Idiopathic scoliosis surgical treatment. Results in Mexico's National Rehabilitation Institute. 24-month follow-up

Tratamiento quirúrgico de la escoliosis idiopática del adolescente. Resultados en el Instituto Nacional de Rehabilitación de México. Seguimiento mínimo de 24 meses

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Abstract

Background: Adolescent's idiopathic scoliosis is defined as a three-dimensional deformity of the spine, which occurs between 10 and 18-year-old, has a spinal curvature $>10^\circ$ in the coronal plane. This deformity affects 2-3% of the general population, however, only 10% of the total will require surgery at some point. The method of choice for management is the use of pedicle screws and rods derotational. **Objective:** To perform a descriptive analysis of patients who received surgical treatment in our institute with pedicle screws and rods. **Methods:** This is an observational, retrospective, analytical, open study, non-probability sampling, in which patients requiring surgical treatment at our institute between 2012 and 2013 were included, the deformities were stratified according to the classification of Lenke. The angle of deformity correction, instrumented levels, amount of bleeding, presence of complications were the variables analyzed. **Results:** Lenke classifying mostly IBN, Moe Nash III, an average of 59.4° Cobb and kyphosis of 47.8° . On average it was followed patients for 35.84 months, detecting an increase 2.28° coronal curvature and sagittal curvature increase of 2.8° . **Conclusion:** Comparing these results and world literature concluded that the treatment of adolescent's idiopathic scoliosis is a safe and reproducible method that provides greater biomechanical and biological advantage over the use of mixed instrumentation used previously.

KEY WORDS: Adolescent idiopathic scoliosis. Pedicle screws. Spinal fusion. Treatment outcome.

Resumen

Antecedentes: La escoliosis idiopática del adolescente se define como una deformidad tridimensional de la columna vertebral que se presenta entre los 10 y los 18 años, y que se manifiesta con una curvatura vertebral en el plano coronal mayor de 10° . Esta deformidad afecta al 2-3% de la población general, pero solo el 10% del total requerirá en algún momento tratamiento quirúrgico. El método de elección para el manejo es el uso de tornillos transpediculares y barras desrotadoras. **Objetivo:** Realizar un análisis descriptivo de los pacientes que recibieron manejo quirúrgico en nuestro instituto con tornillos transpediculares y barras. **Método:** Se trata de un estudio observacional, retrospectivo, analítico, abierto, de muestreo no probabilístico, en el que se incluyeron los pacientes tratados con manejo quirúrgico entre 2012 y 2013. Las deformidades se estratificaron de acuerdo con la clasificación de Lenke. El ángulo de corrección de la deformidad, los niveles instrumentados, el sangrado transquirúrgico y la presencia de complicaciones fueron las variables analizadas. **Resultados:** La mayoría de los pacientes presentaron curvas Lenke IBN, Nash Moe III, Cobb un promedio de 59.4° y cifosis de 47.8° . En promedio se siguió

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a los pacientes por 35.84 meses, detectando un aumento de la curvatura coronal de 2.28° y un aumento de la curvatura sagital de 2.8°. **Conclusión:** Al comparar estos resultados y la literatura mundial se concluyó que el tratamiento de la escoliosis idiopática del adolescente es un método seguro y reproducible que ofrece una mayor ventaja biomecánica y biológica sobre el uso de instrumentación mixta utilizada anteriormente.

PALABRAS CLAVE: Escoliosis idiopática del adolescente. Tornillos transpediculares. Artrodesis de columna vertebral. Resultados de tratamiento.

Introduction

Adolescent idiopathic scoliosis (AIS) is a deformity of the spine in the coronal, axial and sagittal planes, with a curvature greater than 10° in the coronal plane, which affects patients aged between 10 and 18 years, with an impact on the psychological functional, and cosmetic states¹.

Classic presentation (80% of the population) is that of a female patient with a thoracic curvature greater than 20°, rotational deformity and hypokyphosis¹. It is a relatively common pathology, which affects 2-3% of the population, but only 10% of affected individuals will require surgical treatment at some point².

Among the described theories, the genetic factor has been associated as the probable origin of this pathology, without this being conclusive.³ Due to the large variability of presentation, influenced by factors such as gender, age of onset, skeletal growth peak, size and type of curve, its description and study are difficult¹.

King was the first one to establish an anatomomorphological classification of thoracic deformities, but did not take lumbar curvatures into account and, in addition, subsequent studies report high inter-observer and intra-observer variability^{4,5}. The most common classification currently used is the one described by Lenke, designed for surgical planning. With this classification, less limitations are reported than with King's classification, and it is useful for comparing different treatments or single treatments; it has less intra-observer and inter-observer variability, and provides higher certainty in the development of a surgical plan⁶.

If spine deformity has a curvature greater than 50°, respiratory and cardiac function are compromised, and the patient reports chronic pain and fatigue for carrying out daily life activities⁷.

AIS surgical indications are a curvature greater than 50° in the coronal plane, a curvature greater than 40° in a patient with skeletal immaturity, progression of the condition despite conservative treatment with the use of corrective bracing and a deformity that is unacceptable for the patient⁸.

The goals of surgical treatment with pedicle screws and rods are obtaining a significant, functional and esthetic correction, achieving stable vertebral arthrodesis, lower non-union rates (allows performing osteotomies), preventing recurrence and correction loss, and allowing patient early postoperative mobility¹.

In 1962, Harrington described the use of de-rotation rods for the management of scoliosis and reported poor control of the sagittal deformity correction⁹⁻¹¹. In the 1980s, the use of hooks and sublaminar wires was introduced by Cotrel Dubousset and Luque, respectively; these systems allowed an improvement in the control of sagittal and coronal correction, in addition to patient early mobilization^{10,12}.

In 1963, Roy-Camille introduced pedicle screws with the purpose to treat pathologies located only in the lumbar region^{10,13}. However, their use was recommended only under specific circumstances, because of the danger (vascular, nervous and visceral injury) and the difficulty the placement of the screw entailed due to the complicated pedicular morphology, which undergoes an anatomical alteration in terms of volume (varying from 2.5 to 12 mm in width and from 9.6 to 16 mm in height) and direction (orientation in the axial, sagittal and coronal plane), affected by the vertebral level, and patient age and height^{1,5}. To decrease the difficulty in the placement of the pedicle screws, factors that increase safety are taken into account, such as the structural anatomical factor and the pedicular medial wall, which is stronger than the lateral wall¹⁴. Gerztein and Robbins¹⁵ described the safety zone, which covers 4 mm added to the pedicle medial border, corresponding to 2 mm of epidural space and 2 mm of subarachnoid space. This same concept was used for the placement of sublaminar hooks, since these encompass an area of 2-3 mm of this safety zone¹⁶. However, the purpose of the description of the safety zone is not using it in its entirety, since placement is acceptable when the screw exceeds the medial cortical wall by 2 mm^{1,16}.

Currently, hook and wire systems have fallen into disuse due to the implementation and subsequent demonstration of the advantages of treatment with pedicle

Figure 1. Anteroposterior, pre-surgical (A) and post-surgical (B) X-rays of a patient with adolescent idiopathic scoliosis. A post-surgical correction of 54° is observed at the coronal plane with the use of pedicle screws.

screws and rods¹. Placement of pedicle screws and rods corrects the deformity in all three anatomical columns, preventing the crankshaft effect, decreasing the number of instrumented levels and offering a better correction of the deformity^{1,17} (Fig. 1).

Suk et al.¹⁷ are pioneers in the use of pedicle screws in all pedicles, demonstrating their safety in the treatment of AIS. They reported their results with a study that included 462 patients (with 4,604 screws being placed), with malposition observed in 48 patients (1.5% of total screws), out of which only four screws exceeded the medial cortical wall, without any neurological, vascular or visceral injury being reported. They demonstrated that, with appropriate training and experience, the placement of the screws is not influenced by overall vertebral deformity. Kuklo et al.⁴ reported the placement of screws in 20 patients with an overall curvature of 100.2°, with an accuracy of 96.3% in the positioning of the screws, without neurovascular or visceral injuries being reported.

AIS treatment evolution with the use of pedicle screws and rods demonstrates biomechanical superiority, with lower rates of complications, improving the correction of patient's radiographic and clinical deformity, in comparison with the techniques that were previously used in our institute¹.

To date, there are no descriptive studies in Mexico that allow us knowing the radiographic, clinical and functional results of AIS treatment with pedicle screws and de-rotation rods. Knowing the caseload of surgically-treated AIS patients and the prevalence of complications is sought, as well as comparing the results obtained with previously used techniques in our institute

and other specialized centers, in order to know the percentage of correction, and describe and analyze other variables (bleeding, surgical time and instrumented levels).

Method

The medical records of patients aged between 13 and 18 years, diagnosed with AIS, treated with surgical management using pedicle screws and de-rotation rods, operated in our institute between 2010 and 2013, with follow-up of at least 2 years, and who had had complete clinical and imaging records, were reviewed.

Data collection was carried out by two orthopedists who were not directly involved with patients' surgical procedures. Statistical data were analyzed with the SPSS program (version 21). Analysis was performed with descriptive statistics for frequencies, percentages, means and standard deviations. A Kolmogorov-Smirnov test was carried out to verify the normality of the sample, and a t-test for paired (related) samples was used for continuous variables, in order to find out the differences. An analysis of variance (ANOVA) test was carried out to detect correction differences between different Lenke classification groups with regard to correction percentage. All statistical tests were crossed, and a p-value < 0.05, with its 95% confidence interval (CI) was considered statistically significant.

Results

Forty-three AIS-diagnosed patients were identified, out of which 25 met the inclusion criteria for this study. Two males and 23 females were included (92%), with a normal age distribution of 17 years (± 2.79 years). Twenty-two patients had a reducible deformity and three had an irreducible deformity; only two patients had neurological deficit (ASIA D). They were classified, according to Lenke, based on the curve type: type I curvature in 14 patients (56%), type III in 8, type II in 4 and type VI in 2. According the lumbar modifier, there were 11 patients with lumbar modifier B (44%), 9 with lumbar modifier C (36%) and 5 with lumbar modifier A. According to the sagittal modifier, there were 15 patients (60%) with neutral thoracic kyphosis (10-40°), 8 patients with increased kyphosis (greater than 40°) and 2 patients with decreased kyphosis (less than 10°). Coronal deformity was measured with Cobb's method, with an average of 60.8° being found, with a range of 38 to 113° (standard deviation 15.87), as well as an average kyphosis of

Figure 2. Lateral pre-surgical (A) and post-surgical (B) X-ray of a patient diagnosed with scoliosis. The pedicle screws can be observed in the thoracolumbar column.

47.8°, ranging from 10 to 90°. Average compromised levels was 9.92 (range: 6-14). Apical vertebral rotation was also classified by means of Nash Moe's scale, with 14 with subjects being found with a type-3 deformity, 10 with type-2 deformity, and one with type-4 deformity.

After completing the pre-surgical protocol, all 25 patients underwent the surgical procedure. Out of them, 23 were posteriorly approached (92%) and two had an anterior and posterior approach, with 350 to 4,500 cc bleeding (average 1,146 cc), an average surgical time of 320.72 minutes (ranging from 210 to 480 minutes) and with an average of 10.88 instrumented levels (range: 4-15).

Six patients suffered trans-surgical and immediate postoperative complications (infection, hypovolemia, dural injury, spinal cord injury, rod cutting, pleuropulmonary injury), but only three required revision surgery (infection, prolonged surgical time). Average hospital length of stay was 8.88 days (± 7.06 days) (Fig. 2).

After the surgical event, imaging studies were carried out, with an average percentage coronal deformity reduction of 64% ($21.6 \pm 11.66^\circ$) and sagittal deformity reduction of 66.71% ($33.7 \pm 16.6^\circ$) being found, with an average Nash Moe rotational correction of 2.

Patients were followed for at least 24 months (average of 35.84 ± 11.4 months) with interrogation, physical examination and imaging studies (anteroposterior and lateral panoramic radiograph of the spine), with a minimal increase of 2.28° ($23.9 \pm 12.57^\circ$) being observed in coronal curvature. A t-test for related samples was performed to look for statistical significance, with a p-value < 0.0001 being found for the Cobb angle pre-surgically and at the end of the follow-up, with no

difference being observed between the immediate post-surgical and follow-up periods ($p > 0.05$).

An increase in sagittal curvature of 2.8° (average of $35.84 \pm 16.69^\circ$) was reported, with a p-value < 0.001 , with a difference being found between the immediate postoperative period and the follow-up conclusion ($p = 0.017$).

During follow-up, rupture of the rod was reported in one patient, which until the time of the study did not require revision surgery. All patients had the SRS-22 questionnaire applied, where an average result in the pain dimension of 2.8, 3.8 for self-image, 3 for function, 3 for mental health and 3.5 for surgical satisfaction were recorded, in a 1-to-5 scale.

Discussion

There are few reports in the literature on AIS treatment with pedicle screws and rods with long-term follow-up, with a minimum reduction loss being found in most series with a follow-up no longer than 24 months¹.

Our series, composed of 76% of female patients, agrees with Westrick and Ward report², who published a series of 99 patients operated with the referred technique with an incidence of the same gender of 79%. An epidemiological review concludes that AIS total incidence (in operated patients and in those who receive conservative treatment) is much higher in females than in males⁸.

Hwang et al.¹ conducted a multicenter study in 2012, and recorded the type of deformity according to Lenke, with 54.4% being found to have type I, with an average main curvature of 54.7° and a 22.3° kyphosis (measured from T5 to T12). Conversely, in our documentation we reported 56% of type I coronal deformity, an average main curve of 59.4° and kyphosis of 47.8°, with the latter point especially differing. When analyzing this result, we observed how the small size of the study affects, since having patients with a kyphosis deformity of up to 90° skews the mean.

We studied apical vertebral rotation using the Nash Moe scale, with 14 patients being reported with a type III deformity, 10 with a type II deformity and one with a type IV deformity. Kuklo et al.⁴ carried out a study involving 19 Lenke I, Nash Moe III patients. All of them had a radiographic imaging study performed, which was compared against a computed tomography (CT) scan; in all 38 studies was apical vertebral rotation measured with the Nash Moe method, with a trend towards an increase in the Nash Moe score

being observed with the radiological study. The authors referred that even grade 0 determined with a radiographic technique has some degree of rotation that is demonstrated by CT. However, the cost of performing a CT scan only for measuring axial rotation outweighs the benefit, since it exposes the patient to a high degree of radiation, in addition to entailing a high economic cost, without making any difference in the pre-surgical plan carried out with radiological imaging and physical examination⁴.

Kim et al.¹⁸ conducted a retrospective study with 29 patients, where they recorded a surgical time average of 347 minutes, 27 minutes more than the time reported in our study (320.72 minutes). We recorded an average blood loss of 1,146 cc versus a blood loss reported by Kim et al.¹⁸ of 961 cc, with an average difference of 185 cc. When average bleeding elevation was analyzed, patients with larger volume of blood loss were observed to be those with surgeries of longer surgical time and, therefore, longer anesthetic time. Due to the small sample size, the increase in bleeding volume average skews our mean.

Lehman et al.³ report an average of fused levels of 10, while in our study we reported 9.92 fused levels on average. A 2005 study by Suk et al.⁵ found that the use of instrumentation with pedicle screws decreases the number of fused levels in comparison with the use of hybrid fixation, with similar results.

In our series, a rate of complications of 24% was reported, while the complication rate reported in the world literature ranges from 4.4 to 51%^{1,3}. The most important step to avoid complications is the placement of the pedicle screws; a long learning curve is required even for a highly experienced surgeon⁵, and has a significant influence on the large variability in terms of reported complications, such as spinal cord injury, bleeding, dislodgement and fractures.

Suk et al.⁵ carried out a study with 203 AIS-diagnosed patients treated with pedicle screws and rods, and concluded that this type of instrumentation demonstrates great biomechanical advantages over other forms of vertebral instrumentation, by correcting the deformity and maintaining the correction.

At 2 years of follow-up, a loss of coronal deformity reduction of 2.28° was found and a loss of sagittal curvature reduction of 2.8°, in comparison with a 2-year follow-up carried out by Hwang, et al.¹ with a coronal reduction loss of 2.8°, with no kyphosis deformity loss.

Suk et al.⁵ reported their results with a minimum follow-up of 5 years, with a loss of coronal correction of 3%. Di Silvestre et al.¹⁹ compared pedicle screw

Figure 3. Clinical pre-surgical (A) and post-surgical (B) images of a patient undergoing management with pedicle screws and rods. Correction of the deformity, adequate coronal alignment and shoulder and hip symmetry are observed.

instrumentation with hybrid instrumentation, with a follow-up of 6.7 years, and found better maintenance of deformity correction by using pedicle screws and rods. They observed a correction loss of 11.3° with the use of hybrid instrumentation versus a correction loss of 1.9° using pedicle screws. This way, long-term biomechanical superiority of the use of rods and pedicle screws is explained¹⁹.

A follow-up of patient clinical status was carried out using the SRS-22 scale, with an overall result of 75% being found. Lehman et al.³, in a series of 114 patients, reported an overall result of 83.6%. In 2004, Bago et al.²⁰ conducted a study for translation validation and a cultural validation of the SRS-22 questionnaire, which included 175 patients (152 females and 23 males), demonstrating that the Spanish version of the SRS-22 questionnaire is valid, with an excellent reproduction of all items, and is equivalent and adjustable for clinical research (Fig. 3).

In 2007, Rosales-Olivarez et al.²¹ carried out a descriptive study of the National Rehabilitation Institute (INR – *Instituto Nacional de Rehabilitación*) historical records, where they included 120 patients (45 males and 75 females) diagnosed with congenital scoliosis, childhood idiopathic scoliosis, juvenile idiopathic scoliosis and AIS (25%), with an average age of 12 years, treated with a posterior (54%), anterior and mixed approach, using mixed techniques with Luque type I, II and III instrumentation (63%). In said study, a pre-surgical curve of 55.58° is described, while in the analyzed sample we obtained an initial curve of 60.8°; in the previous study, a coronal correction average of 25.92% was reported, which represents 38.8% less than the correction assessed in our current study (64%). They had a complication rate of 17% versus a rate of 24% reported in this study, perhaps because of the larger correction of the curve (14.47 vs. 39.12°), as

well as due to the severity of the cases, in addition to the fact that the use of pedicle screws *per se* implies a higher volume of complications; however an incidence of spinal cord injury of 5% was reported, similar to the 4% in our report.

Pedicle screws current use at the INR for vertebral deformity correction offers greater biomechanical advantage over the previously used mixed instrumentation. By instrumenting the three anatomical columns of the vertebral body, the deformity is corrected and the correction maintained more effectively than with mixed instrumentation, thus lowering the rate of complications, bleeding and the number of instrumented levels⁵.

Conclusions

- AIS treatment with pedicle screws and rods is safe and effective to correct scoliotic deformity and maintain the correction.
- Current use of pedicle screws in our institute offers advantages over the use of previously used hybrid instrumentation for the correction of vertebral deformity in AIS, offering a greater biomechanical advantage and lowering the rate of complications, bleeding and the number of instrumented levels.

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Conflicts of interests

The authors declare that there are no conflicts of interest.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments have been carried out on humans or animals for this investigation.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained informed consent of the patients

and/or subjects referred to in the article. This document is in possession of the corresponding author.

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