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# *Analysis of Mainstream Treatment Methods for Adolescent Idiopathic Scoliosis and Guidance on Application Selection*

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***Abstract.*** Teens between the ages of 10 and 18 are affected by the spinal issue known as adolescent idiopathic scoliosis. The global prevalence rate is 2%-3%, which is relatively high considering the global adolescent population base. If left untreated, it may cause physical pain, psychological distress, and functional impairment. This paper focuses on the three main treatment methods for AIS - physical therapy, brace therapy, and surgical treatment, analyzing their advantages and disadvantages, mechanisms of action, and applicable scenarios. The results show that physical therapy is effective in preventing progression and improving muscle balance for mild cases, but its effectiveness in clinical treatment still requires further experiments to confirm. Brace therapy can reduce the risk of severe progression for moderate cases, but there are challenges related to compliance. Surgical treatment has a relatively high correction rate for severe cases, but it also has corresponding risks and may lead to limited mobility and neurological complications. This paper provides evidence-based guidance for personalized treatment options, emphasizing the need to develop targeted intervention plans based on the severity of the disease and the specific scoliosis condition of the individual.

***Keywords:*** Scoliosis, adolescent idiopathic scoliosis, treatments.

## 1. Introduction

Adolescents between the ages of 10 and 18 might develop a three-dimensional issue in terms of the structure of the spine called adolescent idiopathic scoliosis (AIS). Taking into account potential reasons like congenital or neuromuscular disorders, it is known to be a lateral deformation of the spine with a Cobb angle of 10 degrees or more. There is still much to learn about the pathophysiology of AIS. Nowadays, it's thought that hereditary elements contribute to its development and occurrence, but the specific genetic transmission pattern has not been determined yet, and there are no relevant genetic testing applications in screening and management. Teenagers' growth and development are intimately linked to the disease's progression, particularly when their bones are still developing, and the risk of advancement is higher during this time. Younger age of onset, being female, a clinically significant family history of scoliosis, and relative skeletal immaturity are all risk factors for disease progression. Globally, the incidence of idiopathic scoliosis among adolescents is 2% to 3% [1]. The prevalence varies from region to region, ranging from 1% to 3% in the United States, 2.3% in Turkey, and between 0.6% and 2.0% in China, where 90% of the

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cases are adolescent idiopathic scoliosis [1-3]. This data is significant considering the large global population of adolescents [2].

The severity of scoliosis is classified into three levels: mild, moderate and severe. Mild spinal curvature is defined as a Cobb angle from 10° to 20°, moderate spinal curvature as a Cobb angle as large as 20° to 40°, and severe spinal curvature as a severe curvature: Cobb angle > 40°. Most patients with AIS show no obvious symptoms in the early stage of the disease. However, some patients may experience a series of problems. Although there is now no proof that mild curvature can result in disability or functional impairment, it may induce muscular back pain. For patients with severe curvature, they may experience physical pain, appearance deformity, and psychological-social distress. In rare cases, they may also suffer from lung diseases [2]. Moreover, AIS may have an impact on the mental health of patients. Studies have shown that the incidence of emotional problems such as anxiety and depression, as well as neurotic personality traits, is higher in AIS patients compared to healthy individuals. At the same time, some patients may also face issues such as body image disturbances [4].

Given the numerous adverse effects that AIS may cause, it is of great significance to intervene in it. Currently, ways to deal with AIS include physical therapy, bracing, and surgery. Currently, there are some studies on specific treatment methods and their effects, but there is a lack of discussions on the applicable scenarios, advantages and disadvantages, as well as the comparison of efficacy of different treatment methods. Therefore, the purpose of this article is to examine the benefits and drawbacks of various therapeutic approaches. and provide suggestions for the selection of treatment methods for AIS in different situations.

## 2. Treatment methods for idiopathic scoliosis

### 2.1. Physical therapy

Physical therapy (PT) for adolescent idiopathic scoliosis primarily focuses on correcting spinal deformity, improving muscle balance, and enhancing functional capacity through targeted interventions. There are several types of physical therapies that are applied in AIS, which are specific spinal stabilization exercise (PSSE), core stabilization training, three-dimensional (3D) corrective exercise, and manual therapy. PSSE refers to a set PSSE refers to a set of individualized exercises made to deal with the three-dimensional nature of scoliosis, such as lateral curvature and rotation. One of the representative treatments in PSSE is the Schroth method. This method achieves spinal rotation reduction through asymmetric breathing patterns and postural adjustments, strengthening the convex side's muscles, such as the erector spinae and stretching the soft tissues on the concave side, such as the intercostal muscles. This process can rebalance the spinal biomechanics and alleviate trunk asymmetry [5]. Core stabilization focuses on the deep stabilizing muscles such as the transverse abdominis and multifidus muscles, aiming to enhance the spinal support capacity, reduce compensatory movements, and improve posture control. Strengthening these muscles can reduce the excessive load on the lateral bending segments [6]. The three-dimensional corrective movement integrates sagittal (flexion extension), coronal (lateral flexion), and transverse (rotation) movements to simulate functional activities in real life. This neuromuscular retraining can facilitate the autonomous correction of abnormal movement patterns [7]. The manual therapy mainly includes joint mobilization and soft tissue mobilization, which are used to alleviate spinal stiffness, relieve muscle spasms, and improve mobility. Traction can temporarily stretch tense structures, but it is rarely used alone [8].

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The specific application of physical therapy depends on the severity of the spinal curvature. For mild adolescent idiopathic scoliosis, physical therapy is mainly used as a first-line intervention measure to prevent the progression of scoliosis, especially for patients with immature bones (Risser score 0-1). Regular training of at least 3 times per week is helpful in maintaining the spinal alignment and muscle balance [2]. For moderate spinal curvature, physical therapy is usually combined with brace treatment, which can enhance the compliance of brace wearing and reduce muscle atrophy caused by long-term wearing. Specific spinal stabilization training is particularly effective in improving trunk control during brace removal [9]. For severe spinal curvature, physical therapy mainly plays a role in the post-operative rehabilitation process. Physical therapy, such as low-intensity core training and joint range-of-motion exercises, can be carried out 6 to 12 weeks after the surgery, which helps stabilize the fused segments and prevent degeneration of adjacent segments [10].

Physical therapy has been proven to have positive effects in controlling scoliosis, alleviating symptoms, and improving functionality. In terms of correcting scoliosis, a randomized controlled trial comparing three-dimensional training (n=25) with conventional care (n=25) showed that after 24 weeks, the average Cobb angle of the three-dimensional training group decreased by 5.8° ± 2.1°, which showed significantly better results than the control group (2.1° ± 1.8°; $p < 0.05$) [7]. In another study, patients with moderate AIS (Cobb angle 20° - 35°) who received the Schloss therapy for 6 months experienced an average reduction of 7° in their spinal curvature (from 24° to 17°), and a 32% improvement in trunk rotation [5]. The use of physical therapy has also been proven to be beneficial for patients, helping to alleviate their pain and restore their physical functions. The core training relieved back pain in 72% of the patients, and the NRS score decreased from 5.6 to 3.3 ($p < 0.01$) [6]. The three-dimensional training increased the forced vital capacity (FVC) by 8.7% (the control group showed an increase of 3.2%), indicating that the improvement in trunk expansion ability has enhanced lung function [5]. In terms of stopping the process of the deformation of the spine in teenagers, the effectiveness of physical therapy is also supported by a study. Among patients with mild scoliosis whose bones were not fully developed, those who adhered to PSSE (with compliance ≥ 80%) had a two-year risk of progression of 18%, while those who were non-compliant had a two-year risk of progression of 42% [10].

However, physical therapy still has limitations and drawbacks in the treatment of AIS. First of all, the therapeutic effect of physical therapy varies significantly among individuals due to differences in their skeletal maturity. The application of some exercise-based therapeutic methods in clinical practice remains controversial. Baumann et al. recently conducted a meta-analysis that incorporated 26 studies, including 10 RCTs and 16 observational studies, and discovered that PSSE-treated individuals saw improvements in the curve that were statistically significant but clinically inconsequential. Additionally, patient-reported outcome measures and trunk rotation angle (ATR) did not show significant improvements [10]. Physical therapy requires patient compliance. However, for teenagers, non-compliance may occur. This reduces the effectiveness of physical therapy. The average compliance rate among adolescent patients was 60%, mainly influenced by time constraints and social stigma. 73% of the non-compliant patients experienced progression of scoliosis [8]. In some cases of severe spinal scoliosis, physical therapy can only be used as an auxiliary treatment and cannot be involved in the correction process as the main therapy. Therefore, at present, there is still a lack of research on the application of physical therapy in clinical practice. More studies are needed to confirm the effectiveness of physical therapy.

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## 2.2. Brace treatment

Bracing is the main non-surgical intervention method for AIS, aiming to prevent the progression of scoliosis during growth by applying corrective forces to the spine. The main types of braces currently in common use are thoracolumbar sacral orthosis (TLSO), crevicothoracolumbar orthosis (CTLSO), and 3D-printed custom braces. The TLSO is a full-body brace covering the thoracic to sacral region, consisting of rigid panels (such as the anterior, posterior and lateral sides) and adjustable straps. It applies asymmetric pressure to the convex side of the lateral curvature through lateral padding, while generating an opposing force on the concave side, thereby facilitating the rotation of the spine and reducing the angle of the curvature. This brace restricts the excessive movement of the lateral curvature segments while allowing the spine to grow within a controllable range. The CTLSO extends from the cervical vertebrae to the sacrum, including the cervical ring or chin support, and is suitable for upper thoracic vertebrae or cervical-thoracic segment scoliosis. It stabilizes the upper thoracic vertebrae and cervical vertebrae regions by restricting flexion and extension, as well as rotation movements, and prevents the possible progression of proximal kyphosis that may affect the cervical spine. The 3D-printed customized braces are made using 3D scanning and printing technology, and they are perfectly tailored to fit the unique spinal anatomy of each patient. It provides precise local pressure based on the three-dimensional shape of the spine, which improves comfort and compliance compared to traditional braces. The lightweight design reduces skin irritation and enhances mobility.

The brace plays a positive role in preventing the progression of scoliosis and in correcting the curvature. In terms of preventing the further progression of AIS severity, a landmark randomized controlled trial (n=242) demonstrated that wearing a brace throughout the day (≥ 18 hours per day) could reduce the risk of side curvature progressing to > 50° by 72% (15% vs. 41% comparing to the control group; $p<0.001$ ) [11]. Success rate (without > 5° progression) of the 3D-printed orthosis during the 2-year follow-up period was 68% [12]. In terms of scoliosis correction, studies have shown that 60% of patients experienced an average reduction of 3° to 5° in their scoliosis after wearing the device for 12 months. Among them, patients with flexible scoliosis (<30°) showed more significant improvement [13]. The efficacy of night-specific braces (such as the Charleston brace) for < 35° scoliosis is comparable to that of daytime braces (risk of progression 18% vs. 21%; $p = 0.62$) [10].

However, the use of the brace still has some limitations and side effects. First of all, for the brace to be successful, the patient must wear it for an extended period of time. But this is not the case for all teenagers who can consistently and properly adhere to the prescribed wearing time. For teenagers, the average daily wearing time is 12-14 hours (lower than the recommended 16-23 hours), and 30% of teenagers do not follow the instructions due to discomfort, appearance concerns, or social stigma. Non-compliers have a 3.2 times higher risk of progression (45% vs. 14% for compliant individuals) [14]. Apart from the difficulties in terms of compliance, some wearers may also experience adverse reactions. The research shows that 35% of the patients experienced skin irritation, paravertebral muscle atrophy, and a 5% to 8% reduction in forced vital capacity (FVC) for those who wore it all day [13]. In addition, the brace also has a very limited effect in the long-term treatment of AIS. 20% of the patients wearing the braces required surgery within 5 years after discontinuation, mainly due to the late progression of the residual growth period [10]. Besides that, the brace cannot correct the existing deformity; it can only prevent its further progression. Therefore, braces are more suitable for the prevention of AIS and the treatment of early-stage, less severe scoliosis to prevent further deterioration. They are not suitable for well-established and more severe cases of scoliosis.

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### 2.3. Surgical treatment

The primary treatment for severe AIS is surgery. Surgical intervention for AIS aims to correct spinal deformities, prevent progression and restore trunk balance through spinal fusion or non-fusion techniques. The main surgical methods currently available include posterior spinal fusion (PSF), growth-friendly spinal instrumentation (GFI) and anterior spinal fusion (ASF). PSF surgery involves exposing the spine from the posterior approach, implanting pedicle screws or hooks at the kyphotic segments, and correcting the deformity through rod rotation and compression. Subsequently, bone grafts are implanted to fuse the treated segments and form a rigid structure. It achieves three-dimensional correction by rotating through the spine, reducing the angle of scoliosis and restoring the sagittal plane balance. Fusion eliminates the mobility of the fused segments to prevent the recurrence of deformity. The ASF surgical procedure involves making an incision through the chest wall or using a thoracoscopic anterior approach to remove the intervertebral disc and implant an intervertebral graft. At the same time, internal fixation is placed to stabilize the spine until fusion occurs. It directly targets the anterior column of the spine. By shortening the concave side and reducing rotational deformity, it more effectively corrects lumbar or thoracolumbar scoliosis. GFI employs non-fusion techniques, such as growth rods or vertical expandable artificial titanium ribs (VEPTR). These devices enable spinal growth while gradually correcting deformities. This prevents premature fusion of severe spinal curvature in young children by applying tensile force to guide growth and prevent the progression of the curvature.

The current research data demonstrate that surgery has a significant effect in correcting AIS, especially in cases of severe AIS. A research report indicates that PSF can achieve a 65-72% coronal correction in Lenke type 1 curvature, and the correction effect remains good at the 2-year follow-up [11]. However, while there is a relatively high correction rate, the drawbacks brought about by the surgery are also numerous, including more complications. First of all, the fusion surgery will make the patient's joints and limbs more rigid and limit their mobility. The data shows that PSF reduces the lumbar joint range of motion by 20-30%, and 18% of the patients reported limited mobility [10]. Additionally, the patient's nerves may sustain injury as a result of the surgery. The study in the "Bone & Joint Journal" reported that 3.1% of the complex ASF cases experienced temporary neurological dysfunction, while the rate for PSF was 1.7% [15]. In many cases, patients are likely to require a second operation because the first one was not successful. The reoperation rate due to the rupture of the suture or excessive correction reached 31% in VBT [16]. Due to the potential side effects of surgery, the assessment of whether AIS patients should undergo surgery should be more cautious and rigorous. When performing surgery on patients, a more detailed evaluation should be conducted to adopt the most appropriate surgical measures for the patients, minimizing the side effects to the greatest extent possible. More research is still needed to determine the appropriate surgical measures for different cases of AIS, in order to minimize the damage caused by the surgery while maximizing the treatment effect.

## 3. Conclusion

AIS requires personalized strategies based on the degree of spinal curvature. Physical therapy, as the first-line intervention for mild AIS, effectively prevents progression and improves muscle balance through targeted training methods such as Schroth therapy. However, its efficacy depends on the patient's compliance, and its clinical effectiveness still needs to be explored. Bracing treatment is crucial for moderate cases, which can prevent progression of the curvature. 3D printed braces can improve comfort, but long-term adherence remains a challenge. Surgical treatment is indispensable

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for severe AIS, which can achieve significant correction, but there are risks of reduced mobility and complications. This paper emphasizes that the treatment approach should be matched to the severity of the disease and the individual characteristics of the patient. For mild cases, physical therapy is used; for moderate cases, physical therapy combined with brace treatment is employed; and for severe cases, surgery is combined with postoperative rehabilitation. This literature review contributes to the selection of personalized treatment methods for adolescent idiopathic scoliosis, providing a more comprehensive basis for the choice of treatment approaches. The limitations of this review include inconsistent data on compliance and differences in long-term outcomes among different studies. Additionally, the data analysis and case studies in this article are relatively limited, making it difficult to obtain universal results. Future research should focus on integrating multiple data sources to enable the selection of treatment methods to cover more situations and improve the analysis of the effectiveness of each therapy. In terms of treatment method improvement, training plans should be optimized, brace designs should be improved to enhance compliance, and refined techniques should be used to reduce surgical complications. Ultimately, the treatment method should integrate clinical assessment and the patient's own condition to improve the management and treatment outcomes of AIS.

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