Scientific Research Publishing

Open Journal of Radiology, 2018, 8, 1-12
http://www.scirp.org/journal/ojrad
ISSN Online: 2164-3032
ISSN Print: 2164-3024

Radiological Evaluation of Spinal Instrumentation as Treatment for Adolescent Idiopathic Scoliosis, a Single Saudi Center 5-Year Experience

Amir Monir Ali[1,2]

[1]Department of Radiodiagnosis, Faculty of Medicine, Mansoura University, Mansoura, Egypt
[2]Department of Medical Imaging, Sultan Bin Abdulaziz Humanitarian City, Riyadh, Kingdom of Saudi Arabia
Email: amirmonirali@gmail.com

How to cite this paper: Ali, A.M. (2018) Radiological Evaluation of Spinal Instrumentation as Treatment for Adolescent Idiopathic Scoliosis, a Single Saudi Center 5-Year Experience. *Open Journal of Radiology*, **8**, 1-12.
https://doi.org/10.4236/ojrad.2018.81001

Received: December 31, 2017
Accepted: January 28, 2018
Published: February 2, 2018

Abstract

Aim of the Study: The aim of this work is to radiologically evaluate the postoperative outcomes of spinal instrumentation performed as a treatment for Adolescent Idiopathic Scoliosis (AIS) on 5-year follow up basis, and to correlate with different clinical scenarios. **Materials and Methods:** One hundred (100) AIS consecutive patients treated with spinal instrumentation were included in this study. The study period was from 2012 to 2017. All patients had radiological evaluations including total spine x-rays, low dose CT scan using Orthopedic Metal Artifact Reduction (OMAR) software and MRI, after obtaining the informed consents and approval of the institution ethical board. Radiological evaluation included Cobb angle measurement assessed pre, postoperatively and at regular intervals within the 5-year period. **Results:** Of the 100 patients included, 24 were females and 76 were males. The average age at operation was 16.5 years. Sixty seven (67%) patients showed good correction and maintenance of the spinal curves where the mean Cobb angle was 68˚ preoperatively and 21˚ postoperatively, representing a correction rate of 74%. Thirty three (33%) patients showed complications including postoperative infection (13), surgical revision (4), pseudarthrosis (3), neurological deficits (5), screw loosening (7) and complete hardware failure (1); in whom the preoperative mean Cobb angle was 56˚ compared to the patients with no complications ($p = 0.288$). In males, there were postoperative complications in 27 out of 76 and in females 5 out of 24, ($p = 0.027$). The average duration of follow-up was 3.7 years for all cases. **Conclusion:** Five-year follow up of patients with AIS treated with spinal instrumentation demonstrates good improvement and maintenance of the corrected spinal curves in two thirds of

patients, one third showed variable minor and major complications. Low dose CT scan with OMAR provided an effective modality for evaluation.

Keywords

AIS, Instrumentation, Radiology, Long-Term, Follow up

1. Introduction

AIS is the most common type of spinal deformity treated by surgical fixation. Its onset is usually insidious and its complications may be deadly [1] [2]. Instrumental correction of scoliotic deformities has progressed from Harrington rods, to Cotrel-Dubousset (CD) instrumentation, to the more recent advent of thoracic pedicle screw fixation [3]-[8]. Harrington rod application improved coronal deformity yet, sagittal deformity was almost associated flat-back syndrome [9] [10] [11]. The use of CD instrumentation improved outcomes, but correction of axial rotation remained questionable [3] [4] [5] [6]. Recently, the application of pedicle screws-used in all patients of this study-has improved upon many of the limitations from the preceding constructs and provided good maintenance of correction in the short-term [12]-[19].

Suk *et al.* [7] reported outcomes in 78 patients treated with surgical fixation by pedicle screws and reported improved correction rate at 2 years follow up when compared to hybrid constructs. Other studies showed pedicle screws to provide best immediate postoperative correction of coronal curves, planar translation, and rotation [14] [15] [16]. Good maintenance at 2 years has been reported in both fused and compensatory curves, as well as a reduction in the number of segments fused and a lower revision rate associated with pedicle screw constructs [15] [19].

Although long-term radiological outcomes have been reported for earlier spinal constructs, the radiological evaluation of spinal instrumentation with pedicle screws were mainly based on short follow-up studies with scarce longer term results [20] [21] [22] [23] [24]. Kim *et al.* [25] compared hybrid and screw constructs with 5-year minimum follow-up in proximal junctional kyphosis mainly. This study included a large consecutive number of patients (100) to evaluate the long term radiographic outcomes of the recent spinal instrumentation trend in the management of AIS with correlation to the possible clinical scenarios.

2. Materials and Methods

This study was conducted in Sultan Bin Abdulaziz Humanitarian City (SBAHC), Riyadh, KSA, where 100 AIS patients with spinal pedicle screws fixation were included, after obtaining the informed consents and approval of the SBAHC ethical board. Cases were tracked through the SBAHC Health Information System

(HIS) database. Basic demographic data of all patients was retrieved from medical record files. Patients were followed for 5 years (from October 2012 to October 2017) with average duration of follow-up was 3.7 years for all cases.

Radiological examinations included total spine x-rays, CT scan and MRI at regular 2 years and 5 years intervals. CT scans with 3D reconstruction were performed on a 64-slice CT scanner (Ingenuity; Philips Medical Systems). Parameters used were: Helical CT protocol, Iterative reconstruction: low dose, iDose Level 3 (range, 1 - 5), slice thickness 0.5 mm, slice interval 0.5 mm, matrix 512 × 512, collimation 64 × 0.625 mm, OMAR software, bone window (YD kernel, level 800 HU, width 2000 HU) and soft window (Soft kernel B). The degree of metallic artifacts and clarity of the scanned vertebrae of the 3D reconstruction images using OMAR were evaluated to determine their diagnostic acceptance, only those of satisfactory subjective quality were included.

Radiological evaluation was done by measuring the Cobb angle on the anteroposterior radiographs usually performed immediately postoperative. Preoperative Cobb angle was then compared to the postoperative Cobb angle to calculate the percentage correction rate. This process was repeated and recorded with each follow up visit. Clinical scenarios and complications were divided into groups including good response and maintenance, infection, surgical revision, pseudarthrosis, neurological deficits, instrumentation-related as screw loosening or complete hardware failure. All complications were managed successfully by surgical revisions, physiotherapy and medications.

Image quality evaluation was conducted on the source bone and soft tissue windows as well as the 3D reconstruction images. A blinded consultant radiologist, with more than 15 years of experience in radiological diagnosis, conducted the subjective evaluations, including severity of the spinal metallic artifacts, density of the related paraspinal muscles, clarity of the inter-muscular fat planes, and definition of the scanned vertebral elements using a 5-point scale, Table 1 [26]. Images scoring 3 or more were considered radiologically satisfactory.

Statistical analysis was performed using SPSS 12.0.2® (IBM, Armonk, NY) software using Student *t* tests, Chi square tests and Fisher's exact tests. Results

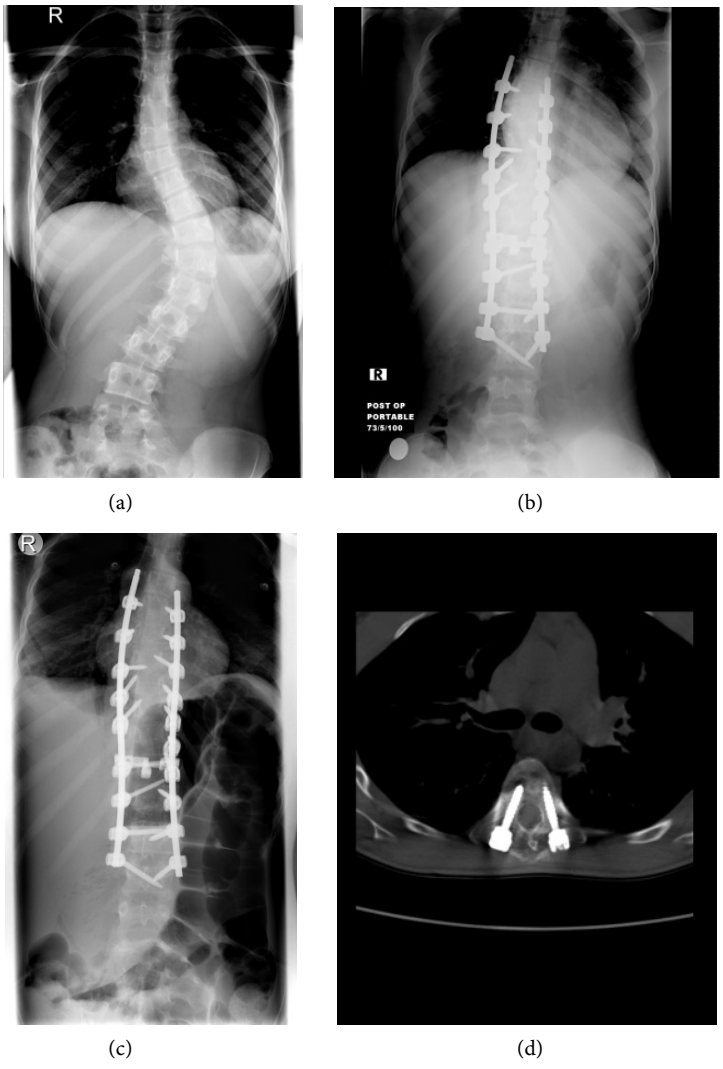
Table 1. Radiological evaluation of OMAR reconstructed image quality.

Score	Severity of Artifacts	Density of Muscles	Clarity of Inter-Muscular planes	Definition of the vertebral elements
1	Severe artifact, obvious distortion	Heterogeneous	Cannot be distinguished	Cannot be distinguished
2	Obvious artifact, mild distortion	Marked	Distinguishable but obscured	Distinguishable but obscured
3	Moderate	Moderate	Moderate	Moderate
4	Little artifact without obvious distortion	Mild heterogeneous	Blurred edges	Blurred edges
5	No artifact	Homogeneous	Clear and sharp edges	Clear and sharp edges

were reported as average and percentage as number of study group was 100. A "*p*" value of 0.05 was considered statistically significant.

3. Results

A total of 100 patients matched the inclusion criteria, 24 (24%) were females and 76 (76%) were males. The average age at operation was 16.5 years and the average duration of follow-up was 3.7 years for all cases. Sixty seven (67%) patients showed good correction and maintenance of the spinal curves over the follow up periods at 2 and 5 year intervals, where the mean Cobb angle was 68˚ preoperatively and 21˚ postoperatively (Figure 1). The calculated correction rate was 74%



(a) (b)

(c) (d)

Figure 1. (a)-(d) Maintained correction over 5-year period with no complications. (a) Preoperative whole spine PXR AP view showing marked smooth left dorso-lumbar scoliosis. Cobb angle = 45˚; (b) immediate post-operative scan with good correction and satisfactory alignment. Cobb angle = 9˚; (c) 2-year follow up scan showing maintained correction with no significant change in the Cobb angle measurement; (d) axial CT scan (bone window with OMAR software) at 5-year interval showing optimum screw positioning with no evidence of loosening or pull-out.

in this group. Thirty three (33%) patients showed complications including postoperative infection (13 cases) (Figure 2), surgical revision (4 cases), pseudarthrosis (3 cases), neurological deficits (5 cases) (Figure 3, Figure 4), screw loosening, malpositioning and pull-out (7 cases) (Figures 5-7) and complete

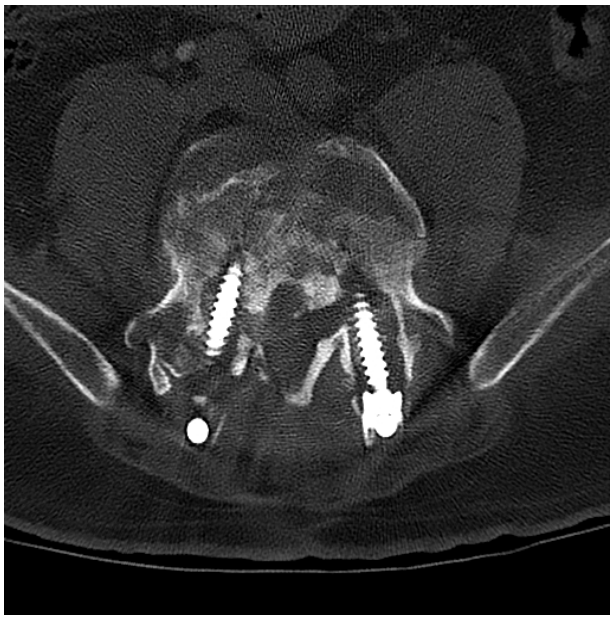


Figure 2. Post-operative infection with screw loosening. Axial CT scan (bone window with OMAR software) showing marked osteolysis due to severe post-operative infection with marked loosening of both fixing screws.

Figure 3. Neural injury. Axial CT scan (bone window with OMAR software) showing the left malpositioned screw markedly encroaching upon the spinal canal.

Figure 4. Screw malpositioning with direct cord and nerve root injury. Axial CT scan (bone window with OMAR software) showing the right malpositioned screw at the level of the exit foramen with direct neural injury.

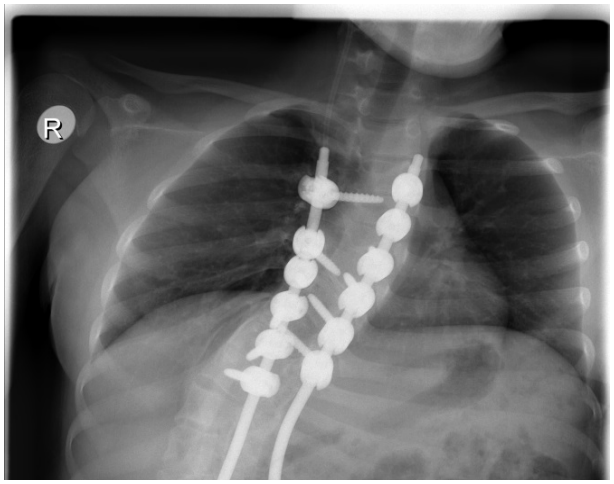


Figure 5. Screw pull-out. PXR AP view of the dorsal spine, 1-year post-operative showing pull-out and loosening of the right upper fixing screws.

hardware failure (1 case) (Figure 8); in whom the preoperative mean Cobb angle was 56˚ compared to the patients with no complications ($p = 0.288$). In males, there were postoperative complications in 27 out of 76 (35.5%) and in females 5 out of 24 (21%), ($p = 0.027$) (Table 2).

Complications took place before the 2-year follow up evaluation in all patients and were managed effectively, resulting in no significant changes between the 2-year and 5-year assessments. Postoperative infection represented almost half of this group and was caused by gram positive organisms in all cases, 12 cases

Table 2. Patient information.

		Patients with no complications (67%)	Patients with complications (33%)	P-value
Age (mean in years)		16.6	17.5	0.252
Gender	Male: (76)	49	27	-
	Female: (24)	19	5	-
Preoperative Cobb (in °)		68	56	0.288
Postoperative Cobb (in °)		21	16	0.204
Correction rate (%)		74	70	0.216
Misplacement rate (%)		9	44	0.454
Average follow up period (in years)		3.2	4.1	-

Figure 6. Screw loosening. Sagittal CT scan (bone window with OMAR software) showing complete and partial loosening of the proximal right 5th and 6th row screws respectively.

were treated successfully over a mean period of 9 months and one case progressed to complete vertebral osteolysis with large epidural abscess and intraspinal extension, treated by antibiotics and requiring drainage of a deep infection (**Figure 2**). One patient had malpositioned screw with high risk of aortic injury (**Figure 7**), which required revision operation. Four patients complained of postop radicular symptoms and sensory deficits that did not require surgical revision. One patient had a neurological deficit in the form of weak right knee

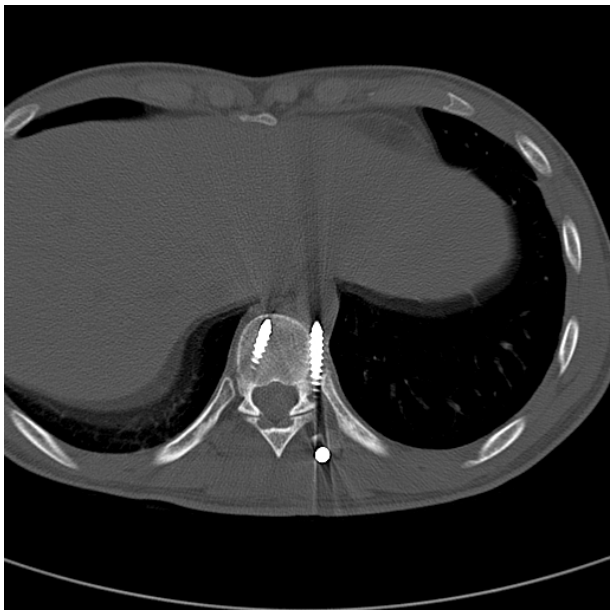
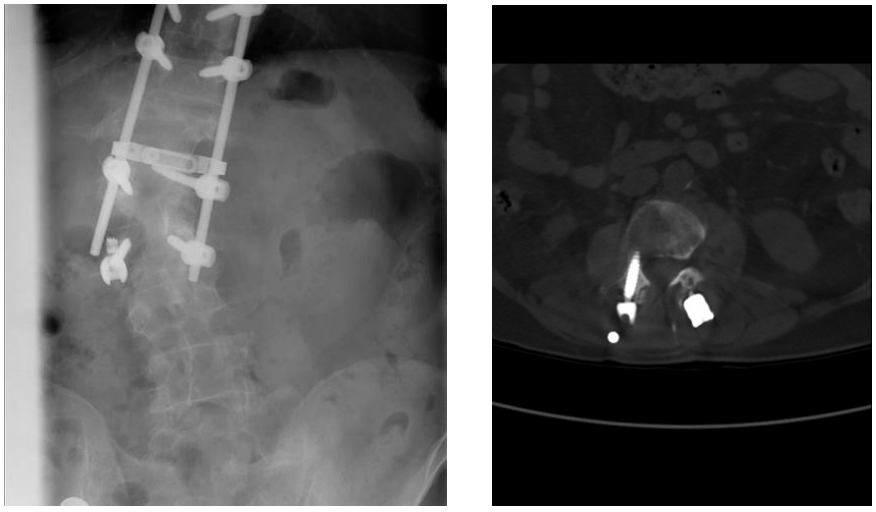


Figure 7. Vascular injury with screw malpositioning. Axial CT scan (bone window with OMAR software) showing direct injury of the descending thoracic aorta by a malpositioned screw.



(a) (b)

Figure 8. (a) (b) Hardware failure. (a) PXR AP view 17 weeks post-operative showing rod and screw dissociation with failed fixation; (b) Axial CT scan (bone window with OMAR software) showing separation of the metallic components.

flexion postoperatively. CT scan was done for this patient and found to be a misplaced screw encroaching upon the corresponding nerve root at the exit foramen (Figure 4), which was subsequently revised. This patient had almost complete neurological recovery at the 5-years follow up visit. One patient had multiple screw pull outs (Figure 7) and one had complete hardware failure and the fixation was removed with replacement (Figure 8). The other cases were treated by physiotherapy with medications (Figure 9).

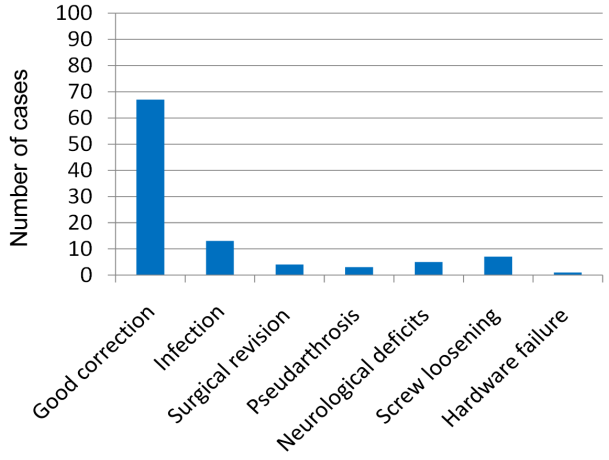


Figure 9. Patient outcome.

4. Discussion

Although the treatment of AIS by spinal instrumentation using pedicle screws is well known in many countries all over the world, this is the first study of its kind in the kingdom of Saudi Arabia, with this large cohort and long term follow up evaluation. Many previous studies comparing earlier instrumentation systems have included the radiological long term outcome evaluation in AIS while the more recent pedicle screws had fewer data to review [27] [28]. Other case studies reported slight increases or progression of radiographic parameters, but most have displayed evidence of correction maintenance with increased follow up periods [27]. Suk *et al.* [7] reported their outcomes on a study group of 203 patients having pedicle screw fixation with at least 5-year follow up, and noted a loss of 3% correction of the main corrected curve over time. Other studies have also reported similar results, but had limited study groups like Hwang *et al.* [27] who assessed pedicle screw fixation in 57 patients with 5-year follow up and noted minimal loss of correction from the immediate post-op (2%), but did not comment on changes took place at the 2-year follow up. Di Silvestre *et al.* [14] compared hybrid and pedicle screw constructs with a mean follow up of 6.7 years and found good maintenance of correction with screws.

Our calculated correction rate was 74% in this study and this comes in agreement with other similar yet smaller cohort studies [27]. We observed that there was no correlation between percentage correction and postoperative clinical scenarios (**Table 2**). About third of patients showed complications in whom the preoperative mean Cobb angle was 56˚ compared to the patients with no complications ($p = 0.288$). Therefore, those with more correction didn't necessarily have better postoperative outcomes. This was the same conclusion by Akil and Riaz [1], who stated that the surgeon should only correct to a point that is safe to do so, and correction does not yield better results and may predispose the young patients to postoperative complications, especially neurological injury.

The clinical application of OMAR for post-spinal instrumentation was performed on all patient population coming for regular postoperative evaluations in

SBAHC, one of the most prestigious rehabilitation centers in the Kingdom of Saudi Arabia with two international accreditations of CARF and JCI and one national accreditation of CBAHI. All cases were scored 3 or more and were accepted by the radiologist (Table 1), which confirmed the feasibility of OMAR in spinal instrumentation imaging. The degree of metallic artifacts and the definition of the adjacent vertebrae were all evaluated 4 and 5 points, impressive of little metallic artifacts with no obvious distortion. With the resulting clear 3D spinal reconstructions, the spinal surgeons could be sure about the relationship between vertebrae and the fixing hardware (e.g., the proper placing and depth of transpedicular screws, no injury of the related nerve roots, no loosening or malplacement), evaluate the status of vertebrae surrounding the implant for osteoporosis or infection, and follow up the healing process of fractures. Thus, this technique would help accurate postoperative assessment of spinal fixation of different reasons. To have a complete evaluation of this OMAR technique, it would be of interest to perform a quantitative image analysis of CT numbers as a complement to the qualitative analysis carried out in this study.

5. Conclusion

Five-year follow up of 100 Saudi patients with AIS treated with spinal instrumentation showed good improvement and maintenance of the corrected spinal curves in two thirds of patients with the regular interval follow up visits. One third of patients in this study showed variable minor and major complications with good overall treatment response at the 5-year interval. Low dose CT scan with the use of orthopedic metal artifact reduction software provided an effective modality for evaluation and follow up.

Acknowledgements

The author would like to thank the SBAHC Biomedical Statistics Department for performing the statistical analysis in this work.

Ethical Approval

This study was approved by the SBAHC Ethical Board.

Conflicts of Interest

The author declares that he has no conflicts of interest.

Author Contributions

Amir MA selected the subject, reviewed the literature, wrote the paper, selected the images and edited the whole work.

References

[1] Akil, A. and Riaz, L. (2012) Fourth-Generation Spinal Instrumentation: Experience with Adolescent Idiopathic Scoliosis at a Tertiary Care Hospital in Pakistan. *Inter-*

national Journal of General Medicine, **5**, 151-155.

[2] Theologis, N., Fairbank, C., Turner-Smith, R. and Pantazopoulos, T. (1997) Early Detection of Progression in Adolescent Idiopathic Scoliosis by Measurement of Changes in Back Shape with the Integrated Shape Imaging System Scanner. *Spine*, **22**, 1223-1227. https://doi.org/10.1097/00007632-199706010-00010

[3] Cochran, T., Irstam, L. and Nachemson, A. (1983) Long-Term Anatomic and Functional Changes in Patients with Adolescent Idiopathic Scoliosis Treated by Harrington Rod Fusion. *Spine*, **8**, 576-584. https://doi.org/10.1097/00007632-198309000-00003

[4] Danielsson, J. and Nachemson, L. (2003) Back Pain and Function 23 Years after Fusion for Adolescent Idiopathic Scoliosis: A Case-Control Study-Part II. *Spine*, **28**, 373-383. https://doi.org/10.1097/01.BRS.0000084267.41183.75

[5] Ecker, L., Betz, R., Trent, S., Mahboubi, S., Mesqarzadeh, M., Bonakdapour, A., *et al.* (1988) Computer Tomography Evaluation in Cotrel-Dubousset Instrumentation in Idiopathic Scoliosis. *Spine*, **13**, 1141-1144. https://doi.org/10.1097/00007632-198810000-00015

[6] Shufflebarger, L., Smiley, K. and Roth, J. (1994) Internal Thoracoplasty. A New Procedure. *Spine*, **19**, 840-842. https://doi.org/10.1097/00007632-199404000-00020

[7] Suk, S., Choon, L., Won-Joong, K., *et al.* (1995) Segmental Pedicle Screw Fixation in the Treatment of Thoracic Idiopathic Scoliosis. *Spine*, **20**, 1399-1405. https://doi.org/10.1097/00007632-199506020-00012

[8] Wood, B., Transfeldt, E. and Ogilvie, W., *et al.* (1991) Rotational Changes of the Vertebral-Pelvic Axis Following Cotrel-Dubousset Instrumentation. *Spine*, **16**, S404-S408. https://doi.org/10.1097/00007632-199108001-00019

[9] Booth, C., Bridwell, H., Lenke, G., *et al.* (1999) Complications and Predictive Factors for the Successful Treatment of Flatback Deformity (Fixed Sagittal Imbalance) *Spine*, **24**, 1712-1790. https://doi.org/10.1097/00007632-199908150-00013

[10] Bradford, S. and Tribus, B. (1994) Current Concepts and Management of Patients with Fixed Decompensated Spinal Deformity. *Clinical Orthopaedics and Related Research*, **306**, 64-72.

[11] Weatherley, R., Draycott, V., O'Brien, F., *et al.* (1987) The Rib Deformity in Adolescent Idiopathic Scoliosis. *Journal of Bone and Joint Surgery*, **69**, 179-182.

[12] Asghar, J., Samdani, F., Pahys, M., *et al.* (2009) Computed Tomography Evaluation of Rotation Correction in Adolescent Idiopathic Scoliosis: A Comparison of an All Pedicle Screw Construct versus a Hook-Rod System. *Spine*, **34**, 804-807. https://doi.org/10.1097/BRS.0b013e3181996c1b

[13] Di Silvestre, M., Bakaloudis, G., Lolli, F., *et al.* (2008) Posterior Fusion Only for Thoracic Adolescent Idiopathic Scoliosis of More than 80 Degrees: Pedicle Screws versus Hybrid Instrumentation. *European Spine Journal*, **17**, 1336-1349. https://doi.org/10.1007/s00586-008-0731-9

[14] Dobbs, B., Lenke, G., Kim, J., *et al.* (2006) Selective Posterior Thoracic Fusions for Adolescent Idiopathic Scoliosis: Comparison of Hooks versus Pedicle Screws. *Spine*, **31**, 2400-2404. https://doi.org/10.1097/01.brs.0000240212.31241.8e

[15] Karatoprak, O., Unay, K., Tezer, M., *et al.* (2008) Comparative Analysis of Pedicle Screw versus Hybrid Instrumentation in Adolescent Idiopathic Scoliosis Surgery. *International Orthopaedics*, **32**, 523-528. https://doi.org/10.1007/s00264-007-0359-0

[16] Kim, J., Bridwell, H., Lenke, G., *et al.* (2005) Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis Following Segmental Posterior Spinal Instrumentation

and Fusion: Minimum 5-Year Follow-Up. *Spine*, **30**, 2045-2050. https://doi.org/10.1097/01.brs.0000179084.45839.ad

[17] Liljenqvist, U. (2002) Comparative Analysis of Pedicle Screw and Hook Instrumentation in Posterior Correction and Fusion of Idiopathic Thoracic Scoliosis. *European Spine Journal*, **11**, 336-343. https://doi.org/10.1007/s00586-002-0415-9

[18] Andersen, O., Christensen, B. and, Thomsen, K. (2006) Outcome at 10 Years after Treatment for Adolescent Idiopathic Scoliosis. *Spine*, **31**, 350-354. https://doi.org/10.1097/01.brs.0000197649.29712.de

[19] Bjerkreim, I., Steen, H. and Brox, I. (2007) Idiopathic Scoliosis Treated with Cotrel-Dubousset Instrumentation: Evaluation 10 Years after Surgery. *Spine*, **32**, 2103-2110. https://doi.org/10.1097/BRS.0b013e318145a54a

[20] Helenius, I., Remes, V. and Yrjonen, T. (2003) Harrington and Cotrel-Dubousset Instrumentation in Adolescent Idiopathic Scoliosis. Long-Term Functional and Radiographic Outcomes. *Journal of Bone and Joint Surgery*, **85-A**, 2303-2309.

[21] Kelly, M., McCarthy, E., McCullough, L. and Kelly, R. (2010) Long-Term Outcomes of Anterior Spinal Fusion with Instrumentation for Thoracolumbar and Lumbar Curves in Adolescent Idiopathic Scoliosis. *Spine*, **35**, 194-198. https://doi.org/10.1097/BRS.0b013e3181bc948e

[22] Tis, E., O'Brien, F., Newton, O., *et al.* (2010) Adolescent idiopathic Scoliosis Treated with Open Instrumented Anterior Spinal Fusion: Five-Year Follow-Up. *Spine*, **35**, 64-70. https://doi.org/10.1097/BRS.0b013e3181c4af52

[23] Kim, J., Lenke, G., Kim, J., *et al.* (2006) Comparative Analysis of Pedicle Screw versus Hybrid Instrumentation in Posterior Spinal Fusion of Adolescent Idiopathic Scoliosis. *Spine*, **31**, 291-298.

[24] Hu, Y., Pan, S.N., Zhao, X.D., Guo, W.L., He, M. and Guo, Q.Y. (2017) Value and Clinical Application of Orthopedic Metal Artifact Reduction Algorithm in CT Scans after Orthopedic Metal Implantation. *Korean Journal of Radiology*, **18**, 526-535. https://doi.org/10.3348/kjr.2017.18.3.526

[25] Boos, N., Dolan, A. and Weinstein, L. (2007) Long-Term Clinical and Radiographic Results of Cotrel-Dubousset Instrumentation of Right Thoracic Adolescent Idiopathic Scoliosis. *Iowa Orthopaedic Journal*, **27**, 40-46.

[26] Jeng, L., Sponseller, D. and Tolo, T. (1993) Outcome of Wisconsin Instrumentation in Idiopathic Scoliosis. Minimum 5-Year Follow-Up. *Spine*, **18**, 1584-1590. https://doi.org/10.1097/00007632-199309000-00003

[27] Hwang, J., Lee, K., Chang, S., *et al.* (2011) Minimum 5-Year Follow-Up Results of Skipped Pedicle Screw Fixation for Flexible Idiopathic Scoliosis. *Journal of Neurosurgery Spine*, **15**, 146-150. https://doi.org/10.3171/2011.4.SPINE10321

[28] D'Andrea, L., Betz, R., Lenke, L., *et al.* (2000) Do Radiographic Parameters Correlate with Clinical Outcomes in Adolescent Idiopathic Scoliosis? *Spine*, **25**, 1795-1802. https://doi.org/10.1097/00007632-200007150-00010