescent idiopathic scoliosis. *Nat Rev Dis Primers* 2015;1:15030.
2. Konieczny MR, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. *J Child Orthop* 2013;7:3–9.
3. Aulisa AG, Guzzanti V, Galli M, Bottaro G, Vitelli O, Ferrara P, *et al.* The familiarity of idiopathic scoliosis: statistical analysis and clinical considerations. *Eur J Orthop Surg Traumatol* 2013;23:781–4.
4. Peng Y, Wang SR, Qiu GX, Zhang JG, Zhuang QY. Research progress on the etiology and pathogenesis of adolescent idiopathic scoliosis. *Chin Med J (Engl)* 2020;133:483–93.
5. Aulisa AG, Guzzanti V, Perisano C, Marzetti E, Menghi A, Giordano M, *et al.* Correlation Between Hump Dimensions and Curve Severity in Idiopathic Scoliosis Before and After Conservative Treatment. *Spine* 2018;43:114–9.
6. San Román Gaitero A, Shoykhet A, Spyrou I, Stoorvogel M, Vermeer L, Schlösser TP. Imaging Methods to Quantify the Chest and Trunk Deform-

mation in Adolescent Idiopathic Scoliosis: A Literature Review. *Healthcare (Basel)* 2023;11:1489.

7. Baird C, Archer J, Gardner A, Rushton A, Heneghan NR. Outcomes Evaluating Quality of Life and Their Measurement Properties in Early-onset Scoliosis: A Systematic Review. *J Pediatr Orthop* 2022;42:e917–24.

8. Perdirolle R, Vidal J. Thoracic idiopathic scoliosis curve evolution and prognosis. *Spine* 1985;10:785–91.

9. DiMeglio A, Canavese F, Charles YP. Growth and adolescent idiopathic scoliosis: when and how much? *J Pediatr Orthop* 2011;31(Suppl):S28–36.

10. Fernandes P, Soares Do Brito J, Flores I, Monteiro J. Impact of Surgery on the Quality of Life of Adolescent Idiopathic Scoliosis. *Iowa Orthop J* 2019;39:66–72.

11. Addai D, Zarkos J, Bowey AJ. Current concepts in the diagnosis and management of adolescent idiopathic scoliosis. *Childs Nerv Syst* 2020;36:1111–9.

12. Negrini S, Aulisa AG, Cerny P, de Mauroy JC, McAviney J, Mills A, *et al.* The classification of scoliosis braces developed by SOSORT with SRS, ISPO, and POSNA and approved by ESPRM. *Eur Spine J* 2022;31:980–9.

13. Kenanidis E, Stamatopoulos T, Athanasiadou KI, Voulgaridou A, Pellos S, Anagnostis P, *et al.* Can we predict the behavior of the scoliotic curve after bracing in adolescent idiopathic scoliosis? The prognostic value of apical vertebra rotation. *Spine Deform* 2021;9:91–8.

14. Mohanty SP, Pai Kanhangad M, Gullia A. Curve severity and apical vertebral rotation and their association with curve flexibility in adolescent idiopathic scoliosis. *Musculoskelet Surg* 2021;105:303–8.

15. Lee CS, Hwang CJ, Jung HS, Lee DH, Park JW, Cho JH, *et al.* Association Between Vertebral Rotation Pattern and Curve Morphology in Adolescent Idiopathic Scoliosis. *World Neurosurg* 2020;143:e243–52.

16. Strube P, Gunold M, Müller T, Leimert M, Sachse A, Pumberger M, *et al.* Influence of curve morphology and location on the efficacy of rigid

conservative treatment in patients with adolescent idiopathic scoliosis. *Bone Joint J* 2021;103-B:373–81.

17. Hawary RE, Zaaroor-Regev D, Floman Y, Lonner BS, Alkhalife YI, Betz RR. Brace treatment in adolescent idiopathic scoliosis: risk factors for failure-a literature review. *Spine J* 2019;19:1917–25.

18. Wong LP, Cheung PW, Cheung JP. Curve type, flexibility, correction, and rotation are predictors of curve progression in patients with adolescent idiopathic scoliosis undergoing conservative treatment : a systematic review. *Bone Joint J* 2022;104-B:424–32.

19. Donzelli S, Fregna G, Zaina F, Livetti G, Reitano MC, Negrini S. Predictors of Clinically Meaningful Results of Bracing in a Large Cohort of Adolescents with Idiopathic Scoliosis Reaching the End of Conservative Treatment. *Children (Basel)* 2023;10:719.

20. Zhang Y, Yang Y, Dang X, Zhao L, Ren J, Zhang L, *et al.* Factors relating to curve progression in female patients with adolescent idiopathic scoliosis treated with a brace. *Eur Spine J* 2015;24:244–8.

21. Aulisa AG, Galli M, Giordano M, Falciglia F, Careri S, Toniolo RM. Initial In-Brace Correction: Can the Evaluation of Cobb Angle Be the Only Parameter Predictive of the Outcome of Brace Treatment in Patients with Adolescent Idiopathic Scoliosis? *Children (Basel)* 2022;9:338.

22. Aulisa AG, Guzzanti V, Marzetti E, Giordano M, Falciglia F, Aulisa L. Brace treatment in juvenile idiopathic scoliosis: a prospective study in accordance with the SRS criteria for bracing studies - SOSORT award 2013 winner. *Scoliosis* 2014;9:3.

23. Charles YP, Canavese F, Diméglio A. Curve progression risk in a mixed series of braced and nonbraced patients with idiopathic scoliosis related to skeletal maturity assessment on the olecranon. *J Pediatr Orthop B* 2017;26:240–4.

24. Sun X, Wu T, Liu Z, Zhu Z, Qian B, Zhu F, *et al.* Osteopenia predicts curve progression of adolescent idiopathic scoliosis in girls treated with brace treatment. *J Pediatr Orthop* 2013;33:366–71.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Data availability

The data associated with the paper are available from the corresponding author upon reasonable request.

Ethical approval

Due to the retrospective nature of the study and the use of previously collected, anonymized data, this study did not involve the recruitment of new patients. Ethical approval was waived in accordance with institutional policies. The authors confirm that this article does not report any studies involving embryos, gametes and human embryonic stem cells conducted by the authors. The authors confirm that this article does not report any studies involving animals conducted by the authors.

Informed consent

Written informed consent was obtained from all participants prior to inclusion in the study and for publication of their data, as described in the appropriate section of the manuscript.

Authors' contributions

Angelo G. Aulisa, Martina Marsiolo participated in the conception, design and coordination, acquisition of data, analysis, and interpretation of data, drafted the manuscript and performed the statistical analysis. Francesco Falciglia, Diletta Bandinelli, Marco Giordano and Luca Basiglini helped to draft the manuscript. All authors read and approved the final manuscript.

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