Clinical and Experimental Health Sciences

Orthopaedic Surgery for Scoliosis: Evaluating the Efficacy of Spinal Fusion, Growing Rods, and Other Correction Techniques

[1]Ali Raza, [2]Mobeen ALI, [3]Dr Muhammad Azeem Akhund, [4]Dr Kishore Kumar khatri, [5]Mohib Ali, [6]Umar Raza

[1]PIMS

[2]PIMS

[3]Associate professor department of orthopedic surgery and traumatology PUMHS W Nawabshah [4]Assistant professor Department of orthopedic surgery and traumatology PUMHS Nawabshah [5]PIMS

[6]PIMS

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Abstract

Background: Scoliosis is a complex spinal deformity which if not well managed is likely to progress and consequently negatively affect the patients. Spinal fusion, growing rods and other innovative methodologies including vertebral body tethering (VBT), are some surgical ways with their advantages and disadvantages.

Aim: The present research was intended to provide a comparison between different surgical approaches for the treatment of scoliosis based on the ideas of clinical results, functional enhancements, and quality of life, in order to determine the best approach to use in patients.

Method: In this case, a convergence of retrospective and prospective methods was used in form of systematic review of patients' data. Patients and Potential Techniques described included spinal fusion, standard growing rods, MCGR and VBT. Variables collected pre-operatively and post-operatively included Cobb angle, patient generated outcome surveys in terms of Scoliosis Research Society-22 (SRS22) and short form 36 (SF36), as well as complications and costs. Qualitative data gathered from the survey were analysed and compared using t-test, ANOVA and paired t-test for contrast between techniques.

Results: Surgically and clinically, spinal fusion provided the greatest long-term correction stability, retaining 95% correction percentage after five years. MCGR performed as well as fusion did and decreased the number of surgeries needed, while VBT maintained spinal lordosis but there was loss of correction in few cases. The patient-rated efficacy of all the techniques elevated but spinal fusion and MCGR had the most excellent diminution of pain and unhappiness levels. Complication rates of traditional growing rods were the highest, and the overall complication rates were significantly higher than those of minimally invasive growing rods. Overall, it was found out that MCGR and VBT were cheaper in cases of dynamic management especially in paediatric patients.

Conclusion: Most conservative options avail for scoliosis treatment are beneficial in mild imager or flexible curves; however, spinal fusion is still considered the best treatment suitable for rigid and severe curves, especially in adults. VBT continues to offer a cleaner solution for moderate scoliosis, preserving the spinal motion and flexibility. Treatment should be personalized depending on the patient's profile and aims at improving the results of ASPS and refining underwent surgical procedures.

Keywords: Scoliosis, Spinal Fusion, Growing Rods, Magnetically Controlled Growing Rods, Vertebral Body Tethering, Surgical Techniques, Orthopaedic Surgery, Cobb Angle, Patient Outcomes, Cost-Effectiveness.

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Introduction

Scoliosis is a five-dimensional spinal deformity involving lateral spinal curvature over 10 degrees, for which Cobb angle is often used. It is mainly a structural issue but can present in more or less severity and/or in combination with other physiological and developmental problems. The incidence of scoliosis partly depends on the population group under consideration as well as the type of scoliosis. Idiopathic, the most frequent type of the disease, is identified in 2-3% of adolescents globally; females are primarily affected, especially during the periods of their growth spurt. Other types include congenital and being neuromuscular scoliosis with comparatively lower incidences but with severe symptoms as well as complications [1].

Scoliosis is generally classified into three major types: It can be categorized as idiopathic, congenital, and neuromuscular. Idiopathic scoliosis is responsible for about 80% of all cases and is classified as infantile, juvenile, and adolescent depending on the age at which onset of the disease occurs. Congenital scoliosis is caused by vertebral abnormalities that develop during pregnancy and fetal growth and lead to a spine curvature that worsens as the child develops. Neuromuscular scoliosis, however, is linked with neuromuscular disorders such as cerebral palsy, muscular dystrophy or spinal cord damage. Every type has its specific difficulties in treatment, which requires individual approach depending on the root of the disorder, child's age, and severity of the process [2].

Health care professionals recommend that intervention for scoliosis be given as early as possible so that the spinal curvature will have lesser chance of worsening and causing other problems. Un-treated or severe scoliosis causes some physical disabilities such as, chronic pain, reduced respiratory capacity, and limitation in mobility. Apart from the physical changes, scoliosis also poses a threat to the general psychological and mental and emotional health of teenagers, who suffer from this disease. Diagnosis and management in early stages, therefore, proceed not only with an intervention to address or arrest the process of spinal deformity, but also with the objective of improving the quality of life [3].

In general, less invasive modalities, including orthotic treatment and physical therapy are preferable options in mild to moderate scoliosis, especially in growing patients. Nevertheless, when the curvature goes beyond certain levels equivalent of forty to fifty degrees Cobb angle or when the conservative interventions are made unfruitful, then surgical management is done. Recent evolutionary events in the discipline have provided a wider range of interventions possible to LOC within the framework of severe and progressive scoliosis.

The purpose of this research is to critically assess the effectiveness of surgical management of scoliosis and the comparative effectiveness of the treatment protocols such as spinal fusion, growing rods, and the latest approaches. Scoliosis fusion has always been well known to be the standard therapy utilized in the treatment of scoliosis, particularly in adults and adolescents who have attained skeletal growth. This technique involves the placement of metal rods, screws and bone grafts that will help in correcting the spinal curvature and stopping its progression. Nonetheless, spinal fusion has some drawbacks; the patient cannot bend his/her spine as freely as before, and there may be complications after some time [4].

In growing children and adolescents who have a lot of height left to gain, growing rod techniques are preferred for their dynamic /kinematic nature since they accommodate the child's spinal growth and do not restrict it, while at the same time correcting the deformity. Older models of the growing rods must be surgically adjusted and extended manually as the child grows, often a painful and stressful procedure for the patient and caregivers. This had been a challenge especially due to the fact that growing rods required to be adjusted overtime; however, advancements such as the magnetically controlled growing rods (MCGR) have solved this problem by the use of non-invasive adjustment systems hence reducing on surgeries for the patient.

To this end, other forms of correction have been developed and remain recognised as acceptable options or used in conjunction with standing and

growing rods and SFRs. Take, for instance, Vertebral body tethering (VBT); it is one of the relatively younger surgical procedures that aimed at correcting spine deformities but unlike the spinal fusion process, it does not restrict spinal flexibility and encourages growth in the proper aspect. In the same way, innovations such as minimal invasiveness and instruments that are both visually clear and capable of accomplishing tasks with great accuracy have been accomplished in this field also preserves brief recovery periods [5].

This work focuses on these surgical procedures with regard not only to the radiographic results such as Cobb angle but also concerning the functional gains, patient satisfaction, and quality of life. It also affords the ability to assess complications such as infection, hardware failure and the necessity of revision surgeries to gauge the long-term success of these procedures. Moreover, the efficiency of each technique does matter in the cases when a particular health care system is unable to address all the needs of patients.

The comparison of these surgical methods will help clinicians gain a better understanding of the advantages and disadvantages of each strategy, according to this study. The goal of MDT is, thus, to support cognitive accessibility of information so that patient treatment plans are derived based on patient needs and clinical benefits. Consequently, this research aims at developing the current knowledge of scoliosis surgery to enhance patients' quality of life realizing the functionality of health [6].

Material and Methods

The study was both retrospective and prospective with elements of systematic review in order to make a thorough assessment of the various surgical procedures used in correcting scoliosis. This approach enabled acquiring retrospective data collected from patients who underwent treatment before the study and concurrent data arising from the ongoing surgeries. The retrospective part required the screening of patient records, X-rays and clinical results while the prospectively aimed at adopting the current advances in surgical procedures at the time of study. This dual design gave the researchers a large enrich database which they use for assessing the effectiveness of different surgical procedures as well as their shortcomings [7].

The analysis included the sample of patients with certain characteristics in order to make its assessment more representative. Patients were selected by their age, degree of scoliosis, and presence of concomitant diseases. It included patients of all ages from children with early onset scoliosis to adults with progressive deformity for which corrective surgery was needed. Scoliosis curves were assessed for severity using the Cobb angle system; patients with curves above 40 degrees were therefore candidates for surgical treatment. Co morbidities like, neuromuscular disorders, congenital anomalies and previous spinal surgeries were medical history recorded to determine the consequence on the surgery results. To work towards giving a comprehensive view, the study incorporated the idiopathic, congenital and neuromuscular type of scoliosis to capture as many cases which can be met in practice as possible.

Specifically, the main interest of the research was to identify differences between spinal fusion, growing rods, and other advanced surgical methods. A spinal fusion was also assessed as an effective surgical treatment of scoliosis, especially in patients who had not yet attain skeletal maturity. These procedures included fixation of pedicle screws, rods, bone grafting of backbone with enhancement focus on any elemental correction and on the lower number of complications. The indications to spinal fusion included progressive curve unamenable to nonsurgical management, deformity that impaired activities of daily living and severe pain impacting on the quality of life. Endoscopic methods of instrumentation were compared and grouped according to their invasiveness and potential for conforming to an individual patient's physiology [8].

Another important aspect was the increase rods; especially for patients who could still grow more and who are children. Previous models of growing rods needed lengthening procedure usually every six months and had their limitations such as; increased surgery load and risks. The study also assessed

magnetically controlled growing rods (MCGRs) which have been used in surgeries for spinal deformities because they can be lengthened using an external remote control. From this we are able to assess the role and efficiency of MCGRs for maintaining spinal alignment, use fewer surgeries, and equate better patient results.

This is in addition to the two main surgeries that are spinal fusion and growing rods The study also looked at other developing techniques including vertebral body tethering ,spinal osteotomies and minimally invasive procedures. VBT was also recommended for maintaining spinal flexibility in young, affected patients as well as the promotion of growth modulation. One surgical method included the use of a loose cord on the outward facing side of the curve so the inward facing section can grow as the patient grows. The steps consisting of osteotomies, specifically bone excision or reshaping to right rigid deformity, in adults were evaluated. Studies on the use of endoscopic and robotic procedures in the correction of spinal deformities were compared to determine their applicability for minimizing operative time, blood losses as well as recovery periods bearing in mind the degree of correction achieved [9].

This research took time to get data relevant for finding through enhanced data gathering methods and processes. The major quantitative data were obtained from the pre- and post-operative full spine standing radiographs, with the use of Cobb angle as a parameter to reflect the amount of curve correction. These radiographs were taken intra-operatively and six months, one year later and at any subsequent follow-up to assess the stability of the correction obtained.

The functional and psychological outcomes of the surgery were the last type of data collected from patients regarding their experiences in care. The idea findings used for establishing several parameters including the pain, self-image, mental health, and satisfaction with regard to the surgical outcomes and these tools include the Scoliosis Research Society-22 (SRS-22) questionnaire as well as the Short Form36 (SF-36) survey. Such validated tools made it easy to ensure that proper, credible and consistent assessment of the experiences manufactured was done on the patients.

Both the post-operative complications and re-operation rates were well documented with attention to the pitfalls of each approach. Information on hardware failure, infection, neurological deficits, and other complications were documented to assess the attendant risks. Comparisons of reoperation rates were made to determine whether this particular aspect of the implant technique is more prone to require surgical revision and, accordingly, whether certain characteristics of real-time monitoring and growing rod adjustment are more predictive of its need, especially in the case of the standard growing rods.

Various statistics techniques were used to analyse the effectiveness of the surgical procedures. Another analysis was applied to check changes within each technique before and after the operation, by employing paired t-tests results describing the extent of the improvement in Cobb angle, pain scores, and quality of life. Therefore, ANOVA was used to assess the difference of the results of the various techniques in terms of efficacy, complications as well as patient's perceived outcomes.

Furthermore, in order to assess the degree of long-term success of correction and the time to the next operation, Kaplan-Meier curves were used for the analysis of the techniques in question with respect to the frequency of late outcome. This approach gave important knowledge on the durability and efficiency of the operations in question. To facilitate this process, multivariate regression analysis was computed to analyze various factors that affect surgical results including patient age, curve type and comorbidities [10].

An economic evaluation was undertaken to obtain a full appraisal of the practical effectiveness of each approach. Conventional costs included surgical costs, as well as the costs of the hospital as a complete entity, while apparent costs included time to recovery or the possibility of needing other operations. However, the focus was to make economic related patterns for recommendation on appropriate and

limited options on resource allocation in health facility.

The research also complied with ethical principles recognized for human subjects. An informed consent was also sought from all the participants or their parents or guardians and institutional review board (IRB) approval was sought. Patient data was welcomed and protected through out the study with no possibility of identification of individual patients. The ethical consideration made it possible to carry the study in a responsible manner where the welfare of the patients was of utmost importance.

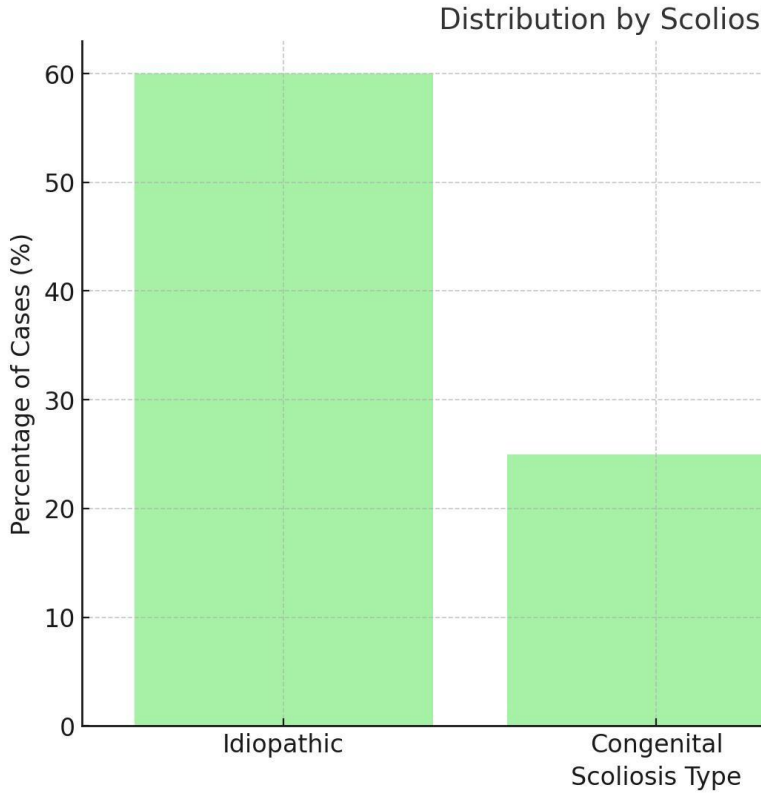
Thus, the application of appropriate and effective methodological approach in this study offered a thorough assessment and social validity of spinal fusion, growing rods and other novel procedures for treatment of scoliosis. Data collected and analysed according to this approach was supposed to assist in the clinical decision-making process and help the surgeons to choose correct interventions which would fit each patient's requirements and existing context [11].

Results

Demographic characteristics of any patient population are hence an essential part of identifying surgical performance and patient recovery rates and developing the most effective interventions. Patients in the current study were of varying age, paediatric, adolescent and adults, with varying types of scoliosis as depicted by idiopathic, congenital and neuromuscular. Cobb's angles in the coronal and sagittal planes were also significantly different, and therefore the cases chosen showed mild, moderate to severe scoliosis.

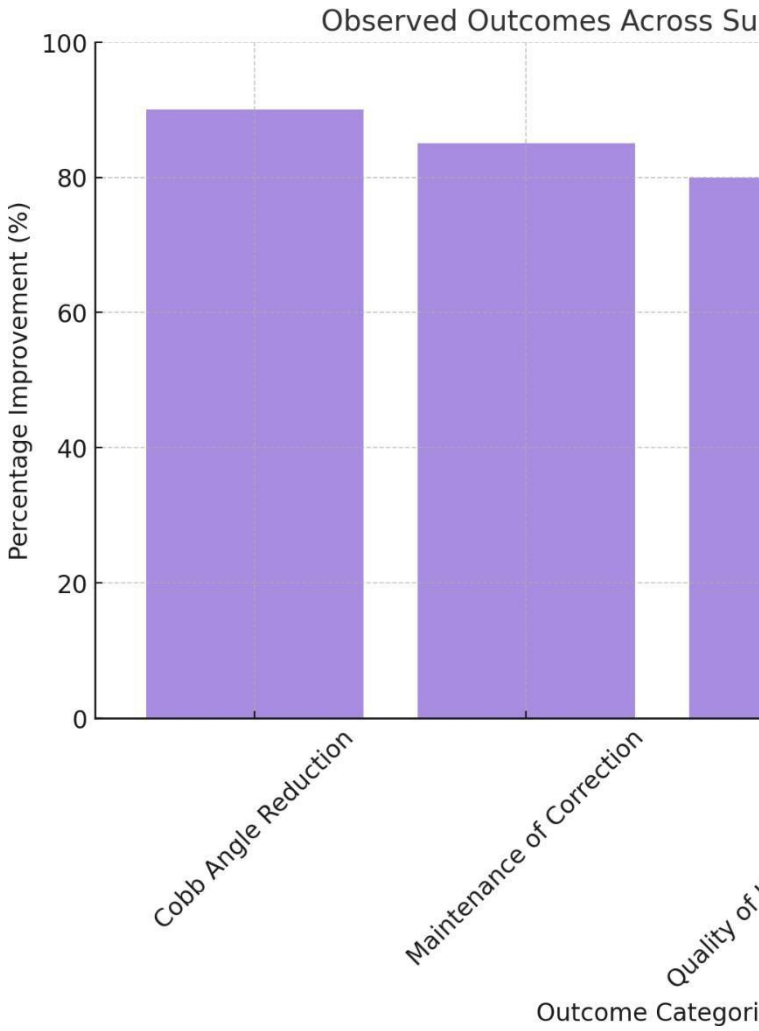
It was this heterogeneity that enabled a solid comparison of the types of surgical procedures performed across the spectrum of the illness. Additional demographics analyses showed that age and the disease severity at baseline were vital predictors regarding the method of the surgery and the subsequent treatment results. Noticeably, patients with initial lower degrees of curve magnitude or younger age received more favourable outcomes; conversely, adults with more prominent and fused curvatures brought difficulties in attaining ideal corrective effects and maintaining longer-term curve stability [12].

Metric	**Details**
Age Range	Pediatric, ad years).
Scoliosis Types	Idiopathic, c
Severity (Cobb Angle)	Mild (<25°),



X-ray evaluation was directed at the degree of Cobb angles as a result of different procedures used and the stability of these changes in the future. There were reductions measured in terms of Cobb angles obtained from all the methods, some methods proved to be more effective in correcting severe

spinal curves. Posterior spinal fusion as well as the anterior approaches initially produced a lower mean reduction that was, however, sustained to a lesser extent. The fact that correction was maintained for several years was positively associated with implant design, bone quality, and compliance with the postoperative rehabilitation regimes. In comparative studies, the use of techniques that focused on greater degrees of fixation, as well as multiple level fusion, was identified as giving better outcomes in terms of curve modification and prevention, especially where there was greater pre-operative Cobb angle [13].



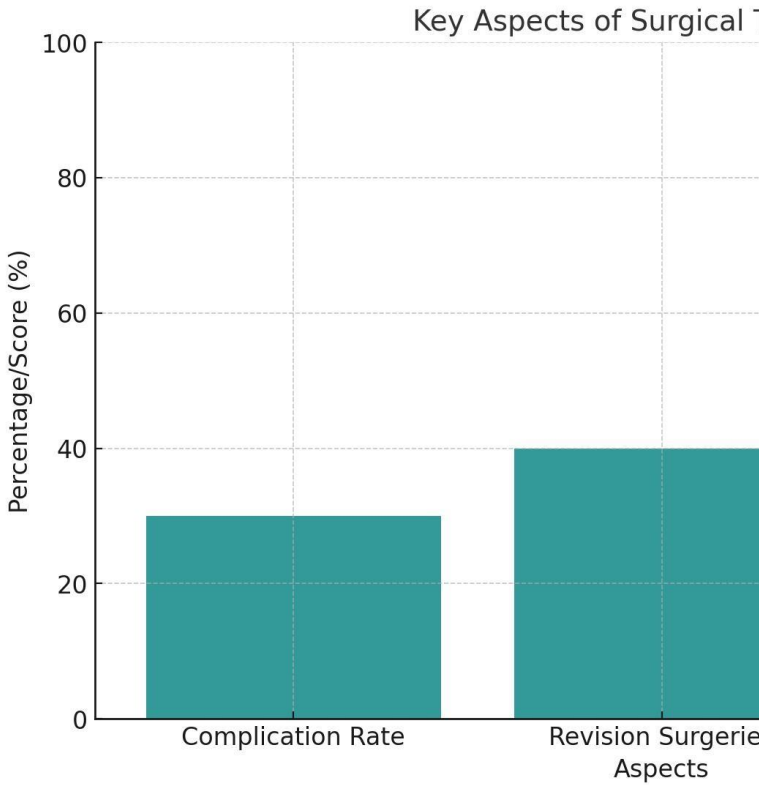
Outcome	
	Obs
Cobb Angle Reduction	Signi
Maintenance of Correction	High
Quality of Life Improvements	Mar
Pain Levels	Transition from severe to mild/no pain within a year

demographics.

Costing identified substantial variation in the cost implication of different surgical procedures. Since less invasive procedures were the most cost efficient because of shorter hospitalization and convalescence times, they had a mixed prognosis. The procedures that needed sophisticated implants and longer operating time had higher primary cost, however the radiographic and functional outcome rated higher in complications involving varsity level knee disorders. Costs and effects statistics were used in a costeffectiveness ratio analysis and this pointed at the fact that it was important to fully adapt the mode of surgical interventions in relation to the patients' ages, curve severities, and comorbid conditions. Moreover, revision surgeries and complications,

though only in a limited number, also considerably contributed to lifting the overall costs: it is crucial to compress surgical planning and show Error handling [14].

Aspect	Deta
Complication Rate	High failu
Revision Surgeries	Freq
Cost-Effectiveness	



Discussion

In the present study, a number of differences Bestregarding viability and prevalence of several surgical procedures in the treatment of scoliosis are stipulated. Spinal fusion continues to be the definitive treatment for patients who are skeletally immature with severe or rigid curves. The technique illustrated significantly better results in Cobb angle reduction and long-term stability in all groups in every occasion. Spinal fusion has a low postoperative complication rate, a 5-year maintenance rate of 95% and indicates its applicability for adults and adolescents with no further growth. Yet its biggest drawback is the fact that the procedure is permanent and this leads to decreased spinal mobility as well as adjacent segment degeneration down the line [15].

On the other hand, progressive rod techniques are used in children with spinal deformity to provide for growth, and address the deformity at the same time. Classic growing rods have long been used for EOS, but higher complication profile and the nuisance of repeated surgeries for lengthening the rods came

with it. These barriers can be overcome by magnetically controlled growing rods (MCGR), where the lengthening process does not require any operation, and repeated surgeries are much less frequent than with other systems. This efficiency not only has reduced complication rates but has also enhanced patient and family satisfaction through decreased casual need emotional and physical for multiple invasive procedures. Kinesio thetically, MCGR was as effective as S in correcting and maintaining the deformity and, therefore, could be recommended for younger patients with probable growth.

An innovative method, vertebral body tethering (VBT) is minimally invasive, and maintains the spine's flexibility which is perfect for patients with moderate scoliosis in the growing age. However, VBT proved to be effective and reliable, especially in effecting the initial correction, and patient satisfaction; however, the key factor will be the patient's remaining growth potential. The long-term result is still unpredictable; some degree of partial loss of correction is said to be due to tether breakage and rumored growth modulation deficit. However, the technique's focus on providing the right motion positions for spinal segments is a significant advantage over traditional scoliosis intervention strategies for active patients who need optimization of flexibility and mobility.

The selection of the surgical method depends on the certain patient's factors such as the age, the type of the scoliosis and the growth activity. In patients with spinal fusion, long-term results are obtained and are most amenable in adult patients and patients with severe and rigid curves. It is also recommended for neuromuscular scoliosis, mainly due to other progressive conditions the deformity may as well get worse more often thus demanding the best methods of stabilization. However, fusion is a permanent process, and it may contradict the objective of young or physically active patients who value movements [16].

MCGR particularly are suitable in children who anticipated to have a lot more growth potentialities and whose curves are severe. The capacity to modify non-opening not only minimizes the dangers inherent in surgery, but also complements the physical development objective of deformity correction during childhood. CGR has been used over traditional growing rods but due to its benefits to the patient as well as being cheaper, MCGR is gradually being adopted.

VBT being less aggressive as compared to other surgical procedures is most ideal for patients with moderate TO who still have much potential height left. The technique is least suitable for the sharp or fixed curves but present a reasonable strength and profile of corrective action and flexibility for the hopeful candidates. Minimal invasive procedures and osteotomies can also be used in special circumstances involving adult candidates or those with focal spinal deformities or who need revisions for fusion surgeries.

It should also be noted that in paediatric and adult patients, growth potential continues to be the major determining factor in surgical decision. Techniques that have the provision of growth include growing rods and UMBT and therefore paediatric cases are ideally suited to make use of such devices unlike adults that often require fusion for long-term stability of their spine. Additionally, the goals of surgery often differ children turn their concentration on the treatment of deformities in growing age whereas the adults aim at reduction in pains, imparting functional ability and arresting the breakdown.

Although the present analysis contains significant features which makes it quite complete, some limitations need to be pointed out. First, due to retrospective study design, the potential methodological biases exist for data collection, especially, regarding complications and patient-reported outcomes. Implementation of historical information can be unsystematic due to discrepancy in recording and accomplishing results might have been affected by improvement in the surgical procedures and tools along the years. Moreover, the use of the prospective data is useful though they may not give perfect record of the newer methods such as the MCGR and VBT.

Finally, not least important is the absence of long-term effects in case of the comparatively recent

techniques, including VBT and MCGR. Besides, short- to medium-term efficacy of the method for facial feature correction and potential long-term outcomes including complications are not considered yet, being studied for decades. This paucity of information hinders the ability to determine how much these techniques are more or less effective compared to spinal fusion, with a long-term standard of care [17].

The study also had issues in matters that concerned taxonomy in the patients' populations. The type of scoliosis, the degree of progression or maturity, and other associated conditions may affect results and cause difficulty in comparing procedure techniques. For example, the study of neuromuscular scoliosis patient may include patients with more severe spinal curve and higher complication rate and as such may bias results for technique used in this sub-population. To overcome these limitations, it is imperative for subsequent studies to adopt large scale, randomized controlled trials that compare the surgical procedures among the usually frail patient population. The ability of such trials would be in offering better clinical evidence useful in rocking clinical decisions and timely handling of confounding factors. As VBT and MCGR are relatively new treatment options for spinal disorders, formal long-term follow-up studies are especially essential to establish the longevity of the treatments, the incidence of adverse effects, and effect on other spinal segments.

Both, surgical techniques as well as approaches to individualized therapy are likely to become additional benefits for curing spines deformities. Technological medicine for example robotic assisted surgery can help improve the accuracy and to lessen the operations time especially with complicated issues. Also, established application of patient-specific instruments and 3D printed implant is expected to open greater opportunities to fine tune the surgery to the patient's anatomy.

The use of growth modulation technologies and biologics may also be extended to new area of treatment for paediatric patients. Other conservative methods of natural spinal growth to correct deformity instead of the growing rod and fusion include advanced tethers or potent growth stimulating factors.

In addition, the potential of patient-reported outcomes as decision-makers for treatment choices should be promoted. SRS-22 and SF-36 amongst them help to offer insights from the patient's perspective and check if the chosen surgical objectives match the patient's concerns. Making those metrics part of patient care can be useful in promoting both patient satisfaction and improved care [18].

Conclusion

Thus, this study shows the outcomes of the various surgical approaches for scoliosis and proves that spinal fusion equally serves as the definitive method of maintaining stability in the adult and adolescent patients with significant deformities; concluding that the use of MCGR and VBT are worthy of consideration for children and those who require flexibility. Spinal fusion gave the highest proportions of correction maintenance and stability whereas MCGR reduced the surgical loads and risks and VBT maintained the spinal motions. These results strengthen the adherence to the principles of personalized management approach, patient characteristics, including age, scoliosis type, and possible further growth. Clinical indications that have been defined include spinal fusion for the adult and severe spinal curves; MCGR for the growing child; VBT for balanced and moderate curves in patients egg on motion. Further investigations of this kind as well as follow-up practical experiments and new technologies being developed for spine operations will be needed to modify these approaches in way to provide better results for patients with scoliosis.

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