

# CONSERVATIVE IDIOPATHIC SCOLIOSIS TREATMENT WITH BRACE PRODUCED USING 3D TECHNOLOGY

TRATAMENTO DA ESCOLIOSE IDIOPÁTICA COM COLETE PRODUZIDO COM TECNOLOGIA 3D

TRATAMIENTO DE LA ESCOLIOSIS IDIOPÁTICA CON CORSÉ PRODUCIDO CON TECNOLOGÍA 3D

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## ABSTRACT

**Objective:** To evaluate the immediate correction capacity of the Wood-Chêneau-Rigo brace (WCR), produced using digital technological resources and robotic engineering, in primary and secondary curves of adolescent idiopathic scoliosis (AIS). **Methods:** A retrospective study was conducted of 138 patients with a diagnosis of AIS and who received a WCR brace from a laboratory that makes orthoses and orthopedic prostheses between 2019 and 2021. These individuals were submitted to an independent analysis of the radiographic parameters by a single researcher, the main outcome of which was the standardized measurement of the main and secondary curves using the Cobb method. The radiographs analyzed were performed in orthostasis before and immediately after the adaptation of the brace on the patient. The correction capacity was calculated as the ratio of the difference between the pre- and post-brace curves to the pre-brace curve. **Results:** The mean correction with the WCR was 48.4% for the main curve and 41.0% for the secondary curve. The level of correction of the main curve was significantly higher in patients with a main curve with the apex of convexity in the thoracolumbar region ( $p = 0.004$ ), especially in the left thoracolumbar region ( $p = 0.010$ ); curves of magnitude between  $10^\circ$  and  $24.9^\circ$  ( $p < 0.001$ ); and curves classified as simple ( $p < 0.001$ ). **Conclusion:** The use of the WCR, which is produced using modern technological resources, was effective in the immediate correction of AIS. Long-term studies on this new modality of conservative scoliosis treatment are necessary. **Level of evidence III; Retrospective study.**

**Keywords:** Scoliosis; Conservative Treatment; Variance Analysis.

## RESUMO

**Objetivo:** Avaliar a capacidade de correção imediata do colete Wood-Chêneau-Rigo (WCR), produzido com recursos tecnológicos digitais e de engenharia robótica, em curvas primárias e secundárias de escoliose idiopática do adolescente (EIA). **Métodos:** Realizou-se um estudo retrospectivo com 138 pacientes com diagnóstico de EIA que adquiriram o colete WCR entre 2019 e 2021 em um laboratório de produção de órteses e próteses ortopédicas. Esses indivíduos foram submetidos à análise independente dos parâmetros radiográficos por um único pesquisador, tendo como desfecho principal a medida padronizada das curvas principal e secundária pelo método de Cobb. As radiografias analisadas foram realizadas em ortostase antes e imediatamente depois da adaptação do colete no paciente. A capacidade de correção foi calculada pela razão entre a diferença das curvas pré e pós-colete e a curva pré-colete. **Resultados:** A média de correção da curva primária com o WCR foi de 48,4% e a da curva secundária foi de 41,0%. O nível de correção da curva primária foi significativamente maior nos pacientes com curva principal com ápice da convexidade na região toracolombar ( $p = 0,004$ ), principalmente toracolombar à esquerda ( $p = 0,010$ ); curvas com magnitude entre  $10^\circ$  e  $24,9^\circ$  ( $p < 0,001$ ) e curvas do tipo simples ( $p < 0,001$ ). **Conclusões:** O colete WCR, produzido com modernos recursos tecnológicos, foi eficaz na correção imediata da EIA. São necessários estudos a longo prazo sobre essa nova modalidade de tratamento conservador da escoliose. **Nível de Evidência III; Estudo retrospectivo.**

**Descritores:** Escoliose; Tratamento Conservador; Análise de Variância.

## RESUMEN

**Objetivo:** Evaluar la capacidad de corrección inmediata del corsé de Wood-Chêneau-Rigo (WCR), producido con recursos tecnológicos digitales e ingeniería robótica, en curvas primarias y secundarias de la escoliosis idiopática del adolescente (EIA). **Métodos:** Se realizó un estudio retrospectivo de 138 pacientes con diagnóstico de EIA que adquirieron el corsé WCR entre 2019 y 2021 en un laboratorio de producción de ortesis y prótesis ortopédicas. Estos individuos fueron sometidos a un análisis independiente de los parámetros radiográficos por un solo investigador, siendo el resultado principal la medición estandarizada de las curvas

Study conducted at the Hospital das Clínicas e Hospital Mater Dei. Belo Horizonte, MG, Brazil.

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principal y secundaria por el método de Cobb. Las radiografías analizadas se tomaron en bipedestación antes e inmediatamente después de la adaptación del corsé al paciente. La capacidad de corrección se calculó por la razón entre la diferencia entre las curvas de antes y de después del uso del corsé y la curva de antes del corsé. Resultados: La corrección promedio de la curva primaria con el WCR fue del 48,4% y de la curva secundaria fue del 41,0%. El nivel de corrección de la curva primaria fue significativamente más grande en pacientes con una curva principal con vértice de la convexidad en la región toracolumbar ( $p = 0,004$ ), principalmente toracolumbar a la izquierda ( $p = 0,010$ ); curvas con magnitud entre  $10^\circ$  y  $24,9^\circ$  ( $p < 0,001$ ) y curvas simples ( $p < 0,001$ ). Conclusiones: El uso corsé WCR, producido con modernos recursos tecnológicos, fue efectivo en la corrección inmediata de la EIA. Se necesitan estudios a largo plazo sobre esta nueva modalidad de tratamiento conservador de la escoliosis. **Nivel de evidencia III; Estudio retrospectivo.**

**Descriptor:** Escoliosis; Tratamiento Conservador; Análisis de Varianza.

## INTRODUCTION

Treatment with a brace is one of the main modalities of conservative treatment of Adolescent Idiopathic Scoliosis (AIS) and its main objective is to prevent the progression of scoliotic curves.<sup>1</sup> The major obstacles to conservative treatment with braces are low adherence, negative psychosocial impact in the adolescent, and correction of the deformity in a single plane. These adversities are considered significant factors in the failure of conservative treatment and they, in theory, could contribute to the undesirable increase in surgically treated cases.<sup>2,3</sup> The Milwaukee and Boston braces are the most frequently used orthoses in the conservative treatment of AIS. The mechanism of action of these two orthoses does not act on vertebral rotation and tends to straighten the physiological curves in the sagittal plane with the potential to produce what is known as flatback.<sup>1,4</sup> The Milwaukee brace has the additional disadvantage of the apparent cervical ring of the orthosis, which contributes to the problem of the self-image of the adolescent with all its repercussions for that age group.<sup>5</sup>

Braces with a proposal of multiplanar correction emerged in the 1990s with the work of Chêneau. This type of brace aimed to correct scoliosis by applying force at multiple points on the trunk. Rigo, Wood et al. improved the Chêneau brace, creating the Wood-Chêneau-Rigo (WCR) brace, which was widely used in Europe starting in 2004.<sup>6</sup> The treatment principle of the WCR is to create different areas of pressure and expansion in the trunk to generate different degrees of rotation in the vertebrae and multifocal corrective forces, including the axial, sagittal, and coronal planes.<sup>1,7</sup> The application of emerging technologies, such as 3D surface scanning, digital modeling software, 3D printers, and especially high precision robotic technology seem to have the potential to make this brace more effective, as well as more acceptable and lighter.

The literature on the results of conservative WCR treatment related to AIS curves is relatively new and scarce, especially when involving new technologies in the orthosis planning and manufacturing process. The objective of this study is to evaluate the immediate correction capacity of the WCR brace, made using digital technological resources and robotic manufacturing, on AIS scoliotic curves.

## METHODS

### Study design

A retrospective study was conducted to evaluate the immediate correction capacity of the WCR brace on primary and secondary scoliotic curves in patients with adolescent idiopathic scoliosis.

### Ethics

This work is part of a line of research on adolescent idiopathic scoliosis and was approved by the Research Ethics Committee of the Hospital Mater Dei in Belo Horizonte. The identification number of the opinion is CAAE: 44775621.1.0000.5128.

### Study location and period

This study was conducted between January 2019 and January 2021 with patients diagnosed with adolescent idiopathic scoliosis who were referred to an orthosis and prosthesis laboratory in Belo Horizonte to have a WCR brace made.

### Main event

The main event of this study was the ability of the WCR brace to immediately correct the scoliotic curve. The correction capacity was calculated as a percentage using the formula: (initial curve – final curve/initial curve) x 100. The percentage was calculated for both primary and secondary curves.

### Secondary variables

The secondary variables studied were sex, age, convex side of the main curve, apex of the main curve, location of the curve, type of curve, Risser classification, and magnitude. Table 1 describes the name and operational definition of each variable studied.

### Sample

One hundred and sixty-six patients with adolescent idiopathic scoliosis were admitted for the manufacture of a WCR brace during the period studied. The data and the radiographic images analyzed were obtained from the database of this institution and are stored by the laboratory as part of their regular brace production process. Twenty-eight of the 166 patients initially evaluated in this study were excluded for insufficient data or for not being between 10 and 17 years of age. One hundred and thirty-eight individuals comprised the final sample of this study.

### Study development

Data collection was performed from digital radiographs stored in the database of this laboratory. Only patients diagnosed with

**Table 1.** Description of the secondary variable studied.

Variable	Characterization
1. Sex:	Male or female
2. Age:	Age in years on the date of brace manufacture
3. Side of the curve:	According to the location of the convexity of the main curve: right or left
4. Apex of the main curve:	Vertebra or disc farthest from the midline that belongs to the convexity of the main curve. After defining the apex of the main curve, the Scoliosis Research Society (SRS) topographical classification <sup>8</sup> was used: thoracic (T2 to disc T11-T12), thoracolumbar (between T12 and L1), lumbar (disc L1-L2 to disc L4-L5)
5. Location of the curves:	Defined according to the SRS topographical classification <sup>8</sup> and the side of the curve, subdivided into right thoracic, left thoracic, right thoracolumbar, left thoracolumbar, right lumbar, and left lumbar
6. Type of curve:	According to the number of structured curves: simple (one curve), double (two curves), and triple (three curves)
7. Risser:	Risser sign grade of the iliac crest in the AP radiological incidence. Grades 0, 1, 2, 3, 4 and 5. Risser classification grouping: Group A (Risser sign 0, 1 or 2) and Group B (Risser sign 3, 4 or 5)
8. Magnitude:	Magnitude of the curves measured using the Cobb method. Stratification of magnitude: Group 1 (curve $\leq 24,9^\circ$ ), Group 2 ( $25^\circ$ to $40^\circ$ ), and Group 3 ( $> 40^\circ$ ).

adolescent idiopathic scoliosis and who had panoramic anteroposterior radiographs of the spine in the orthostatic position taken before and immediately after the fabrication of the WCR brace were selected. All demographic and radiographic data collection was performed by a single qualified orthopedist investigator who was a member of the Brazilian Society of Orthopedics and Traumatology (SBOT). After identifying the terminal vertebrae in the radiographs, the researcher measured the Cobb angle of each curve before and after use of the brace using Surgimap® software. The following secondary variables related to the scoliotic curves were also analyzed: apex of the main curve, location of the curve, type of curve, Risser classification, and magnitude. The Risser sign was also grouped into Group A (0,1,2) and Group B (3,4,5).<sup>3,9</sup>

### Fabrication of the WCR

The brace fabrication process involved four steps: three-dimensional scanning of the trunk of the patient using CAD/CAM Captevia V3.4® software; planning of the scoliotic curve correction from the scanned images and the digital panoramic anteroposterior spinal radiograph using Rodin 4D® software (Figure 1); production of an individualized mold of the trunk with the proposed correction using robotic technology (Victor Unlimited® robot) from the final file generated by the Rodin 4D® software; and, finally, making the WCR brace in polypropylene using the mold as a base. Figures 2 and 3 illustrate a case from the sample studied, with pre- and post-brace radiographs and short-term aesthetic results (three months), respectively. From start to finish the process involved professionals from different areas, including physicians, physical therapists, graphic designers, engineers, and orthotic and prosthetic technicians.

### Data analysis

Following the compilation of the data and radiographic images of these 138 patients, the percentage of correction was calculated for each curve and a descriptive statistical analysis of the profile of the study participants was prepared. A study of the association of the secondary variables with the percentage of correction was conducted through univariate and multivariate analyses.

In the descriptive analysis, the absolute and relative frequencies of the categorical variables and the mean, standard deviation, median, minimum and maximum quartile values of the continuous variables were presented. Univariate and multivariate analyses were performed to investigate possible demographic or radiographic factors associated with the greater correction capacity of the WCR

brace. The univariate analysis was conducted using non-parametric tests because, according to the Shapiro Wilk test, the percentage of correction of the primary and secondary curves did not present normal distribution. The Mann Whitney test was used to compare the percentage of correction of the primary and secondary curves between variables with two categories and the Kruskal Wallis test was used for variables with three or more categories. For the multivariate analysis, a multivariate linear regression model with the variables that presented significance at 20% in the univariate analysis was considered. The significance and the plausibility of the possible terms of interaction were evaluated in the adjusted model. The adequacy of the final model was investigated by analyzing graphs and significance levels to verify the assumptions using the Faraway tests for homoscedasticity and the Shapiro Wilk test for normality of the residuals.

The analyses were performed using RStudio, version 1.4.1106 software, considering a significance level of 5% for multivariate analysis.

## RESULTS

Most of the 138 patients studied were female (79.7%) with the convexity of the main curve predominantly on the right (54.4%). After analyzing the location of the apex of the main convexity, most curves were classified as thoracic (44.9%). There were more patients with a double curve (63.8%) than with a simple curve. Individuals with Risser 0, 1, or 2 (classified as Group A) accounted for 62.3% of the total number evaluated, and curves of a magnitude between 25 and 40 degrees, which belong to Group 2, were the most frequent, at 44.1% (Table 2).

Table 3 shows the results of the analysis of the distribution of the continuous study variables. It was observed that when they began to use the brace, the mean age of the patients was  $13 \pm 1.6$  years, with a minimum age of 10 years and a maximum age of 16 years. The mean Risser classification was  $1.8 \pm 1.8$ . Considering that the primary curve has the greatest magnitude, patients with simple curves only have primary curves while those with double curves have both a primary curve and a secondary curve. The mean degrees of the primary curves was  $35.3^\circ \pm 11.4$  prior to using the brace and was measured at  $19.2^\circ \pm 11.2$  after the beginning of treatment with the WCR. The mean percentage of correction of this curve was  $48.4\% \pm 23.1$ , with a minimum value of 0% and a maximum value of 97.4% (Figure 4). As regards the secondary curve, the mean value was  $27.2^\circ \pm 9.9$  before using the WCR and  $16.4^\circ \pm 9.1$  after starting treatment with the orthosis. The mean percentage of correction of the secondary curve was  $41.0\% \pm 23.4$ , with a minimum value of 1.9% and a maximum value of 100% (Figure 5).

The evaluation of the percentage of correction of the primary and secondary curves between the categorical variables is shown in Table 4. As can be observed, the percentage of correction of the primary curve was significantly higher in individuals in whom the apex of convexity of the main curve was located in the thoracolumbar region ( $p = 0.004$ ), mainly on the left ( $p = 0.010$ ); curves of magnitude between  $10^\circ$  and  $24.9^\circ$ , which are classified as Group 1 ( $p < 0.001$ ); and simple curves ( $p < 0.001$ ).

In Table 5, the association of the percentage of correction of the primary and secondary curves between the continuous variables, including the items "age at the start of WCR use" and "Risser classification", was evaluated by means of simple linear regression analysis. However, no significant association was found between the variables and the study outcomes.

The multiple linear regression model, which included the magnitude and type of curve variables, explained 18.4% of the variability of the percentage of primary curve correction and was considered the model with the best adjustment among all those evaluated. In relation to the variable magnitude, it was observed that Group 3 presented, on average, a reduction of 17.8% of the percentage of primary curve correction in comparison to Group 1. And considering the type of curve, an average reduction of 11.4% of the percentage of correction of the primary curve was observed in patients with a

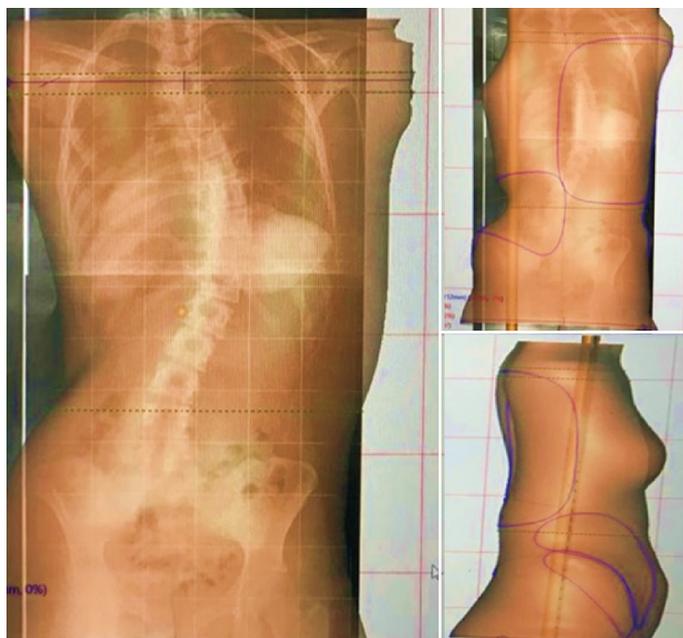
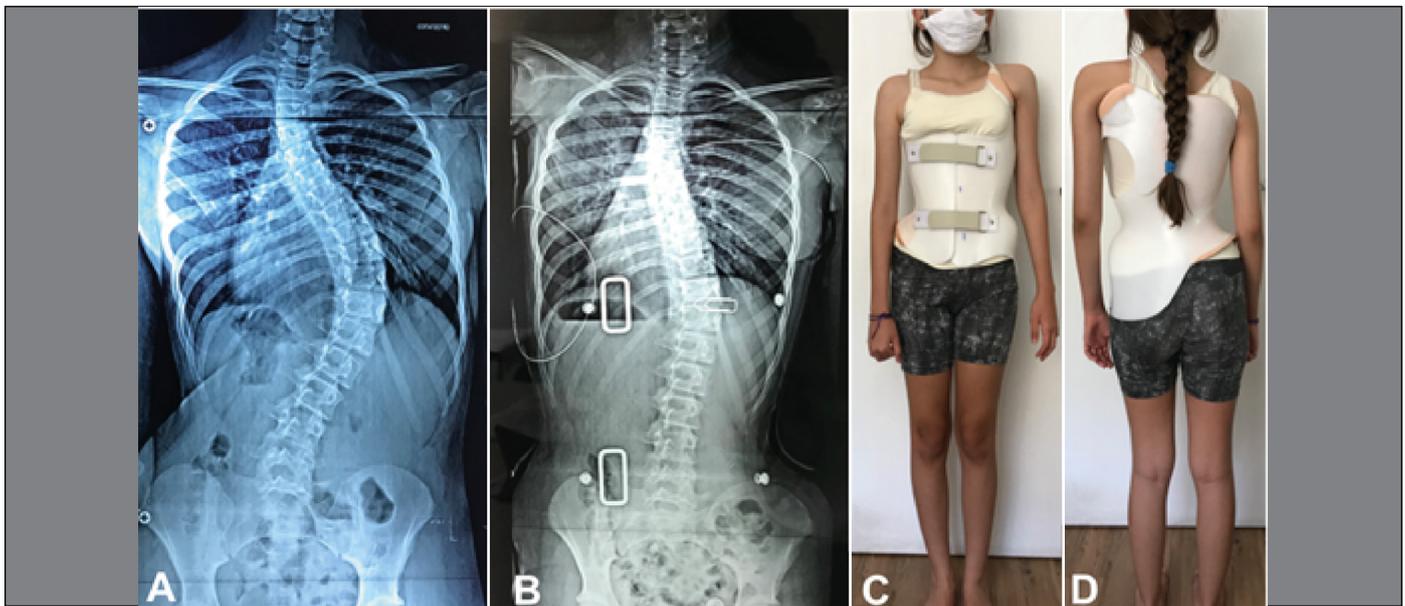


Figure 1. Scan and correction of the curve.



**Figure 2.** A: pre-brace radiograph, B: Immediate post-brace radiograph, C and D: anterior and posterior views of the adapted brace on the patient.



**Figure 3.** A: Posterior pre-brace view, B and C: Posterior view during medical follow-up three months after starting to use the brace.

double curve compared to those with simple curves (Table 6).

Evaluating the sample power (post-hoc) for various factors, we observed that the power ranged from 15% to 98%, with the sample power always being above 90% for the significant variables. To calculate the power, we considered the effect size (mean and standard deviation of the percentage of correction of the factors in each category), a significance level of 5%, and the sample size.

**DISCUSSION**

Treatment for adolescent idiopathic scoliosis remains controversial. A review study of Cochrane<sup>10</sup> conducted in 2010 concluded that the level of scientific evidence for the treatment of AIS with a

**Table 2.** Analysis of the categorical variables of the sample profile.

Characteristics		n	%
Sex	Female	110	79.7
	Male	28	20.3
Side of main convexity	Right	75	54.4
	Left	63	45.7
Apex of main convexity	Thoracic	62	44.9
	Thoracolumbar	41	29.7
Location of the curve	Lumbar	35	25.4
	Right thoracic	59	42.8
	Left thoracic	3	2.2
	Right thoracolumbar	9	6.5
	Left thoracolumbar	32	23.2
Type of curve	Right lumbar	7	5.1
	Left lumbar	28	20.3
	Simple curve	50	36.2
Grouping by Risser classification	Double curve	88	63.8
	A	86	62.3
Magnitude	B	52	37.7
	Group 1	29	21.0
	Group 2	61	44.2
	Group 3	48	34.8

n: absolute frequency; grouping by Risser classification: A (0, 1, 2) / B (3, 4, 5); magnitude: Group 1 (0-24.9°) / Group 2 (25-40°) / Group 3 (>40°).

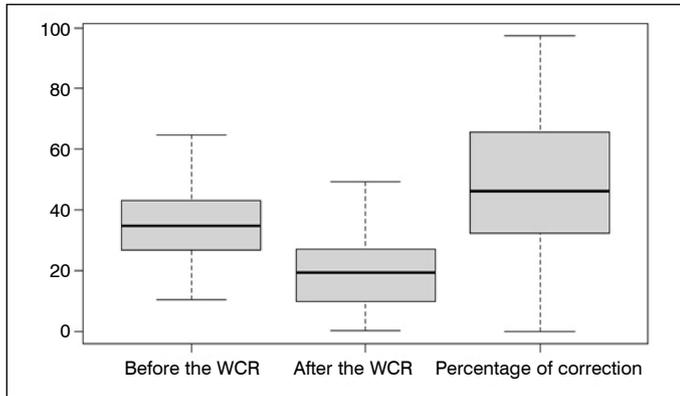
brace is low. In a systematic review conducted between 1970 and 2010, Davies et al.<sup>11</sup> identified eight cohort studies, five of which were prospective and three retrospective, comparing conservative treatments that use orthoses with those that do not. The authors concluded that indication of a brace may be advantageous, but there was not yet any strong evidence about its effectiveness. The multicenter BRAIST study evaluated 242 patients, 146 of whom were treated with braces and 96 with observation. It was concluded that treatment with orthosis had a 72% success rate, while the observational method had a success rate of 48%.<sup>3</sup>

The experience with the Wood-Chêneau-Rigo (WCR) brace is relatively recent. The possibility of the brace being produced using advanced technologies permits correction of scoliosis in the three planes of the deformity.<sup>6,12</sup> The present study evaluated the immediate correction capacity of the WCR, and a mean correction of 48.4% for the primary and 41.0% for the secondary curves was observed. The mean value for adequate correction of the primary curve using a

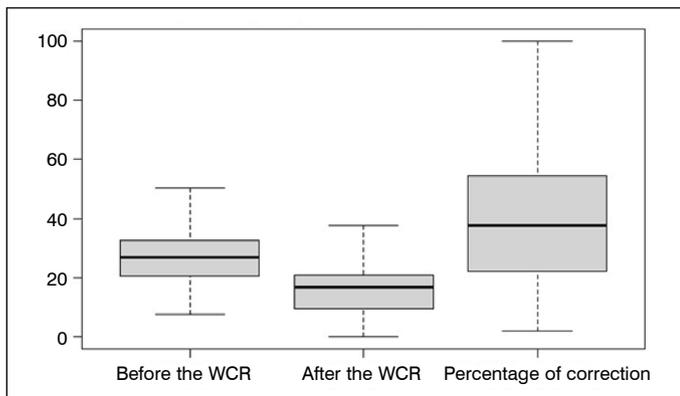
**Table 3.** Analysis of the continuous variables of the sample profile.

Characteristics	n	Mean	Standard deviation	Minimum	1st Quartile	Median	3rd Quartile	Maximum
Age at the beginning of the study	138	13.0	1.6	10.0	12.0	13.0	14.0	16.0
Risser Classification	138	1.8	1.8	0.0	0.0	2.0	4.0	5.0
Degrees (°) of the primary curve before the WCR	138	35.3	11.4	10.6	26.9	34.8	43.1	64.8
Degrees (°) of the primary curve after the WCR	138	19.2	11.2	0.3	9.7	19.4	26.9	49.4
Percentage (%) of primary curve correction	138	48.4	23.1	0.0	32.3	46.3	65.5	97.4
Degrees (°) of the secondary curve before the WCR	88	27.2	9.9	7.5	20.8	26.9	32.4	50.3
Degrees (°) of the secondary curve after the WCR	88	16.4	9.1	0.0	9.5	16.7	20.7	37.5
Percentage (%) of secondary curve correction	88	41.0	23.4	1.9	22.3	37.6	54.1	100.0

n, frequência absoluta; WCR, Wood-Chêneau-Rigo



**Figure 4.** Boxplot of the percentage of correction of the primary curve.



**Figure 5.** Boxplot of the percentage of correction of the secondary curve.

brace is controversial, with some authors considering a value close to 50% reduction to be ideal,<sup>1,13</sup> while others claim that a decrease of 25% associated with good three-dimensional correction is sufficient to prevent the progression of scoliosis and that larger corrections could generate other negative bodily compensations.<sup>13</sup> The results in our study are similar to those of Korovessiset al.,<sup>14</sup> who reported 41% immediate correction for the primary curve using the WCR and better results with thoracolumbar curves. The epidemiological profile analyzed in the work was also similar to that described for AIS,<sup>15</sup> with a predominance of female individuals with convex right thoracic curves.

The WCR brace had a greater correction capacity for single curves of magnitude less than 25° and located in the thoracolumbar region. The least amount of correction was observed in the double curves and in those of greater magnitude. A possible explanation is the greater rigidity of curves of large magnitude and the greater biomechanical demand required of the correction system in double curves, which, in general, make them more complex.

The patients evaluated in this study used the same orthoses and prostheses laboratory for the fabrication of the WCR, but their

prescriptions were written by different physicians. Data analysis showed that some professionals indicated a brace for curves smaller than 25 or larger than 40 degrees, and even prescribed the WCR for curves up to 65 degrees and in mature skeletons (Risser greater than 3). The correction capacity was greater for curves between 10 and 24.9 degrees, a group for which treatment with a brace is not usually indicated. The reason for the greater correction is possibly due to the greater flexibility of the curve in this group. New studies are necessary to assess the long-term benefits of using orthoses in patients with curves less than 24.9 degrees. It was also observed that adolescents with Risser above three who were treated with WCR benefitted from treatment with this brace, at least in a short-term analysis, as there was an immediate reduction of the scoliotic curves after starting to use the orthosis.

Long-term comparison of the WCR with other types of braces, such as the Milwaukee and the Boston, requires further study. The Milwaukee is the most studied orthosis for AIS,<sup>16</sup> so consequently more is known about its positive and negative effects. Misterska et al. published a study that found negative emotional experiences on the part of patients who were still using the brace 20 years after the end of treatment.<sup>5</sup> Its cervical ring is one of the main reasons for aesthetic discomfort and related psychosocial impact.<sup>17</sup> The percentage of failure is also significant with the use of the Milwaukee brace, Lonstein and Winter<sup>18</sup> and Noonan et al.<sup>19</sup> reporting 47% and 48% failure, respectively. There is also the possibility of increased cervical and lumbar pain after prolonged use of this brace.<sup>20</sup> Regarding the Boston brace, the gain from the cosmetic point of view with the use of this orthosis, which does not address the rotational component, may be less than that suggested by an analysis limited to reduction of the Cobb angle in the coronal plane.<sup>21</sup> In addition to the possibility of flatback,<sup>4</sup> another problem is adherence to the treatment. Nicholson et al. observed that the Boston brace was used only 65% of the time it was prescribed.<sup>22</sup> The main advantages of the WCR are its ability to correct in the three body planes, its weight, and its aesthetic appearance.<sup>23</sup> Precise fabrication enables the orthosis to be lighter and to fit the body better, making it more comfortable and increasing treatment adherence. In a retrospective review study, Minsk et al. compared the use of the WCR with that of the Boston brace in individuals with AIS and concluded that adolescents treated with the brace with three-dimensional technology were less likely to progress to surgery and had a lower rate of curve progression.<sup>23</sup>

Our study has several limitations. One of them is the retrospective nature of the study, which depends on information contained in medical records. Another is the lack of standardization in radiographic documentation, making it impossible to analyze the effect of using the WCR on sagittal alignment and on rotations of the vertebrae included in the scoliotic curves.

Consistent data that prove the level of efficiency of the WCR after prolonged use, and whether it is, in fact, superior to the others, are still scarce in the literature. This study is a preliminary stage of a work that aims to analyze the results of the long-term use of this brace.

**Table 4.** Univariate comparison of the percentages of correction of the primary and secondary curves.

Characteristics		Percentage (%) of correction of the primary curve				p value	Percentage (%) of correction of the secondary curve				p value
		Mean	Standard Deviation	Median	Q1-Q3		Mean	Standard Deviation	Median	Q1-Q3	
Sex	F	48.8	21.7	47.3	35.5-61.6	0.496	39.7	22.6	36.8	23.3-52.3	0.313
	M	47.0	28.3	43.2	25.3-75.0		46.0	26.8	47.3	21.3-61.7	
Side of the main convexity	R	44.9	20.1	45.6	31.5-55.4	0.082	41.4	23.3	38.2	22.6-54.6	0.782
	L	52.6	25.8	48.7	35.5-74.2		40.3	23.8	37.3	22.8-51.9	
Apex of the main convexity	T	44.3	20.3	45.2	29.0-55.2	0.004**	41.9	23.9	38.6	26.1-53.8	0.887
	TCL	58.6	25.1	61.6	38.2-77.2		42.9	27.8	33.2	28.3-67.1	
	L	43.8	22.2	41.6	27.9-58.0		38.5	20.4	37.4	20.4-53.3	
Location of the curve	RT	45.0	20.4	45.6	31.3-55.4	0.010**	42.0	24.2	39.0	25.5-54.6	0.914
	LT	30.8	12.5	24.3	23.6-34.7		37.3	-	37.3	37.3-37.3	
	RTCL	47.6	17.9	47.6	32.6-51.1		29.6	6.1	32.9	27.7-33.1	
	LTCL	61.7	26.2	65.7	46.7-79.1		45.7	29.9	36.0	28.6-73.5	
	RL	41.0	22.2	35.9	24.3-55.8		44.2	23.2	53.9	20.0-55.9	
	LL	44.5	22.6	42.6	32.6-58.2		37.3	20.1	36.7	21.2-49.6	
Grouping by Risser classification	A	49.8	23.5	45.8	34.3-67.3	0.531	43.0	23.7	38.8	24.8-54.9	0.331
	B	46.1	22.5	47.6	32.1-60.5		38.1	23.1	33.2	20.4-51.4	
Magnitude	G1	60.4	27.9	67.5	38.5-77.8	< 0.001**	53.3	23.7	61.7	28.9-67.1	0.080
	G2	51.8	21.5	50.0	35.9-68.4		44.1	26.4	39.3	24.2-58.2	
	G3	36.9	16.2	39.9	22.5-47.6		34.9	18.4	33.2	21.4-43.4	
Type of curve	SC	58.8	23.9	61.3	46.1-76.6	< 0.001*	-	-	-	-	-
	DC	42.6	20.6	41.2	30.4-51.4		-	-	-	-	

Q1-Q3: first and third quartiles; F: female; M: male; R: right; L: left; T: thoracic; TCL: Thoracolumbar; L: lumbar; RT: right thoracic; LT: left thoracic; RTCL: right thoracolumbar; LTCL: left thoracolumbar; RL: right lumbar; LL: left lumbar; A: Risser 0,1,2; B: Risser 3,4,5; G1: 10-24.9°; G2: 25-40°; G3: >40°; SC: simple curve; DC: double curve. \*Mann-Whitney Test significance at 5%; \*\* Kruskal Wallis Test significance at 5%.

**Table 5.** Univariate linear regression analysis in relation to the percentages of correction of the primary and secondary curves.

Characteristics	Percentage of correction of the primary curve				Percentage of correction of the secondary curve			
	Beta	Standard error	p value	CI 95%	Beta	Standard error	p value	CI 95%
Age at start of WCR use	-0.3	1.2	0.793	-2.7 2.1	-1.0	1.5	0.510	-4.1 2.1
Risser classification	-0.8	1.1	0.453	-3.0 1.4	-1.7	1.4	0.234	-4.5 1.1

CI 95%: confidence interval of 95%; WCR: Wood-Chéneau-Rigo.

**Table 6.** Multivariate regression analysis of the percentage of correction of the primary and secondary curves.

Characteristics	Percentage of correction of the primary curve				Adjusted R <sup>2</sup>
	Beta	Standard error	CI 95%	p value	
(Constant)	64.0	4.1	55.9 72.0	< 0.001	0.184
Magnitude					
Group 1	reference				
Group 2	-4.7	4.9	-14.4 5.0	0.340	
Group 3	-17.8	5.3	-28.3 -7.3	0.001	
Type of curve					
Simple curve	reference				
Double curve	-11.4	4.0	-19.3 -3.5	0.005	

CI 95%: confidence interval of 95%, Adjusted R<sup>2</sup>: coefficient of determination.

**CONCLUSION**

The WCR brace demonstrated good capacity for the immediate correction of curves in patients in the study sample who underwent conservative orthotic treatment for AIS.

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**REFERENCES**

- Gallo D, Wood G, Dallmayer R. Quality Control of Idiopathic Scoliosis Treatment in 147 Patients While Using the RSC® Brace. JPO: Journal of Prosthetics and Orthotics. 2001;23(2): 69-77.
- Negrini S, Donzelli S, Aulisa AG, Czaprowski D, Schreiber S, de Mauroy JC, et al 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis Spinal Disord. 2018; 13: 3.

3. Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med*. 2013;369(16):1512-21.
4. Cheung JPY, Chong CHW, Cheung PWH. Underarm bracing for adolescent idiopathic scoliosis leads to flatback deformity: the role of sagittal spinopelvic parameters. *Bone Joint Jo*. 2019; 101-B(11): 1370-8.
5. Misterska E, Glowacki J, Glowacki M, Okret A. Long-term effects of conservative treatment of Milwaukee brace on body image and mental health of patients with idiopathic scoliosis. *Plos One*. 2018;13(2): e0193447.
6. Rigo M, Jelačić M. Brace technology thematic series: The 3D Rigo Chêneau-type brace. *Scoliosis Spinal Disord*. 2017;12:10.
7. Rigo MD, Villagrasa M, Gallo D. A specific scoliosis classification correlating with brace treatment: description and reliability. *Scoliosis*. 2010;5(1): 1.
8. Scoliosis Research Society. SRS Terminology Committee and Working Group on Spinal Classification Revised Glossary of Terms: Working Group on 3-D Classification (Chair Larry Lenke, MD), and the Terminology Committee. March 2000. 2000. Disponível em <http://https://www.srs.org/professionals/online-education-and-resources/glossary/revised-glossary-of-terms>.
9. Souza MPM, Pereira AFF, Rangel TAM, Medeiros RC, Cabral LTB, Ferreira MAC, et al. Radiographical analysis of flexibility of idiopathic scoliosis in prono and supino. *Coluna/Columna*. 2020;19(1):13-7
10. Bettany-Saltikov J, Grivas TB, ES V. Braces for idiopathic scoliosis in adolescents (Review). *Cochrane Database of systematic reviews (Online)*. 2010.
11. Davies E, Norvell D, Hermsmeyer, J. Efficacy of bracing versus observation in the treatment of idiopathic scoliosis. *EvidBased Spine Care J*. 2011;2(2): 25-34.
12. Grivas T, Mauroy JC, Wood G, Rigo M, Hresko MT, Kotwicki T, et al. **Brace Classification Study Group (BCSG): Part one - definitions and atlas**. *Scoliosis Spinal Disord*. 2016;11:43.
13. Wood G, Rigo M. The principles and biomechanics of the Rigo Chêneau type brace. *Intechopen*. 2017.
14. Korovessis P, Syrmpeis V, Tsekouras V, Varfakastanis K, Fennema P. Effect of the Chêneau Brace in the natural history of moderate adolescent idiopathic scoliosis in girls: cohort analysis of a selected homogenous population of 100 consecutive skeletally immature patients. *Spine Deform*. 2018; 6(5): 514-22.
15. Pinto EM, Alves J, Castro AM, Marcos S, Miradouro J, Teixeira A, et al. Leg length discrepancy in Adolescent Idiopathic Scoliosis. *Coluna/Columna*. 2019; 18(3): 192-5.
16. Ovadia D, Eylon S, Mashiah A, Wientroub S, Lebel ED. Factors associated with the success of the Rigo System Chêneau brace in treating mild to moderate Adolescent Idiopathic Scoliosis. *J Child Orthop*. 2012; 6(4):327-31.
17. Maruyama T, Takeshita K, Kitagawa T. Milwaukee brace today. *Disabil Rehabil Assist Technol*. 2008; 3(3):136-8.
18. Lonstein JE, Winter RB. The Milwaukee brace for the treatment of Adolescent Idiopathic Scoliosis. A review of one thousand and twenty patients. *J Bone Joint Surg Am*. 1994;76(8):1207-21.
19. Noonan KJ, Weinstein SL, Jacobson WC, Dolan LA. Use of the Milwaukee brace for progressive idiopathic scoliosis. *J Bone Joint Surg Am*. 1996;78(4): 557-67.
20. Misterska E, Glowacki J, Okret A, Laurentowska M, Glowacki M. **Back and neck pain and function in females with Adolescent Idiopathic Scoliosis: A follow-up at least 23 years after conservative treatment with a Milwaukee brace**. *Plos One*. 2017;12(12): e0189358.
21. Olafsson Y, Saraste H, Soderlund V, Hoffsten M. Boston brace in the treatment of Idiopathic Scoliosis. *J Pediatr Orthop*. 1995;15( 4):524-7.
22. Nicholson GP, Ferguson - Pell MW, Smith K, Edgard M, Morley T. The objective measurement of spinal orthosis use for the treatment of Adolescent Idiopathic Scoliosis. *Spine*. 2003;28(19):2243-50.
23. Minsk MK, Venuti KD, Daumit GL, Sponseller PD. Effectiveness of the Rigo Chêneau versus Boston-style orthoses for Adolescent Idiopathic Scoliosis: a retrospective study. *Scoliosis Spinal Disord*. 2017;12:7.