

70. Consensus-Based Guidelines for Research in Bracing in Idiopathic Scoliosis by the SRS Comprehensive Care Committee in Collaboration with SOSORT

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Hypothesis

We hypothesize that a multidisciplinary panel of experts will achieve consensus using a structured Delphi process on recommendations for research in bracing for idiopathic scoliosis (IS).

Design

Hybrid consensus study using a Delphi process followed by an in-person nominal group technique.

Introduction

Significant variability exists in the current literature of bracing research and outcome reporting, highlighting the need to standardize study design and reporting practices to ensure cross-study consistency and comparability. Previous efforts by Scoliosis Research Society (SRS) and Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) have been proposed. However, these recommendations were created over 10 years ago, and the evolving demands of current bracing practices require updated guidelines.

Methods

Three consecutive, anonymous Delphi rounds were administered to 30 multidisciplinary bracing experts invited to participate in this study by the SRS Complementary Care Committee based on their relevant clinical expertise, scholarly productivity, and leadership in the field. Participants completed anonymous, online questionnaires with controlled feedback by a core group of six facilitators. Results from the Delphi process were presented at a final in-person meeting during the 60th Annual SRS Meeting (September 2025). Consensus was defined as $\geq 80\%$ agreement, with non-consensus items refined and redistributed in subsequent rounds.

Results

Of the 30 invited experts, response rates across Delphi rounds were 80%, 83%, and 77%, with 21 experts in attendance at the final, in-person meeting. Consensus was reached on 121 items across 6 domains (38 study methodology, 15 brace prescription and compliance, 25 study outcomes, 6 patient-reported outcomes, 12 skeletal maturity, and 25 radiographs) which were refined and consolidated into a final 28-item summary of consensus-based guidelines for research in bracing IS (Figure 1).

Conclusion

Consensus-based research guidelines for bracing treatment in patients with IS were successfully developed. These recommendations will serve to strengthen methodological rigor and promote consistency across published bracing research and lead to the broader improvement of patient care through higher quality evidence and more effective bracing practices.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

 2025 Consensus-Based Guidelines For Research* in Bracing Idiopathic Scoliosis 			
STUDY METHODOLOGY	OUTCOMES/PROs	RADIOGRAPHS	SKELETAL MATURITY
- Specify brace type(s) used (according to SOSORT-SRS-ISPO-POSNA guidelines) - Clearly define inclusion/exclusion criteria - Report objective measures of brace wear compliance (i.e. Thermal sensors) - Bracing curves <15° and >70° should not be typically studied - Include an explanation for inclusion of patients with curves that reach standard surgical indications (i.e. 50°) and a plan to limit progression - Ideally, include a minimum of 2-year follow-up - Follow patients until skeletal maturity before reporting results as final - Include patients in the <u>main analysis</u> using an intention-to-treat (ITT) approach - Conduct a <u>secondary</u> per-protocol analysis including only patients who met criteria and provided complete primary outcome data - Stratify data analysis between compliant and non-compliant populations - Separately analyze patients not achieving study endpoints that are excluded from main analysis	- Report progression to, or avoidance of, surgery - Report curve changes >5° (progression and improvement) and stabilization of curves (changes ≤5°) - Report brace problems including: - Pain - Skin Lesions - Psychosocial effects - Track and report Patient Reported Outcomes (PROs) - Track clinically important variables at least every 6 months including: - Height - Weight - Skeletal Maturity - Menarche Status	- Standardize radiographic protocols with descriptions of timing and technique - Always report radiographic criteria including: - Cobb angles of primary & compensatory curves - Curve apex location - Curve direction - Coronal balance - Can report radiographic criteria including: - Thoracic kyphosis - Lumbar lordosis 3D parameters - Obtain routine radiographs during active brace treatment at least every 12 months - Obtain and report in-brace radiographs after every new brace is prescribed - Obtain radiographs at least 12 hours out of brace	- Document skeletal maturity at time of brace prescription and at least ONCE every 12 months - Document skeletal maturity until patients are skeletally mature - Sanders (ideally) - Tri-radiate cartilage - Risser - Document menarche status of female patients at each follow-up visit
COMPLIANCE			
- Clearly define bracing compliance - Compliance can be described in different ways including: - Percent of prescribed hours - Total or range of hours worn - Minimal wear time threshold - Report changes in brace-wear prescriptions and prescribed hours			
*Please note, these recommendations are for research purposes and are NOT best practice guidelines. Different approaches in specific research situations may be acceptable with documentation and explanation of the deviation.			

2025 Consensus-based guidelines for research in bracing idiopathic scoliosis

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

71. Doomed to fail? Early Brace Adherence Predicts Long Term Brace Wear Behavior

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Hypothesis

Physicians are able to predict long term brace adherence in idiopathic scoliosis patients at the three-month bracing check-point.

Design

Retrospective chart review

Introduction

As bracing has become the primary non-operative treatment for idiopathic scoliosis (IS), consistent adherence to prescribed brace wear remains essential for achieving optimal clinical outcomes. Early patterns of brace use may provide important insight into long-term compliance, yet the predictive value of short-term adherence has not been fully characterized. This study evaluated whether brace adherence at three months predicts long-term brace adherence in patients treated for IS.

Methods

292 children (65 M, 227 F) with IS ages 7-16 yrs, curves 16°-50°, treated with either anterior or posterior opening thoracic-lumbar-sacral orthoses (TLSO) between 2017 and 2023 were reviewed. Brace adherence was measured using iButton temperature sensors. Patient demographic data and radiographic data was also collected.

Results

292 TLSO braces were prescribed during the study period (49 anterior opening; 243 posterior opening). Average age at brace prescription was 12.5yrs $\pm$ 1.46. Average pre brace major curve Cobb angle was 30.3° $\pm$ 6.9. Overall brace adherence for the cohort was 68.9%, with an average wear time of 12.6 hrs. Using 80% of prescribed hours as a cut off for brace adherence, there was a significant difference in patients' 3-month brace adherence between brace adherent (n= 121, 97.9%) and non-adherent (n=171, 65.1%) subgroups (p=0.000). Additionally, 3-month average brace usage strongly correlated to overall brace compliance (r=0.824, p<0.01). Using a linear regression controlling for brace type, Risser score, age, Cobb angle, and sex, each 1%-point increase in 3-month brace adherence was associated with a 0.8%-point increase in overall, final brace compliance (p=0.000).

Conclusion

Three-month brace adherence was strongly associated with long-term brace adherence in patients with IS. Early compliance with brace wear appears to be a meaningful predictor of sustained adherence throughout treatment. These findings suggest that the three-month bracing checkpoint may serve as a critical window for identifying patients at risk for long-term non-adherence and for implementing targeted interventions to improve brace wear behavior.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

72. A Step Closer To Bringing Idiopathic Scoliosis Monitoring At Home: A Smartphone App Accurately Generates Digital Twins in 624 Pediatric Patients

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Hypothesis

A smartphone-based, AI-powered 3D surface topography application can estimate Cobb angles and detect clinically significant scoliosis compared with radiography.

Design

Diagnostic accuracy study comparing smartphone-based 3D Cobb angle estimates with radiographic measurements for detection of scoliosis $\geq 20^\circ$.

Introduction

Idiopathic scoliosis is the most common pediatric spinal deformity, affecting 1–4% of adolescents. Despite most patients not requiring treatment, screening and follow-up rely on repeated radiographs with cumulative radiation exposure. Surface topography offers a non-invasive, radiation-free alternative by linking torso asymmetry to spinal curvature.

Methods

In this prospective cohort study (November 2022–March 2025), pediatric patients (aged 5–21 years) with suspected or confirmed IS were enrolled at five centers across three countries. Each underwent biplanar radiographs and smartphone-based surface scans at the same visit. Agreement was evaluated using Spearman's correlation and Bland–Altman analysis. Factors associated with discrepancies were assessed using Kruskal–Wallis and correlation tests. Diagnostic performance for detecting scoliosis $\geq 20^\circ$ was summarized with accuracy, precision, recall, and confusion matrix analysis ($\alpha = 0.05$).

Results

A total of 624 radiograph–scan pairs were analyzed (76.7% female; mean age 13.6 ± 2.4 years). Surface scan–derived Cobb angles correlated strongly with radiographic measurements ($r = 0.775$, $p < 0.001$), with a mean bias of -3.6° and limits of agreement from -16.9° to 24.0° . Prediction errors were significantly influenced by brace status, scan quality, site, Cobb class and skin type. When the analysis was limited to high-quality scans ($n = 382$), the correlation improved ($p = 0.861$), with a mean bias of 2.4° , limits of agreement ranging from -14.4° to 19.2° , and 42% and 74% of predictions falling within $\pm 5^\circ$ and $\pm 10^\circ$ of the reference values, respectively. For detecting scoliosis $\geq 20^\circ$ using all scans, the model achieved an accuracy of 84%, precision of 90%, and recall of 89%.

Conclusion

The smartphone-based 3D imaging system showed moderate agreement with radiographic Cobb angles and was adequate for detecting clinically significant scoliosis, though accuracy was influenced by curve and patient factors. Further longitudinal, real-world studies are needed to define its role as a complementary radiation-free tool.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

73. Casting and Bracing are Associated with Worsening Quality of Life (QOL) in Early Onset Scoliosis (EOS) Patients – Does QoL Improve with Surgery?

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Hypothesis

Casting and bracing can lead to decreases in QoL that may improve after surgery.

Design

Multicenter retrospective review.

Introduction

QoL changes in EOS patients undergoing nonoperative management have been less well-studied than in surgically-treated patients. Our purpose was to 1) assess whether QoL changes in EOS patients undergoing nonoperative treatment, and 2) compare QoL changes when these patients undergo surgery.

Methods

Idiopathic EOS patients ages 0-18 years undergoing observation (OBS), bracing (BRACE), or casting (CAST) who completed ≥ 2 EOSQ-24s were included. Patients who later underwent surgery had to have ≥ 1 preoperative and ≥ 1 postoperative EOSQ-24. Univariate and multivariate linear regression analyses were conducted. Age was considered in the multivariate model both continuously and as tertiles (≤ 2 , 3-5, ≥ 6 years).

Results

612 patients (260 OBS, 159 BRACE, 193 CAST) were analyzed. Compared to OBS, CAST had significantly greater decreases in Daily Living (-7.1 ± 2.3 , $p < 0.01$, uni), Parental Impact (-4.8 ± 1.9 , $p < 0.05$, multi age continuous), and Physical Function (-5.5 ± 2.7 , $p < 0.05$, multi age tertile). CAST also had greater decreases in Transfer in all models (-6.3 ± 2.1 , $p < 0.01$, uni; -7.6 ± 2.6 , $p < 0.01$, multi age continuous; -8.3 ± 2.7 , $p < 0.01$, multi age tertiles). BRACE had a significantly greater decrease in Emotion (-4.3 ± 2.2 , $p < 0.05$, multi age tertile). There were no group differences in the remaining domains, including General Health, Pain, and Child Satisfaction (Table). 88 patients (2 OBS, 47 BRACE, 39 CAST) transitioned to surgery. Compared to BRACE, CAST had a significantly greater increase in Parent Satisfaction (12.5 ± 5.5 , $p < 0.05$, uni) after surgery.

Conclusion

Children treated with casting experienced worsening QoL over time, as demonstrated by greater decreases in Daily Living, Parental Impact, Physical Function, and Transfer scores, compared to children who were observed. Children who were braced had a greater decrease in Emotion score. Compared to bracing, parents of casting patients had a greater increase in Satisfaction after surgery, suggesting a greater parental burden with casting that was partially alleviated postoperatively. Although nonoperative treatment is generally considered to be more benign than surgery, the potential long-term impact on QoL should be discussed with families.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

74. Boys with Adolescent Idiopathic Scoliosis Treated with Nighttime Bracing Have Similar Outcomes to Girls

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Hypothesis

Boys with adolescent idiopathic scoliosis (AIS) treated with nighttime bracing have worse outcomes than girls.

Design

Retrospective review

Introduction

The few studies evaluating brace treatment outcomes specific to boys with AIS have found inferior results. We evaluated brace adherence and curve progression in boys with AIS treated with nighttime bracing compared to girls.

Methods

All children with AIS Risser stages 0 to 2, major curves 15° to 40° with predominantly thoracolumbar/lumbar curves treated with Providence nighttime braces prescribed ≥8 hours per night from 2015 to 2019 were retrospectively reviewed until either skeletal maturity or surgery. Brace adherence was measured using iButton temperature sensors at brace discharge. Brace outcomes included curve progression ≥6° and progression to surgical threshold of ≥45° among boys versus girls and boys with curves <25°, and the traditional SRS bracing guidelines of curves 25-40°.

Results

66 boys and 241 girls were included. At brace prescription, boys were older and had similar curve magnitudes (24° vs. 24°), triradiate cartilage status, body mass index, and years braced (Table). In-brace correction was similar (103% vs. 103%). From brace prescription to skeletal maturity or surgery, boys grew more (12cm vs. 9cm, $p=0.007$). Boys had similar brace wear adherence throughout bracing (6.4hrs vs. 7.0hrs, $p=0.09$). Boys also had similar amounts of curve progression (4° vs. 2°, $p=0.56$) and similar rates of curve improvement ≥6° (17% vs. 20%, $p=0.60$), curve progression ≥6° (32% vs. 29%, $p=0.66$), and progression to surgical magnitude (8% vs. 4%, $p=0.19$). Boys with curves <25° ($n=40$) had similar amounts of curve progression (4° vs. 2°, $p=0.42$) and similar rates of progression to surgical magnitude (10% vs. 4%, $p=0.13$) as girls ($n=151$). Boys with curves ≥25° ($n=26$) also had similar progression (5° vs. 3°, $p=0.49$) and similar rates of surgery (8% vs. 3%, $p=0.37$) as girls ($n=116$).

Conclusion

Contrary to the literature from full-time bracing, boys with predominantly thoracolumbar/lumbar AIS treated in Providence nighttime braces have similar brace wear adherence and treatment outcomes to girls. Nighttime bracing for boys should be offered more frequently as a highly effective non-operative treatment approach.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

	Boys (n=66)	Girls (n=241)	p-value
Race/Ethnicity			
White	67% (n=44)	71% (n=171)	0.65
Hispanic	11% (n=7)	11% (n=26)	
Black	8% (n=5)	6% (n=15)	
Other	9% (n=6)	5% (n=11)	
Asian	6% (n=4)	7% (n=18)	
Initial age (years)	13.8±1.5 (n=66)	12.3±1.2 (n=241)	<0.001*
Initial body mass index (kg/m ²)	18.5±2.8 (n=66)	18.1±2.7 (n=238)	0.27
Initial primary curve			
Thoracic	6% (n=4)	16% (n=38)	0.042*
Thoracolumbar/Lumbar	94% (n=62)	84% (n=116)	
Brace design			
Double	20% (n=11)	34% (n=78)	0.08
Thoracolumbar	66% (n=37)	50% (n=116)	
Lumbar	14% (n=8)	15% (n=35)	
Initial Risser stage			
0	64% (n=42)	76% (n=184)	0.005*
1	9% (n=6)	12% (n=30)	
2	27% (n=17)	11% (n=27)	
Initial triradiate cartilage			
Open	47% (n=31)	46% (n=110)	0.91
Closed	54% (n=35)	54% (n=131)	
Initial curve magnitude (°)	24±4 (n=66)	24±4 (n=241)	0.66
In-brace correction (%)	103±29 (n=55)	103±29 (n=227)	0.93
Years braced	2.4±0.9 (n=64)	2.2±0.9 (n=235)	0.29
Total brace wear (hr/day), according to sensor data	6.4±2.5 (n=51)	7.0±2.4 (n=191)	0.09
Growth (cm)	11.9±7.5 (n=66)	9.2±5.6 (n=237)	0.007*
Total curve progression (°)	4±12 (n=66)	2±9 (n=241)	0.56
Improvement ≥6°	17% (n=11)	20% (n=47)	0.60
Stable, between -5° and 5°	52% (n=34)	51% (n=124)	0.99
Progression ≥6°	32% (n=21)	29% (n=70)	0.66
Progression to full-time brace	8% (n=5)	11% (n=27)	0.39
Progression to 45°	9% (n=6)	5% (n=13)	0.26

*p<0.05. Initial=time of brace prescription

Characteristics, anthropometrics, and outcomes in boys versus girls

75. Nighttime Bracing is Equivalent to Full-time Bracing in Avoiding Curve Progression to Surgery in AIS Curves 20-35°

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Hypothesis

Nighttime bracing (NTB, 8 h/night) has similar radiographic outcomes as full-time bracing (FTB, ≥ 18 h/day) in adolescent idiopathic scoliosis (AIS).

Design

Retrospective cohort

Introduction

Studies comparing NTB to FTB lack adherence data and do not control curve type, curve magnitude, and skeletal maturity. This study compares radiographic outcomes between NTB and FTB in AIS.

Methods

Patients braced at Risser 0-2 with AIS curves 20°–35° between 2015–2019 were followed until skeletal maturity or progression to a surgical threshold ($\geq 45^\circ$). Temperature sensors determined brace wear. First, NTB versus FTB cohorts were compared. Next, patients were propensity score-matched for curve magnitude and triradiate cartilage (TRC) status at brace initiation to compare NTB versus FTB within 1) thoracic and 2) thoracolumbar/lumbar curve subgroups. Primary outcomes were curve progression $\geq 6^\circ$ and progression to surgery.

Results

520 (265 NTB, 255 FTB) patients were 12.5 ± 1.3 yrs at brace initiation. The NTB group had more thoracolumbar/lumbar curve types (86% vs 14%, $p < .001$), smaller curves (24° vs 27°, $p < .001$), and lower rates of open TRC (47% vs 56%, $p = .027$). Brace wear averaged 7.0 ± 2.3 h for NTB (86% adherence) and 12.1 ± 5.8 h for FTB (66% adherence). NTB demonstrated greater curve improvement $\geq 6^\circ$ (21% vs 11%, $p = .002$), less curve progression $\geq 6^\circ$ (31% vs 45%, $p < .001$), and less progression to surgery (6% vs 20%, $p < .001$). Multivariable linear regression analysis including sex, BMI, TRC status, brace type, curve type, and curve magnitude identified open TRC and larger curves as predictors of progression to surgery, not brace type. In matched thoracic pairs ($n = 37$), NTB and FTB curves averaged 27° with 51% open TRC, and had similar progression $\geq 6^\circ$ (24% vs 32%, $p = .44$) and progression to surgery (5% vs 11%, $p = .67$). In matched thoracolumbar/lumbar pairs ($n = 32$), NTB and FTB curves averaged 24°, 59% open TRC, and also had similar progression $\geq 6^\circ$ (31% vs 28%, $p = .78$) and progression to surgery (13% vs 9%, $p = 1.00$).

Conclusion

Nighttime bracing is equivalent to full-time bracing in stopping curve progression in skeletally immature AIS curves $\leq 35^\circ$. When matched by curve type, magnitude, and skeletal maturity, radiographic outcomes remained similar between NTB and FTB, supporting NTB as a viable, lower-burden treatment option for appropriately selected patients.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

	Nighttime brace	Full-time brace	p-value
<i>Total Sample</i>	n=265	n=255	
Female Sex	78% (n=208)	84% (n=215)	0.088
Initial age (yrs)	12.6±1.3	12.3±1.2	0.023
Initial curve type			<0.001
Thoracic	14%	86%	
Thoracolumbar/Lumbar	86%	14%	
Initial curve magnitude (°)	24.4±3.3	26.9±4.0	<0.001
Initial Risser grade			0.210
0	75%	75%	
1	11%	15%	
2	14%	10%	
Open TRC status	47%	56%	0.027
Initial BMI	18.3±2.9	19.2±3.5	0.003
Years braced	2.2±0.9	2.0±1.0	<0.001
Avg brace wear (h)	7.0±2.3	12.1±5.8	<0.001
Growth (cm)	9.7±6.0	9.0±5.8	0.166
Final curve magnitude (°)	26.7±10.8	33.5±12.7	<0.001
Total curve progression (°)	2.3±10.1	6.6±11.7	<0.001
Curve improvement ≥6°	21%	11%	0.002
Curves stable (-5° to 5°)	48%	44%	0.317
Curve progression ≥6°	31%	45%	<0.001
Progression to surgery	6%	20%	<0.001
<i>Matched thoracic pairs</i>	n=37	n=37	
Open TRC status	51%	51%	1.00
Initial curve magnitude (°)	23.5±2.6	23.5±2.6	0.969
Final curve magnitude (°)	26.2±10.5	27.9±11.9	0.581
Curve improvement ≥6°	17%	13%	0.562
Curve progression ≥6°	24%	32%	0.439
Progression to surgery	5%	11%	0.674
<i>Matched thoracolumbar/lumbar pairs</i>	n=32	n=32	
Open TRC status	59%	59%	1.00
Initial curve magnitude (°)	26.7±3.9	26.7±3.9	1.00
Final curve magnitude (°)	30.5±12.6	31.0±10.3	0.925
Curve improvement ≥6°	14%	7%	0.670
Curve progression ≥6°	31%	28%	0.784
Progression to surgery	13%	9%	1.00

*Bold indicates p<0.05. TRC=triradiate cartilage. Initial=time of brace prescription; Final=skeletal maturity or progression to surgery.

76. Impact of Skeletal Maturity in Vertebral Body Tethering: Early Outcomes from a Prospective, Multicenter Study

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Hypothesis

Risser and Sanders stages do not significantly affect most vertebral body tethering (VBT) outcomes at 2 year follow-up.

Design

Multicenter prospective cohort

Introduction

VBT in older patients is seen as controversial with less potential for permanent correction due to growth modulation. This study compares early (2 year) VBT outcomes in Risser 0-2 vs. 3-5 and Sanders 1-4 vs. 5-8 patients as this is a threshold for treatment in published POSNA/SRS guidelines.

Methods

All qualifying patients with adolescent idiopathic scoliosis (AIS) who underwent thoracic and lumbar VBT between 2019 and 2023 were prospectively enrolled from 9 institutions with minimum 2-year follow-up. Patients were grouped by preop Risser and Sanders stages. Fisher's exact tests, independent, and paired t-tests were used for analysis of outcomes.

Results

164 patients met inclusion and exclusion criteria and were prospectively enrolled. No significant differences were observed in the preoperative demographics, reoperation rates, complication rates, or fusion rates between the skeletally maturity groups. Over the 2-year follow-up, patients demonstrated improvements in thoracic (48 ± 11 vs. $24 \pm 11^\circ$, $p < 0.001$) and lumbar (38 ± 13 vs. $20 \pm 9^\circ$, $p < 0.001$) curve magnitudes, with no significant differences in sagittal plane parameters or shoulder alignment.

Conclusion

Curve correction, reoperation, fusion, and complication rates were similar at 2-years in Risser 3-5 and Sanders 5-8 patients compared to Risser 0-2 and Sanders 1-4 patients. Given the known incidence of cord breakage after 2 years, this should not be interpreted as an endorsement for VBT in older patients with little potential for growth modulation, but as an important early time point of which longer-term follow-up is required.

	Risser 0-2 (n=135)	Risser 3-5 (n=29)	p-value
Age at surgery (years)	12.9 ± 1.4	14.1 ± 1.3	<0.001*
% Female	80.7%	65.5%	0.085
Height (cm)	156.7 ± 9.6	163.6 ± 9.8	<0.001*
Weight (kg)	47.4 ± 10.7	52.9 ± 11.2	0.014*
BMI	19.2 ± 3.4	19.7 ± 3.4	0.450
Preop Major Curve Magnitude (°)	51 ± 10	50 ± 9	0.587
Preop Thoracic Curve (°)	48 ± 11	46 ± 12	0.355
Preop Lumbar Curve (°)	39 ± 13	36 ± 15	0.381
Preop T2-T12 (°)	24 ± 12	26 ± 15	0.443
Preop Lumbar Lordosis (°)	-55 ± 11	-58 ± 12	0.176
Preop Shoulder Height	1.2 ± 1.5	0.5 ± 0.5	0.055
First Erect Major Curve Magnitude (°)	27 ± 8	28 ± 9	0.668
	Sanders 1-4 (n=123)	Sanders 5-8 (n=41)	p-value
Age at surgery (years)	12.8 ± 1.4	13.9 ± 1.3	<0.001*
% Female	76.4%	82.9%	0.514
Height (cm)	156.9 ± 10.2	161.1 ± 8.4	0.019*
Weight (kg)	47.4 ± 11.5	51.1 ± 8.7	0.059
BMI	19.1 ± 3.5	19.7 ± 3.2	0.309
Preop Major Curve Magnitude (°)	51.5 ± 10.3	47.1 ± 7.7	0.013*
Preop Thoracic Curve (°)	49 ± 11	43 ± 11	0.002*
Preop Lumbar Curve (°)	39 ± 13	36 ± 13	0.143
Preop T2-T12 (°)	24 ± 12	22 ± 13	0.434
Preop Lumbar Lordosis (°)	-56 ± 11	-54 ± 11	0.507
Preop Shoulder Height	1.2 ± 1.5	0.8 ± 0.8	0.230
First Erect Major Curve Magnitude (°)	28 ± 8	25 ± 8	0.049*
	Preoperative	2-year	p-value
Height (cm)	157.4 ± 10.2	163.6 ± 9.2	<0.001*
Risser 0-2	156.3 ± 9.9	163.0 ± 9.0	<0.001*
Risser 3-5	162.8 ± 10.4	166.4 ± 9.5	<0.001*
Sanders 1-4	156.5 ± 10.6	163.6 ± 9.6	<0.001*
Sanders 5-8	160.2 ± 8.2	163.4 ± 7.9	<0.001*
Major Curve Magnitude (°)	51 ± 9	25 ± 11	<0.001*
Risser 0-2	51 ± 9	26 ± 11	<0.001*
Risser 3-5	49 ± 8	24 ± 10	<0.001*
Sanders 1-4	52 ± 9	27 ± 11	<0.001*
Sanders 5-8	47 ± 8	22 ± 10	<0.001*
Thoracic Curve (°)	48 ± 11	24 ± 11	<0.001*
Lumbar Curve (°)	38 ± 13	20 ± 9	<0.001*
T2-T12 (°)	24 ± 13	25 ± 15	0.338
Lumbar Lordosis (°)	-55 ± 12	-53 ± 11	0.272
Shoulder Height Difference (cm)	1.0 ± 1.4	1.0 ± 0.8	0.997
	Risser 0-2 (n=135)	Risser 3-5 (n=29)	p-value
Reoperation	16	1	0.312
Fusion	3	1	0.545
Major Complication	6	0	0.592
	Sanders 1-4 (n=123)	Sanders 5-8 (n=41)	p-value
Reoperation	16	1	0.074
Fusion	4	0	0.573
Major Complication	5	1	0.532

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper,
‡SRS Funded Research Grant

77. Prospective, Multicenter Comparison of Hybrid and Bilateral VBT in the Treatment of Idiopathic Scoliosis

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Hypothesis

Bilateral VBT and hybrid procedures have similar radiographic and clinical outcomes at min 2-yr f/u

Design

Prospective, multicentre

Introduction

Vertebral body tethering (VBT) has shown to be safe and effective with motion-preservation being the advantage over fusion. For double major curves (Lenke 1C, 3C, 6C) two procedures have recently emerged: bilateral double VBT (both curves tethered) and hybrid procedure (thoracic posterior fusion and lumbar VBT). Our aim was to compare outcomes between these two methods at min 2 yr f/u to gain insight around treatment decisions and patient selection.

Methods

A prospective, multicentre non-fusion database identified consecutive patients that underwent either a bilateral single row, single tether VBT procedure (BSTG) or hybrid construct (HG) with min 2yr f/u. Preop, periop, and postop clinical, radiographic and complication data were compared between groups. Linear mixed-effects models were used, adjusted for baseline values.

Results

49 BSTG patients were compared to 45 HG patients. Mean age for BSTG was 12.7 $\pm$ 1.4yrs and HG was 12.7 $\pm$ 1.5yrs. Avg preop thoracic curve was 49.6 $\pm$ 8.7° in BSTG and 57.6 $\pm$ 12.7° in HG (p=0.001) and mean preop lumbar curve was 45.1 $\pm$ 12.2° (BSTG) compared to 54.2 $\pm$ 10.3° (HG) (p=0.004). Mean ORT, EBL, and LOS was significantly less in BSTG compared to HG (p=0.009, p<0.001, p<0.001, respectively). Adjusted mean post-op pain scores were significantly lower at 2yrs in BSTG compared to HG (VAS: 0.7 [95%CI: 0.3, 1.1] vs 1.6 [95%CI: 1.2, 2]; p=0.002). Adjusted mean thoracic coronal Cobb was significantly improved in HG compared to BSTG (13.4 [95%CI: 10.7, 16.1] vs 25.4° [95%CI: 22.9, 27.9]; p<0.0001) at 2yrs as well adjusted mean lumbar coronal Cobb (HG: 14.2° vs 21.4°; p<0.0001). No significant difference in thoracic or lumbar prominence was noted between groups (p=0.08, p=0.19, respectively). BSTG showed significantly better range of motion at 2yrs in forward flexion (p<0.001) and left/right lateral flexion compared to HG (p=0.0003/p=0.04). Despite 24% reported complications in BSTG compared to 44% in HG (p=0.3), there was no difference in adjusted mean SRS outcome scores in all domains across all f/u time-points between groups (p>0.05).

Conclusion

HG provides better coronal Cobb correction compared to BSTG. However, BSTG appears to preserve better spinal motion, is associated with decreased periop morbidity and lower pain scores at 2yrs post-op. The choice between these procedures will depend on patient priorities.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡ SRS Funded Research Grant

Table

Patient Demographics	BSTG	HG	P-value
Mean age(yrs)	12.7+/-1.4	12.7+/-1.5	
Gender (%)	M=18 F=82	M=24 F=76	
Mean Baseline Thoracic Cobb (°)	49.6+/-8.7	57.6+/-12.7	0.001*
Mean Baseline Lumbar Cobb (°)	45.1+/-12.2	54.2+/-10.3	0.004*
PeriOp Outcomes	BSTG	HG	P-value
Mean ORT (minutes)	335.4+/-100	410.8+/-154	0.009*
Mean EBL (cc)	184.7+/-155	433.4+/-315.7	<0.001*
Mean LOS (d)	3.9+/-1.7	6.0+/-2.1	<0.001*
Post-op Outcomes (2 yr Adjusted Means)	BSTG	HG	P-value
Pain VAS Score	0.7	1.6	0.002*
Thoracic Cobb (°)	25.4	13.4	<0.0001*
Lumbar Cobb (°)	21.4	14.2	<0.0001*
Thoracic Rib Prominence (°)	6.6	8.4	0.08
Lumbar Prominence (°)	4.4	3.3	0.19
Forward Flexion (cm)	14.0	11.1	<0.001*
Left Lateral Flexion (cm)	16.3	12.5	0.0003*
Right Lateral Flexion (cm)	15	12.8	0.04*
SRS Outcome Scores (2 yr Adjusted Means)	BSTG [95% CI]	HG [95% CI]	P-value
Pain	4.2[4.4,4.4]	4.3[3.9,4.5]	0.84
Self-Image	4.2[3.9,4.6]	4.3[3.9,4.6]	0.57
General	4.5[4.3,4.7]	4.4[4.1,4.6]	0.58
Mental	4[3.8,4.3]	3.9[3.6,4.2]	0.34
Satisfaction	4.5[4.3,4.7]	4.4[4.4,4.7]	0.48
Total	4.3[4.1,4.4]	4.2[4.4,4.4]	0.64
Complications	BSTG	HG	P-value
Neurologic	0	2	
Pain	5	11	
Radiographic	2	2	
Reoperations	1	2	
SSI	0	3	
GI	1	0	
Medical	2	0	
Pulmonary	1	0	
Total	12	20	0.3

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

78. Defining Multidomain “Success” After Vertebral Body Tethering for Adolescent Idiopathic Scoliosis

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Hypothesis

VBT will significantly improve major Cobb angle and SRS-22 Total, with most patients achieving composite success (VBT-SS ≥ 6) at follow-up.

Design

Single-site, retrospective cohort study with prospective follow-up when available.

Introduction

Outcomes after vertebral body tethering (VBT), which aims to correct coronal deformity while preserving motion through growth modulation for adolescent idiopathic scoliosis (AIS), are inconsistently reported. We applied a pragmatic multidomain success framework to evaluate VBT performance at midterm follow-up.

Methods

AIS patients aged 8–18 years undergoing primary VBT with approximately 2-year follow-up were included. Six pre-specified success domains were assessed: (1) safety and durability (no conversion to fusion and no unplanned reoperation), (2) coronal correction (final major Cobb $\leq 30^\circ$ or $\geq 50\%$ correction), (3) spinal balance (coronal balance ≤ 20 mm and sagittal vertical axis ≤ 50 mm), (4) function (clinically meaningful SRS-22 Total improvement, $\Delta \geq 0.23$), (5) satisfaction/cosmesis, and (6) composite success defined by a VBT Success Score (VBT-SS ≥ 6). Paired analyses compared pre- and postoperative radiographic and SRS-22 outcomes.

Results

A total of 148 patients (mean age 14.4 ± 1.7 years; 85.6% female) were included. Major Cobb angle improved from $54.1 \pm 10.3^\circ$ to $28.9 \pm 10.9^\circ$ ($\Delta -25.2 \pm 11.2^\circ$, $p < 0.001$), with mean correction of $46.3 \pm 17.8\%$. Secondary curves improved from $45.6 \pm 10.9^\circ$ to $24.9 \pm 9.6^\circ$ ($\Delta -20.7 \pm 11.7^\circ$, $p < 0.001$). Mean SRS-22 Total score improved from 3.49 to 4.29 ($\Delta +0.80$, $p < 0.001$). Domain-level and composite success outcomes are summarized in Table 1, with composite success achieved in 85.1%.

Conclusion

A multidomain definition of success provides a clinically meaningful assessment of VBT outcomes beyond isolated radiographic metrics. Within this framework, avoidance of fusion, together with maintenance of balance and functional improvement, emerged as a central determinant of composite success. This framework enables transparent benchmarking and improves patient counseling.

Table 1. Multidomain Success Framework and Outcomes After Vertebral Body Tethering.

Domain	Operational Definition	Outcome
Safety & Durability	No fusion conversion or unplanned reoperation	127 / 148 (85.8%)
Coronal Correction	Final major Cobb $\leq 30^\circ$ or $\geq 50\%$ correction	85 / 148 (57.4%)
Spinal Balance	Coronal ≤ 20 mm and SVA ≤ 50 mm	86 / 105 (81.9%)
Function (PROs)	SRS-22 MCID ($\Delta \geq 0.23$)	40 / 60 (66.7%)
Satisfaction / Cosmesis	Patient/parent-reported satisfaction	39 / 53 (73.6%)
Composite Success (VBT-SS ≥ 6)	≥ 6 weighted domains met	126 / 148 (85.1%)

Success rates are reported among patients with available data for each domain.

Figure 1. Conceptual multidomain framework for defining success after vertebral body tethering, integrating safety, deformity correction, spinal balance, patient-reported function, and satisfaction into a composite success score (VBT-SS).

Figure 1. Conceptual multidomain framework for defining success after vertebral body tethering, integrating safety, deformity correction, spinal balance, patient-reported function, and satisfaction into a composite success score (VBT-SS).

79. Double Major Curves in AIS: Results of a Novel Hybrid Approach Combining Thoracic Fusion with Lumbar Vertebral Body Tethering

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Hypothesis

Patients undergoing hybrid fixation will demonstrate adequate clinical and radiographic outcomes.

Design

Retrospective review of prospective single institution study

Introduction

Currently, AIS patients with double major curves are offered fusion for both curves which provides excellent radiographic outcomes, but fusion of the lumbar segment limits motion and may predispose to degenerative disease. The hybrid approach combines thoracic fusion with lumbar VBT with the hope of minimizing these potential downsides, but this approach is limited by paucity of data.

Methods

78 patients were identified who underwent the hybrid approach with 15 being treated for double major curves with minimum 2 yr f/u (mean 2.6yrs). Clinical and radiographic variables were collected and compared from pre-op, first erect (FE), and last visit (LV) utilizing Students t-test.

Results

Patients were skeletally immature with a mean age of 13.3 ± 1.6 years (female=60%) and a mean Sanders score of 3.9 ± 1.7 . 9 patients had a Lenke 6 curve type, and 6 Lenke 3. PSF procedures took a mean of 356 ± 79 minutes, and VBT procedures had a duration of 370 ± 64 minutes. Estimated blood loss (EBL) was 141 ± 115.4 mL for VBT and 387 ± 236.9 mL for PSF. Thoracic curves improved from $63.9 \pm 10.3^\circ$ pre-op to $14.9 \pm 5.7^\circ$ at FE ($p < 0.001$), which was unchanged at LV ($13.8 \pm 7.1^\circ$, $p = 0.474$). Lumbar curves improved from $62.0 \pm 10.6^\circ$ pre-op to $23.9 \pm 8.1^\circ$ at FE ($p < 0.01$) and continued to improve at LV (13.3 ± 7.8 , $p < 0.01$). Both thoracic kyphosis (pre-op= $24.0 \pm 12.2^\circ$, post-op= $26.5 \pm 7.7^\circ$, $p = 0.55$) and lumbar lordosis (pre-op= 59.5 ± 9.8 , post-op= 53.8 ± 12.7 , $p = 0.54$) did not change. Thoracic scoliometer improved from $14.8 \pm 4.3^\circ$ to $4.3 \pm 4.6^\circ$. 5 patients (33%) required revision surgery: 4 underwent tether release for overcorrection 1 one had removal of a prominent tether screw. SRS self-image and satisfaction scores improved postoperatively. No patients have required extension of fusion into the lumbar spine.

Conclusion

Hybrid fixation with thoracic PSF and lumbar VBT is a viable option for patients with structural thoracic and lumbar curves. Even large lumbar curves (those outside of indications for VBT) demonstrate modulation with high probability of avoiding lumbar fusion.

Demographic Information				
Total number of VBT	15			
Female	9 (60%)			
AJS	12 (80%)			
Years follow-up	2.6 ± 0.4			
Age at index procedure	13.3 ± 1.6			
Radiographic Information	PreOp	FE	Latest	p-value
Proximal thoracic	20.3 ± 8.4	7.1 ± 4.5	4.6 ± 4.0	<0.01
Main thoracic	63.9 ± 10.3	14.9 ± 5.7	13.8 ± 7.1	<0.01
Lumbar	62.0 ± 10.6	23.9 ± 8.1	13.3 ± 7.8	<0.01
Kyphosis (T5-T12)	24.0 ± 12.2	22.1 ± 8.1	26.5 ± 7.7	0.55
Lordosis (T1-S1)	59.5 ± 9.8	53.8 ± 12.7	61.2 ± 11.4	0.54
Open triradiate cartilage	4 (26.7%)	3 (20.0%)	0 (0%)	0.10
Sanders	3.9 ± 1.7			
Risser	1.5 ± 1.9	1.5 ± 1.9	4.1 ± 1.0	<0.01
Thoracic scoliometer	14.8 ± 4.3		4.3 ± 4.6	<0.01
Lumbar scoliometer	11.2 ± 7.8		3.8 ± 6.3	0.03
Postop correction				
FE % correction thoracic	76.1 ± 8.7%			
FE % correction lumbar	61.6 ± 10.6%			
2Y % correction thoracic	74.1 ± 13.0%			
2Y % correction lumbar	78.2 ± 11.3%			
Reoperation Information				
Number of subjects requiring reoperations	5 (33.3%)			
Months from index	23.6 ± 6.2			
SRS Scores	PreOp	Latest	p-value	
Function	3.9 ± 0.9	4.3 ± 0.6	0.24	
Pain	3.7 ± 1.4	4.1 ± 0.5	0.44	
Self Image	3.4 ± 0.3	4.1 ± 0.6	0.01	
Mental health	3.9 ± 0.4	4.1 ± 0.8	0.55	
Satisfaction	3.4 ± 0.9	4.6 ± 0.5	<0.01	
Total mean	3.7 ± 0.6	4.2 ± 0.5	0.09	

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

80. First 30 AIS Patients Treated With Posterior Fusion of Structural Disc Levels (SDL) And Fusionless Treatment Of Non-SDL Had Preserved ROM And Less Fusion: A Prospective Study

Saechin Kim, MD, PhD; Nadim J. Kheir, MD; Philip Hanna, MBBS ; Hao-Hua Wu, MD

Hypothesis

A posterior angular correction (PAC) surgical method with fusion of structural disc levels (SDL) and with fusionless treatment of non-SDLs (nSDL) that correct fully with bending or are in the compensatory curve can preserve range of motion and decrease fusion levels.

Design

Prospective

Introduction

For PAC, constructs placed transversely into the pedicle screw tulips of the same vertebra have tulips oriented longitudinally. By manipulating the constructs posterolaterally, the disc angle is corrected and maintained with rods inserted into open tulips for fusion and polyethylene terephthalate bands into closed tulips for posterolateral vertebral tethering (PLVT).

Methods

The number of levels fused for each patient is compared to matched historical posterior fusion controls (MHC). Radiographic measurements assess for adding on phenomenon and side bending (SB) ROM. SRS 22r was scored pre-op and at each f/u. T-test statistical analysis (Microsoft Excel) was done with significance set at $<.05$.

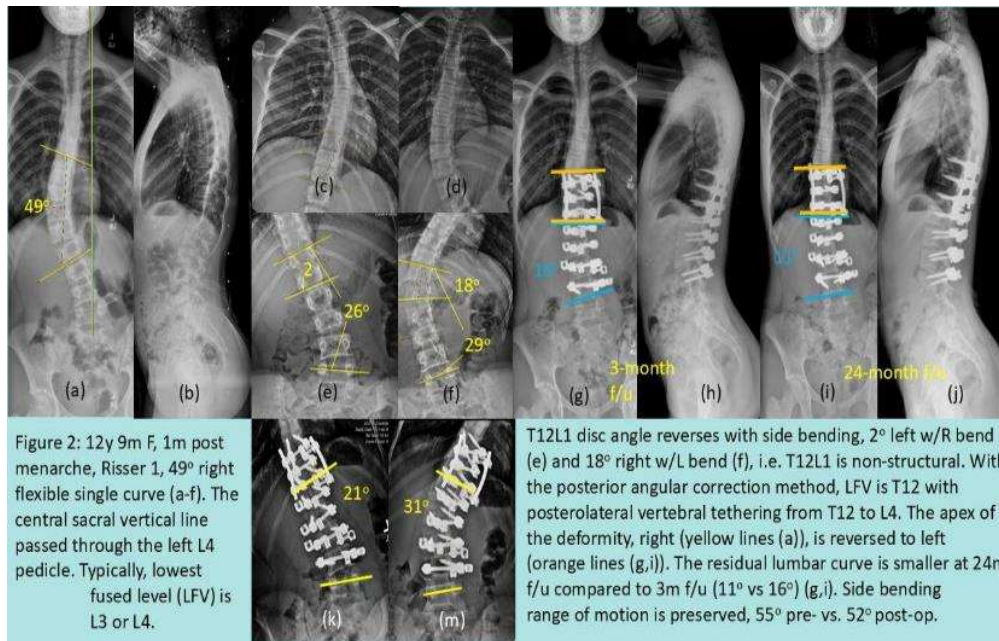
Results

Of the first 30 AIS patients treated with the PAC method (avg 42.3 m, min. 24 m f/u), 4 were lost to f/u, leaving 26 patients. Avg age was 16.1 $\pm$ 2.3 years, pre-op main curve was 56 $\pm$ 10, and post-op main curve was 19 $\pm$ 12 for avg correction of 66% of the main structural curve. The number of levels fused (avg 4.9 $\pm$ 1.8) was less than in the MHC (avg 11.1 $\pm$ 1.9) and the difference was statistically significant ($p<.0001$). SB lumbar ROM was preserved: pre-op (32.1 $\pm$ 12.9) vs. post-op (36.8 $\pm$ 13.0) ($p=.25$). In Fig. 1, for a single curve with central sacral vertical line (CSV) intersecting the left L4 pedicle, last fused vertebra (LFV) is T12 for T10-T12 fusion as T12L1 was nSDL. PLVT was done between T12 and L4. For double curves, structural disc levels in both structural curves are fused and PLVT done between and below the fusions. There was one complication in which bilateral pedicle screws at the LFV were found to be broken at 1 year f/u but at 5-year f/u, curve correction was maintained and patient declined revision surgery. SRS-22r scores at final f/u was 4.5/5 and pre-op was 4.0/5 ($p<.001$).

Conclusion

The PAC method appears to be safe and results in significantly fewer levels fused compared to matched historical controls and preserves lumbar SB ROM in AIS with diverse ages and Lenke classifications.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant



T10-T12 fusion as T12L1 is non-structural

81. What Could Possibly Go Wrong? A Comprehensive Assessment of Complications Following Vertebral Body Tethering

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Hypothesis

Less mature patients with greater growth potential will experience a greater frequency of postoperative complications.

Design

Retrospective, multi-center cohort

Introduction

Vertebral body tethering (VBT) is a maturing technology, utilized with increasing frequency to treat scoliosis by growth modulation and without spinal fusion. Several outcome studies on VBT have reported targeted complications, but no study has provided a comprehensive analysis of all complications in a large, multi-center cohort of VBT patients.

Methods

Patients who had minimum 2-year follow up (FU) or who experienced a complication prior to 2-year FU were included. Complications were categorized according to the Clavien Dindo (CD) system. In addition to descriptive statistics, Chi Square and Mann-Whitney U tests were used to analyze differences between groups with and without complications.

Results

323 patients were included with average follow-up 37 months. 97% were treated with off-label use of an adult spinal deformity instrumentation system prior to dedicated VBT systems receiving FDA approval in the United States. 62 patients (19%) experienced 75 CD III complications. (Figure 1) The most common reoperations (CD IIIb) were 38 VBT revisions in 37 patients (11.5%), most commonly for broken tethers or adding on and posterior spinal fusion in 26 (8.0%) patients, most commonly for adding on or broken screws. No patients experienced a CD IV or V complication. In patients with CD III complications, mean age was lower (11.5yrs vs 12.5yrs, $P=0.0002$), mean Risser score was lower (0 vs 1, $P=0.002$), mean Sanders core was lower (3 vs 4, $P<0.00001$), mean weight was lower (42kg vs 48.1kg, $P<0.00001$), and mean BMI was lower (18.2 vs 19.4, $P=0.003$) preoperatively. No significant differences in CD III complication rates were found based on curve location, sex, ASA class, preoperative, 1st erect, or final FU curve size, or growth modulation.

Conclusion

Younger, more immature patients had significantly more complications/reoperations following VBT, likely due to the less predictable effects of growth. Older, more mature patients had fewer overall complications. Because the differences were small and the mean follow up still relatively short, these findings should be interpreted with caution until longer term outcome data is available.

Summary of Complications Following Vertebral Body Tethering									
	I	II	IIIa	IIIb		I	II	IIIa	IIIb
Curve Progression					Pulmonary				
Adding On >10°	14			8	atelectasis	2		1	
LIV migration	1				Chylothorax	1			
Overcorrection >7°	6			10	hypoxia		1		
Instrumentation					low O2 sats	1			
Broken Screw				5	pneumonia		1		
screw pullout	2				Pneumothorax	7	1	2	1
Broken tether	55			10					
Other Reoperations					Infection				
PSF (unspecified reason)				11	wound dehiscence				1
removal of screws				1	GI				
supplemental fixation				2	constipation	1			
tether other curve				2	nausea and vomiting	1			
tether release				4	Medical				
tether removal				5	C diff diarrhea		1		
tether replacement				1	low back pain	1			
tether revision				8	shotness of breath	1			
Dural Tear					superficial wound infection	1			
dural tear				3	tingling thigh	1			
Postop Pain					UE weakness, swelling	1			
back pain	7				Neurologic				
chest pain	1				UE tingling	1			
shoulder pain	1								
Unplanned Return to Operating Room (UPROR)									
VBT revision (supplementation, release, replacement, or removal)						38			
PSF						26			
blood patch						2			
tether other curve						2			
chest tube						1			
I&D						1			
lumbar drain						1			
reintubated						1			
removal of screws						1			
thoracic drains						1			
thoracoscopy, CT						1			
Clavien Dindo Classification of Complications									
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions								
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications.								
Grade III	Requiring surgical, endoscopic or radiological intervention								
- IIIa	Intervention not under general anesthesia								
- IIIb	Intervention under general anesthesia								

Figure 1

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

82. Tether Breakage Across First-Generation and Second-Generation Vertebral Body Tethering Devices

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Hypothesis

Observable differences in rate of breakage or in breakage patterns will be observed from first generation of VBT devices to second.

Design

Retrospective review of a prospective multi-center study.

Introduction

Tether breakage is a significant complication that can occur when performing vertebral body tethering (VBT) in patients with adolescent idiopathic scoliosis (AIS). This study aims to define the rate of tether breakage in second-generation device systems compared to their first-generation counterparts, as the incidence of tether breakage across VBT models remains unknown.

Methods

AIS patients enrolled in prospective and retrospective surgical outcome registries and who underwent thoracic VBT from 2011-2021 with at least two years of follow-up were analyzed. Radiographic tether breakage, as defined by an increase in adjacent screw angle $> 5^\circ$ during the postoperative period, was analyzed across the first-generation and the second-generation VBT devices from within the same product line. Independent-t and Fisher tests were performed to assess differences in pre-surgical clinical factors and tether breakage reported rates and outcomes.

Results

Two hundred thirty-one patients were included in the final analysis. In total, radiographically identified tether breakage occurred in 116 patients (50%). In the first-generation, tether breakage was measured in 93 patients (52%) and was found to occur at a similar rate in the second generation (23 patients; 44%; $p = 0.46$). No differences were observed in the rate of tether revision (6% vs. 4%; $p = 0.71$) or the rate of conversion to posterior spinal fusion (1% vs. 8%; $p = 0.69$) across device generations. Interestingly, the surgeon observed rate of tether breakage significantly decreased from the first generation of VBT devices to the second (21% vs. 2%; $p < 0.001$).

Conclusion

Tether breakage remains high in cases that utilize the new tether devices and is comparable to rates observed with the older models, despite lower rates of surgeon-reported breakage. This evidence suggests that surgeons should continue to remain hypervigilant during the postoperative period of growth-modulating VBT procedures; however, further investigation is needed to assess the rate of tether rupture in more modern growth-modulating practices such as double-row or hybrid constructs.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

	Total (n=231)	First- Generation (n=179)	Second- Generation (n=52)	p-value
Tether Breakage* - Any location				
Observed	116 (50%)	93 (52%)	23 (44%)	0.46
Not Observed	115 (50%)	86(48%)	29 (56%)	
Tether Breakage – Periapical Region**				
Observed	57 (25%)	47 (26%)	10 (19%)	0.36
Not Observed	174(75%)	132(74%)	42(81%)	
Tether Breakage – End Segments				
Observed	69 (30)	58 (32%)	11 (21%)	0.12
Not Observed	162 (70%)	121 (68%)	41 (79%)	
Reported Breakage				
Observed	38 (17%)	37 (21%)	1 (2%)	<0.001
Not Observed	193 (84%)	142 (79%)	51 (98%)	

Table 1. Observed and Reported Tether Breakage Rates

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper,
‡SRS Funded Research Grant

83. Does Larger-Diameter Tether Improve Outcomes After Vertebral Body Tethering? A 4 mm vs. 5 mm Comparative Study

Alice Baroncini, MD, PhD; Jil Frank; Miguel Pishnamaz, MD; Per D. Trobisch, MD

Hypothesis

A stronger, 5-mm tether provides better correction and less tether breakage than a 4-mm tether after VBT.

Design

Retrospective analysis of prospectively collected data, single-surgeon database.

Introduction

The outcomes of vertebral body tethering (VBT) are improving thanks to a better understanding of surgical technique, timing, and ideal patient characteristics. Still, the influence of implant characteristics on outcomes is largely unknown.

Methods

Consecutive AIS patients treated with VBT were reviewed. Inclusion criteria were Sanders ≤ 5 , preoperative Cobb $\leq 70^\circ$, and ≥ 2 -year follow-up. Cohorts were defined by tether diameter (4 or 5 mm). Analyses were performed by curve (double instrumentations contributed two curves). The primary endpoint was change in Cobb from 6 weeks to 2 years ($\Delta = 2Y - 6W$; negative values indicate continued correction). The success rate and the rate of tether breakage were calculated for each group (success = curve $< 35^\circ$ at the last available follow-up).

Results

Thirty-eight patients were included (4 mm=20; 5 mm=18); with same level of skeletal maturity (Sanders median 3.8 ± 1 vs 3.7 ± 1 ; $p=0.8$). Thoracic instrumented curves showed mean Δ of $1.4 \pm 8.8^\circ$ (4 mm) versus $-4.8 \pm 10.8^\circ$ (5 mm), mean difference -5.5° (95% CI -13.4 to 1.5), Welch $p=0.1$; Mann-Whitney $p=0.09$. Lumbar/thoracolumbar curves showed mean Δ of $8.5 \pm 9.2^\circ$ (4 mm) versus $0.3 \pm 12.7^\circ$ (5 mm), mean difference -8.3° (95% CI -17.7 to 1.2), Welch $p=0.08$; Mann-Whitney $p=0.08$. The success rate was 75% in the 4mm group and 83% in the 5mm group (80% for thoracic curves in both groups, 78% and 92% for lumbar curves, respectively). The incidence of tether breakage at 12M was 30% in the 4mm group and 22% in the 5mm group, at 2Y it was 60% in the 4 mm group and 33% in the 5mm group, at 36m it was 25% and 11%, respectively. Tether breakages occurred in 16/20 (80%) patients with 4mm tethers versus 10/18 (55%) with 5mm tethers; thoracic rupture was 11/19 (58%) versus 2/11 (18%) ($p=0.057$). Overall, 66% of thoracic instrumentations showed a breakage in the 4mm group, vs 20% in the 5mm group. In lumbar curves, a breakage was observed in 78% of the instrumentations with 4mm tether vs. 61% with 5mm.

Conclusion

5mm tethers showed a tendency toward better 6-week to 2-year growth modulation, higher success rate and fewer ruptures, particularly for thoracic curves. Findings are suggestive but not yet conclusive and warrant confirmation in larger cohorts.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

84. Who Breaks and Why? A Validated Predictive Model of Tether Failure After Vertebral Body Tethering in Adolescent Idiopathic Scoliosis

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Hypothesis

A multivariable predictive model can accurately identify patient-specific risk of tether failure following vertebral body tethering (VBT).

Design

Single-surgeon retrospective cohort of 117 AIS patients (11-18 years), with primary VBT and minimum 2 year follow up. Retrospective cohort study

Introduction

Vertebral body tethering (VBT) is a motion-preserving alternative to posterior spinal fusion for adolescent idiopathic scoliosis (AIS). Despite increasing utilization, tether breakage remains a common complication and a leading cause of revision. Existing studies describe individual risk factors but do not provide patient-specific risk estimation. A validated predictive model may improve candidate selection, counseling, and surgical strategy.

Methods

A multivariable logistic regression model was developed in 117 AIS patients (ages 11–18) undergoing primary VBT with minimum 2-year follow-up. Demographic, skeletal maturity, curve, and surgical variables were analyzed. Tether breakage timing (<24 months vs ≥24 months), location, and cumulative failures were recorded. Internal validation was performed using a temporal split. Model discrimination was assessed using area under the ROC curve (AUC), determined discrimination with CI=95%.

Results

Overall tether failure occurred in 38.5% of patients, with 15.4% occurring before 2 years and 23.1% after. Patients with failure were younger, less skeletally mature, and had larger preoperative curves. Increasing age, Sanders stage, and Risser grade were independently protective, reducing breakage risk by 28% (OR 0.72, $p=0.004$), 42% (OR 0.58, $p<0.001$), and 24% (OR 0.76, $p=0.02$) per unit increase, respectively. Thoracolumbar/lumbar primary curves increased failure risk by 65% (OR 1.65, $p=0.03$). Each increase in Lenke classification raised failure risk by 35% (OR 1.35, $p=0.02$), and each 10° increase in major Cobb angle increased failure risk by 18% ($p=0.02$). The model demonstrated acceptable discrimination (AUC 0.75, 95% CI 0.67–0.83).

Conclusion

This internally validated multivariable model identifies patients at increased risk for tether failure following VBT and demonstrates clinically meaningful discrimination. Patient-specific risk stratification may improve VBT candidate selection, inform surgical strategy, and enhance preoperative counseling, supporting its role in decision-making for AIS treatment.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

85. Is rhBMP-2 Worth the Risk? A Data-Driven Look at Fusion Outcomes and rhBMP-2 Related Complication Burden in High-Risk Adult Spinal Deformity Patients

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Hypothesis

In adult spinal deformity (ASD) surgery, recombinant human bone morphogenetic protein-2 (rhBMP-2) is associated with reduced pseudarthrosis/rod fractures without increase in BMP-related adverse events, even among biologically high-risk patients.

Design

Retrospective cohort

Introduction

Though rhBMP-2 is widely used to enhance spinal fusion, its use remains controversial due to complication concerns. In patients undergoing ASD surgery, we evaluated the association between rhBMP-2 use and outcomes, with dedicated analyses of high pseudarthrosis risk groups (obesity, diabetes, and osteoporosis/osteopenia).

Methods

A retrospective cohort study was performed of patients undergoing ASD surgery with ≥ 5 -level fusion between 2009-23, and ≥ 2 year follow-up. Patients were stratified based on rhBMP-2 use. Primary outcome was pseudarthrosis/rod fracture, as this relates directly to the fusion process. Secondary outcomes were mechanical complications and BMP-associated adverse events including new onset radiculitis, wound complications, and seroma. Sub-analyses were performed in high pseudarthrosis risk groups. Multivariable logistic regression was used to adjust for relevant confounders.

Results

Among 288 patients undergoing ASD surgery (mean age: 62.5 ± 17.5 years; 74.0% females), 118 (41.0%) received rhBMP-2. Entire Cohort: rhBMP-2 use was independently associated with reduced risk of pseudarthrosis/rod fracture (16.1% vs. 38.2%, $p < 0.001$; OR=0.24, 95%CI 0.10–0.58, $p=0.002$). rhBMP-2 was not significantly associated with increased radiculitis, wound complications, or seroma formation. Obesity: rhBMP-2 use was independently associated with reduced risk of mechanical complications (46.0% vs. 66.1%, $p=0.037$; OR 0.20, 95%CI 0.05–0.88, $p=0.033$). Diabetes: Incidence of mechanical complications was similar between BMP-treated and BMP-free groups ($p>0.05$). Osteoporosis/Osteopenia: rhBMP-2 use was independently associated with reduced risk of reoperation for mechanical complications (16.4% vs. 46.5%, $p < 0.001$; OR 0.20, 95%CI 0.05–0.83, $p=0.026$).

Conclusion

In patients undergoing ASD surgery, rhBMP-2 use was independently associated with fewer mechanical complications without an increase in BMP-related adverse events. rhBMP-2 demonstrated differential efficacy across high-risk populations, benefiting patients with obesity and osteoporosis/osteopenia but not patients with diabetes.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant