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Effects of bracing on pelvic parameters in adolescent idiopathic scoliosis

A retrospective study

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Abstract

To evaluate the effects of Chêneau bracing on Cobb's angle (CA) and spinopelvic parameters in adolescent idiopathic scoliosis (AIS) patients. In this retrospective study, we evaluated 51 AIS patients who received Chêneau bracing treatment between January 2020 and August 2021. The prebracing and in-bracing radiographs were analyzed about the spinopelvic parameters. The CA, pelvic coronal obliquity angle, thoracolumbar kyphosis (TLK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), sagittal vertical angle, and coronal vertical angle were measured. Paired t-test was used to compare prebracing and in-bracing spinopelvic parameters. The Pearson correlation analysis was used to identify the relationships between the variations in the spinopelvic parameters. The mean age at the initiation of bracing was 13.6 ± 1.5 years. The mean prebracing CA was 24.0° ± 6.3°. There were no statistically significant differences between prebracing and in-bracing measurements of sagittal and coronal vertical angles. However, there were statistically significant differences between the prebracing and in-bracing measurements of the CA, pelvic coronal obliquity angle, TLK, LL, PT, and SS. A significant correlation was observed between PT and thoracolumbar kyphosis variations in the sagittal plane. The pelvic coronal obliquity angle variation was correlated to the prebracing pelvic coronal obliquity angle in the coronal plane. Chêneau's bracing effects of AIS can be extended to the pelvis. Affected by the Chêneau brace, the pelvis should be retro-rotated correspondingly to TLK hyperkyphosis on the sagittal plane, whereas in the coronal plane, pelvic obliquity was improved independently. The effect of Chêneau braces on the pelvic parameters should be fully considered before bracing treatment.

Abbreviations: AIS = adolescent idiopathic scoliosis, CA = Cobb's angle, CVA = coronal vertical angle, LL = lumbar lordosis, PCOA = pelvic coronal obliquity angle, PIP = elvic incidence, PT = pelvic tilt, SS = sacral slope, SVA = sagittal vertical angle, TLK = thoracolumbar kyphosis.

Keywords: adolescent idiopathic scoliosis, bracing, pelvic rotation, spinopelvic parameters.

1. Introduction

AIS is a 3-dimensional deformity characterized by coronal, sagittal, and rotational spine deformities.[1] For moderate deformities, bracing is the most common treatment.[2] It has been shown that patients with AIS usually have an abnormal spinopelvic balance and pelvic morphology.[3] Furthermore, a significantly higher prevalence of pelvic rotation was observed in patients with thoracolumbar curves than in thoracic curves.

Pelvic parameters have been considered predictors of curve progression and brace treatment success.[4] Unfortunately, most bracing studies on the AIS focused on the CA behavior.[5] There is no study to assess the behavior of pelvic parameters in AIS patients under bracing treatment.

Evaluating in-bracing pelvic parameters can better understand the Chêneau bracing mechanisms in controlling the curve progression. So we aimed to assess the effects of bracing on pelvic parameters in thoracolumbar AIS.

2. Methods

2.1. Study design and ethics

This study was an observational, retrospective study. All of the subjects signed a written informed consent form. This study

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protocol was approved by the ethical committee of the Second Central Hospital of Baoding(Reference no.: 20214; March 2, 2021). The study was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Setting and sampling technique

The medical records of consecutive patients with AIS who underwent Chêneau bracing between January 2020 and August 2021 in our department were reviewed.

We excluded patients with congenital scoliosis, syndromic scoliosis, structural leg discrepancies, and patients aged 16 or more at the time of bracing. Inclusion criteria for the brace indication were: Lenke5 AIS, skeletal immaturity, premenarcheal or postmenarcheal by less than 1 year, a CA between 15° and 45° receiving Chêneau brace (Fig. 1), having ongoing bracing treatment for at least 6 months before the study.

2.3. Sample size estimation

According to the pretrail experimental results, the mean prebracing CA was 24°, the mean in-bracing CA was 12°, and the average standard deviation of CA was 14°. We set $\alpha = 0.05$, $1\text{-}\beta = 0.85$, and used the "power and sample size calculator" to calculate the sample size online. The total sample size was 40. Considering the loss to follow-up rate of 20%, it was estimated that we needed at least 50 cases to be included in our study.

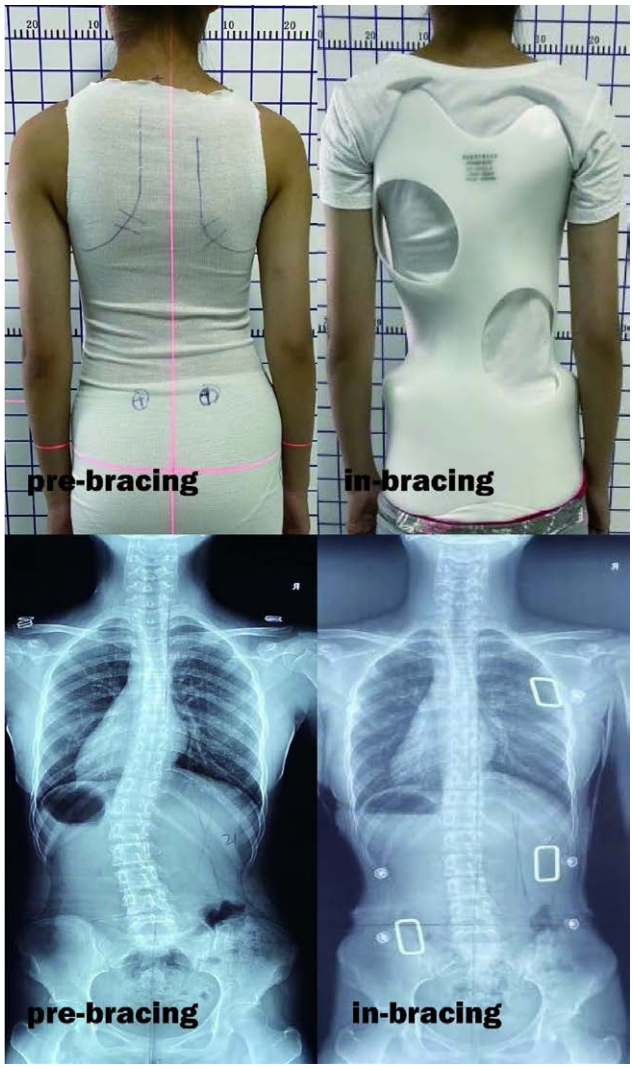

Figure 1. The Chêneau brace for adolescent idiopathic scoliosis. After Chêneau brace treatment, Scoliosis was significantly improved in adolescent idiopathic scoliosis.

2.4. Intervention

All of the subjects underwent Chêneau bracing treatment. The principle of Chêneau bracing included: (1) three-point systems in the frontal plane; (2) pair-of-force for regional derotation in the horizontal plane; (3) maintaining physiological alignment in the sagittal plane.

2.5. Radiographic assessment

Standing full spine radiographs were ensured that patients were utterly erect. Radiological parameters of prebracing and in-bracing were measured from anteroposterior and lateral standing radiographs of the whole spinal. All measurements were performed by Surgimap Spine Software (New York, USA). Measurements were all conducted by 2 investigators (radiologists) independently. An average score was used for any size with < 5 degrees difference. Any difference beyond 5 degrees was discussed between the investigators, with a final consensus on the measurement used for analysis. The cutoff of 5 degrees was based on documented radiographic measurement errors in a scoliotic curve.

2.6. Primary and secondary outcome variables with working definition

Primary outcome variables included a comparison between prebracing and in-bracing spinopelvic parameters; Secondary outcomes included the relationships between the variations of the spinopelvic parameters.

The spinopelvic parameters of prebracing and in-bracing radiographs included (Fig. 2):

Cobb's angle (CA): The angle between the lines drawn along the upper endplate of the most tilted superior vertebra and the lower endplate of the most tilted inferior vertebra.

Pelvic coronal obliquity angle (PCOA): The angle between the line connecting the top of both iliac crests and the horizontal line on standing AP radiographs.

Thoracolumbar kyphosis (TLK): The angle between the lines drawn along the upper endplate of the T10 vertebra and lower endplate of the L2 vertebra on standing lateral radiographs

Lumbar lordosis (LL): The angle between the lines drawn along the superior endplate of L1 and the superior endplate of S1 on standing lateral radiographs.

Pelvic incidence (PI): The angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the axis of the femoral heads.

Pelvic tilt (PT): The angle between the line connecting the midpoint of the sacral plate to the femoral head axis and the vertical axis.

Sacral slope (SS): The angle between the line drawn along the superior plate of S1 and a horizontal line.

Sagittal vertical angle (SVA): The sagittal angle between the line drawn from the center of the C7 vertebral body to the center of the upper sacral endplate and the vertical line.

Coronal vertical angle (CVA): The coronal angle between the line drawn from the center of the C7 vertebral body to the center of the upper sacral endplate and the vertical line.

2.7. Comparison

prebracing and in-bracing spinopelvic parameters of the subjects were compared.

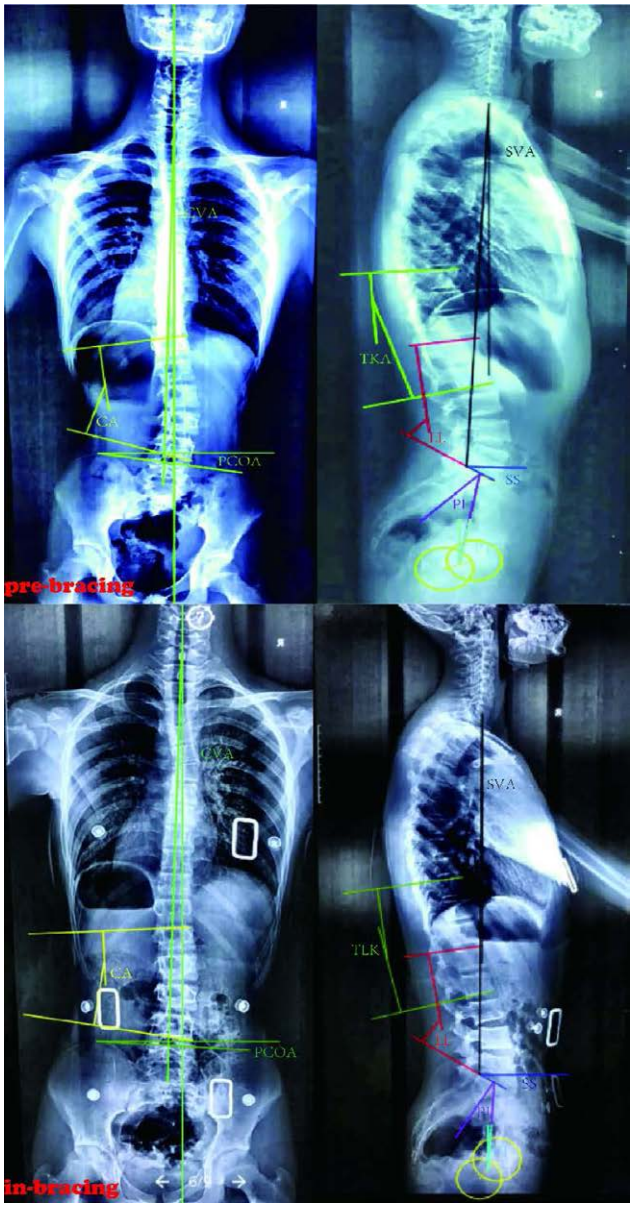

Figure 2. The spinopelvic parameters. CA = Cobb's angle, CVA = Coronal vertical angle, LL = Lumbar lordosis, PI = Pelvic incidence, PCOA = Pelvic coronal obliquity angle, PT = Pelvic tilt, SS = Sacral slope, SVA = Sagittal vertical angle, TLK = Thoracolumbar kyphosis.

2.8. Statistical analysis

The data were analyzed using SPSS Statistics 2E5 (IBM Corp, Armonk, NY) Shapiro–Wilk test found that the data were normally distributed. Paired t-test was used to compare prebracing and in-bracing spinopelvic parameters.

The Pearson correlation analysis was used to identify the relationships between the variations in the spinopelvic parameters.[6] $P < .05$ was considered statistically significant. Reference to the interpretation of "r": Strong correlation(0.81–1.0); Moderate correlation(0.51–0.8); Mild correlation(0.2–0.5).

3. Results

3.1. Demographics and baseline of the patients

A total of 51 patients with AIS, 41 women and 10 men were included in this study. The mean age at the initiation of bracing was 13.6 ± 1.5 (11–16) years. The mean initial curve magnitude was 24.0° ± 6.3°(11.0°–39.3°), the mean absolute curve magnitude was 10.8° ±7.3°(0°–28.5°), and the mean corrective rate was 57.1%. The mean brace-wearing time was 14.9 ± 8.5 months. Overall, 29 patients (71%) had full brace compliance (20 to 23 hours), and 12 (29%) patients had partial compliance (16 to 20 hours).

The average PCOA was 1.0° ± 2.6°. Only 13 patients had a PCOA of 0° (25.5%). 12 patients (23.5%) had PCOA less than –1°, whereas 26 patients (51.0%) had PCOA of 1° or more.

The average PT was 6.1° ± 8.1°. 14 patients had a PT of more than 10°(27.5%). 72.5% of patients had PT <10°, whereas 11 patients (21.6%) had PT of 0° or less.

3.2. Effect of braces on spinopelvic parameters

3.2.1. Influence on parameters in the sagittal plane. After wearing the brace, TLK, LL, and SS were significantly reduced, and PT increased ($P < .05$). This change indicates a decrease in the overall curvature of the spine and a posterior rotation of the pelvis. Table 1 shows prebracing and in-bracing measurements of the sagittal parameters. According to the results, the TLK, LL, PT, and SS had statistical significance.

3.2.2. Influence on parameters in the coronal plane. In-bracing CA and PCOA are smaller than those before the brace is worn. The difference was statistically significant ($P < .05$). This phenomenon suggested that braces can significantly improve scoliosis while correcting pelvic tilt in the coronal plane. Table 2 shows the prebracing and in-bracing measurements of the coronal parameters, the CA and PCOA were statistically significant.

3.3. Correlation analysis on the variation of spinopelvic parameters

3.3.1. The correlation analysis on sagittal parameters variation. The correlation analysis of sagittal parameters variation is shown in Table 3. In the sagittal plane, PT variation negatively correlated with TLK, but there was no statistically significant relationship between the other spinopelvic parameters and TLK values.

3.3.2. The correlation analysis of coronal parameters variation. The correlation analysis of coronal parameters variation is shown in Table 4. In the coronal plane, the PCOA

Table 1

prebracing and in-bracing sagittal parameters (°).

Variable	Prebracing	In-bracing	Paired t	*P*
TLK	8.9 ± 8.9	6.0 ± 6.8	3.35	0.00*
LL	46.5 ± 10.6	43.3 ± 8.9	2.16	0.04*
PI	38.6 ± 11.7	39.9 ± 8.8	1.15	0.26
PT	6.1 ± 8.1	9.9 ± 7.0	3.56	0.00*
SS	32.6 ± 8.2	30.2 ± 7.2	2.63	0.01*
SVA	1.1 ± 3.6	0 ± 3.5	1.87	0.07

Table 2

prebracing and in-bracing coronal parameters (°).

Variable	Prebracing	In-bracing	Paired t	*P*
CA	24.0 ± 6.3	10.8 ± 7.3	16.11	0.00*
PCOA	1.0 ± 2.6	0.6 ± 2.0	4.58	0.00*
CVA	1.5 ± 1.6	1.4 ± 1.6	0.28	0.78

Table 3

Correlation analysis of sagittal parameters variation.

	Variation of TLK	
Variable	**r**	***P***
Variation of LL	0.17	0.22
Variation of PI	0.18	0.20
Variation of PT	0.29	0.04*
Variation of SS	0.06	0.66
Variation of SVA	0.19	0.18

*A mild negative correlation between TLK and PT was observed.

Table 4

Correlation analysis of coronal parameters variation.

	Variation of PCOA	
Variable	**r**	***P***
Variation of CA	0.14	0.31
Pro-bracing CA	0.09	0.52
Pro-bracing PCOA	0.67	0.00*
Pro-bracing CVA	0.27	0.06

*A moderate positive correlation between original PCOA and variation of PCOA was observed.

variation was positively correlated to prebracing PCOA. However, CA variation had no statistically significant correlation with PCOA variation.

4. Discussion

Scoliosis changes the spinal column in all 3 anatomical planes, and all spinopelvic parameters are affected.[7] Restoring the balance in the spinopelvic parameters is an important goal of bracing treatment, especially for thoracolumbar AIS.[8] In these patients under Chêneau bracing treatment, the sagittal and coronal rotation of the pelvic is integrant to regulating the spinopelvic malalignment.

4.1. Influence of braces on spinopelvic parameters in the sagittal plane

In our study, the braces decreased the spine's overall curvature and a posterior rotation of the pelvis in the sagittal plane. For spinal parameters, our finding is consistent with Saeedi's study,[9] which found that braces can significantly reduce thoracic kyphosis and LL. But in the pelvic area, they found no statistical influences of bracing on PI, PT, and SS. Differences may be attributable to differences in Lenke classification of included patients. Like our study, Fang, M. Q reported that,[10] after wearing Chêneau braces, thoracic kyphosis and LL significantly decreased, and PT increased significantly from 4.5°to 8.3°.

Previous studies showed that the PI is a relatively fixed value.[11] The Chêneau brace has a pad in front of the pelvis resisting antirotational stress in the apical vertebral region. The pelvic pad may cause posterior rotation of the pelvis. Our study's significant diminution of LL and TLK may modify sagittal balance. The pelvis retroverted, and PT increased to adapt to the modification of sagittal balance.

4.2. Influence of braces on spinopelvic parameters in the coronal plane

The CA has been used as the main factor to assess bracing effectiveness in AIS cases. In the present study, the mean degree of curve correction was 57.1% which had statistically significant between baseline and final measurements. This result is also in line with the study of Katz and Durrani,[12] which found that a minimum of 25% CA correction was needed to predict the satisfactory outcome of bracing treatment in AIS patients.

The current study results showed that the Chêneau bracing treatment did not significantly affect the whole balance parameter such as CVA and SVA. However, it showed statistically significant effects on regional spinopelvic parameters such as CA and PCOA. In a subsequent correlational analysis, there was no significant correlation between the variation of CA and the pelvic parameters. Therefore, our hypothesis of the direct effects of bracing on the pelvic parameters was accepted.

4.3. Correlations of the spinopelvic parameters

The increased PT combined with decreased SS constituted the evidence of retroverted rotation of the pelvis in the present study. In the subsequent correlation analysis, a negative correlation between TLK and PT was observed, Whereas correlation between TLK and LL was absent. This phenomenon suggests that the reduced TLK caused by corrective forces of the brace was compensated by pelvic retro-rotation.

Coronal pelvic obliquity was prevalent in patients with thoracolumbar curves, such as Lenke5/6.[13] Pelvic obliquity can be classified by its anatomical pathogenesis(suprapelvic, intrapelvic, intrapelvic problem, or any combination).[14] Suprapelvic type is secondary to the spinal deformity in which scoliosis may drive the pelvis into an asymmetrical position. In the present study, we observed a positive relationship between original PCOA and variation of PCOA, which means that the more tilted to the pelvis's concave side of the lumbar curve, the more influenced by bracing. Bracing treatment could correct scoliosis as well as pelvic obliquity simultaneously.

5. Limitations

Nonetheless, this study had several limitations. Some of which are significant to the conclusions we can reach. The retrospective nature, as well as the small cohort, make it difficult to draw definitive conclusions. Additionally, the short-term effects of bracing were analyzed for them. Although previous studies[15] showed a significant correlation between immediate in-brace correction and the outcome of brace treatment in AIS, long-term studies should be performed to evaluate the effect of immediate in-brace changes of pelvic parameters on the outcome of brace treatment in AIS. Furthermore, the spinal radiographs were not centered on the pelvis and, therefore, there could be some parallax effect in measuring the pelvic parameters.

6. Conclusions

Chêneau brace will decrease the spine's overall curvature and a posterior rotation of the pelvis in the sagittal plane. Chêneau brace treatment could correct scoliosis and pelvic obliquity in the coronal plane.

Author contributions

GJM and HYZ conceived and designed the study. YH and JZZ analyzed the data. KPL wrote the manuscript. All authors read and approved the final manuscript.

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