

COMPARATIVE ANALYSIS OF PEDICLE SCREW VERSUS HYBRID INSTRUMENTATION IN POSTERIOR SPINAL CORRECTION AND FUSION OF ADOLESCENT IDIOPATHIC SCOLIOSIS

ADÖLESAN İDİOPATİK SKOLYOZDA PEDİKÜL VİDASINA KARŞI HİBRİD SİSTEM ENSTRUMENTASYONU İLE POSTERİOR SPİNAL DÜZELTME VE FÜZYONUN KARŞILAŞTIRMASI

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SUMMARY:

The aim of this study was to compare the results of pedicle screw versus hybrid instrumentation in posterior spinal correction and fusion of adolescent idiopathic scoliosis. For this purpose 19 females having adolescent idiopathic scoliosis that underwent posterior spinal fusion in our institute were included in this retrospective comparative study. 11 of 19 patients who were treated with posterior spinal fusion via pedicle screws formed Group I where the remaining 8 patients who were fused posterior via hybrid instrumentation formed Group II. The mean age at the operation time in Group I was 12 (range 10-13). The mean age in Group II was 12.5 (range 11-13). The average follow-up period was 43 months

(range 22-71 months) in group I and 54.6 months (range 23-71 months) in Group II. All of the cases were classified according to the Lenke Classification System for idiopathic scoliosis preoperatively. At the preoperative, postoperative and last follow-up period the magnitudes of the curves in thoracic and lumbar regions were measured according to the Cobb method. Deviation in the sagittal plane, thoracic kyphosis and lumbar lordosis were also noted. The loss of blood during the procedures, pulmonary function tests and complications in the postoperative period were also evaluated. At the end the retrospective data of two groups underwent statistical analysis. There was not a significant difference between the parameters of both groups in terms of age, follow-up period, respiratory

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function tests, curve correction and correction durability, complications, thoracic kyphosis, and lumbar lordosis. The blood loss during the procedure in Group I was significantly higher than Group II ($p<0.02$). Additionally, even it was not significant according to the statistical analysis, the durability of lumbar curve correction in Group II deteriorated much more than Group I during the follow-up period which should be considered to be of value clinically. As a conclusion, both pedicle screw and hybrid posterior instrumentation in the surgical treatment of adolescent idiopathic scoliosis are valid and safe methods displaying similar clinical and radiographic results, but hybrid instrumentation causes significantly less bleeding during the procedure when compared with pedicle screw instrumentation respectively.

Level of evidence: Retrospective comparative clinical trial, Level III

Keywords: Adolescent Idiopathic Scoliosis, Pedicle Screw, Posterior Instrumentation, Hybrid

ÖZET:

Bu çalışmada adölesan idiyomatik skolyozun posterior spinal düzeltme ve füzyon işlemi ile tedavisinde kullanılan pedikül vidaları ile hibrid enstrümantasyonun sonuçları karşılaştırılmıştır. Geriye dönük ve karşılaştırmalı olan çalışmamıza adölesan idiyomatik skolyoz nedeniyle posterior spinal füzyon uygulanmış 19 kadın hasta dâhil edildi. Posterior spinal füzyonun pedikül vidası ile sağlandığı 11 hasta Grup I; posterior füzyonun hibrid enstrümantasyon ile sağlandığı 8 hasta ise Grup II olarak adlandırıldı. Ameliyat esnasında ortalama yaş Grup I'de 12 yıl (dağılım 10-13), Grup II' de 12,5 yıl (dağılım 11-13) idi. Ortalama

takip süresi Grup I'de 43 ay (dağılım 22-71 ay), Grup II'de 54,6 ay (dağılım 23-71) idi. Hastaların hepsi ameliyat öncesi dönemde idiyomatik skolyoz için kullanılan Lenke Sınıflandırma Sistemi'ne göre sınıflandırıldı. Ameliyat öncesi, ameliyat sonrası erken dönem ve son poliklinik kontrollerinde torakal ve lomber bölgelerdeki eğriliklerin dereceleri Cobb metoduna göre ölçüldü. Sagittal plandaki sapma miktarı, torakal kifoz ve lomber lordoz miktarları da not edildi. Ameliyat esnasındaki kan kaybı miktarı, solunum fonksiyon testleri ve ameliyat sonrası dönemdeki komplikasyonlar da ayrıca değerlendirildi. İki gruptan geriye dönük olarak elde edilen bilgiler istatistiksel değerlendirmeye alındı. Yaş, takip süresi, solunum fonksiyon testi sonuçları, eğrilikteki düzelme miktarı ve bu düzeltmedeki devamlılık, komplikasyonlar, torakal kifoz ve lomber lordoz miktarları açısından iki grup arasında anlamlı fark tespit edilmedi. Grup I'de uygulanan ameliyattaki kan kaybı miktarının Grup II'deki kayıba göre anlamlı derecede fazla olduğu tespit edildi ($p<0.02$). Her ne kadar istatistiksel analize göre aradaki fark anlamlı olmasa da, klinik önemi olması açısından, Grup II'de elde edilen lomber eğrilikteki düzelme kaybının takip süresi boyunca Grup I' e göre daha fazla olduğu gözlemlendi. Sonuç olarak, adölesan idiyomatik skolyozun cerrahi tedavisinde pedikül vidaları veya hibrid teknik ile elde edilen posterior enstrümantasyon yöntemleri geçerlilikleri olan, güvenilir, klinik ve radyografik olarak benzer sonuçların elde edilebildiği yöntemlerdir, ancak, pedikül vidası ile karşılaştırıldığında, hibrid enstrümantasyon yöntemi ameliyat esnasında belirgin olarak daha az kan kaybına neden olmaktadır.

Anahtar kelimeler: Adölesan İdiyomatik Skolyoz, Pedikül Vidası, Posterior Enstrümantasyon, Hibrid

Kanıt düzeyi: Retrospektif karşılaştırmalı klinik çalışma, Düzey III

INTRODUCTION:

Since the introduction of Harrington rod instrumentation in 1960, the correction techniques in scoliosis surgery have changed from Harrington principles of concave distraction to segmental realignment by a variety of possibilities, including the rod rotation maneuver and by segmental approximation via cantilever maneuvers with Cotrel-Dubousset instrumentation ⁽⁵⁾. Universal spine instrumentation sets allow implants comprising hooks (applied to the lamina, pedicle or transverse process), pedicle screws or some combination of these to be used ⁽³⁾. Pedicle screw fixation, initially used in lumbar spine and with increasing frequency in thoracic spine to treat scoliosis demonstrated significant advantages in the correction of deformity, rotation and the ability to save motion segments compared with hook fixation ⁽¹⁾. Recent clinical research suggests that thoracic pedicle screw instrumentation (all-screw instrumentation) is more effective than hybrid lumbar screw thoracic hook instrumentation in correcting spine deformity ⁽⁷⁾.

However, when lamina hooks are used in conjunction with pedicle screws, the benefit of a screw-only instrumentation has been statistically insignificant or nonexistent ⁽³⁾.

The aim of this study was to compare the clinical and radiographic results of pedicle screw versus hybrid instrumentation in posterior spinal correction and fusion of adolescent idiopathic scoliosis (AIS).

MATERIALS AND METHODS:

Between 2002 and 2006, 19 patients with surgically treated AIS in our institute all of whom attended follow-ups were included in the study; of these, 11 patients were treated with posterior spinal correction and fusion using all pedicle screws (Group I) and 8 patients were treated with posterior correction and fusion via hybrid system (hooks and pedicle screws) (Group II). The mean age at the operation time in Group I was 12 (range: 10-13). The mean age in Group II was 12.5 (range: 11-13). All of the patients in both groups were females incidentally (Table-1).

Table - 1. Demographics and radiographic measurements of the patients of both groups. (PRE-OP: preoperative, POST-OP: postoperative, n: number, FVC: forced vital capacity, FEV1: forced expiratory volume in one second)

Group I				thoracal curve			lumbar curve			kyphosis			lordosis			pulmonary function tests	
n	age	blood (cc)	follow up (months)	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	FVC (%)	FEV1 (%)
1	12	1000	41	40	16	12	32	11	14	71	53	83	53	20	50	90	92
2	12	1000	23	48	10	10	21	0	0	10	28	27	36	31	28	85	85
3	10	1000	53	82	44	44	0	0	6	65	62	38	45	40	35	78	73
4	12	4000	22	63	13	13	35	22	22	50	40	40	40	35	31	84	76
5	13	2000	71	71	34	34	48	25	25	15	23	23	28	29	29	81	84
6	11	500	31	64	21	21	33	18	18	25	38	38	40	47	47	83	86
7	13	2000	32	36	18	13	30	5	0	28	32	30	35	38	46	86	90
8	12	1500	54	90	36	36	62	28	28	60	32	30	20	30	32	84	87
9	13	2000	55	64	13	12	44	8	8	49	40	40	43	34	34	90	95
10	13	1500	58	44	0	0	40	18	21	33	24	24	28	27	27	82	85
11	11	3500	33	32	6	22	16	16	3	50	30	29	47	55	57	81	83

Table - 1. Demographics and radiographic measurements of the patients of both groups. (PRE-OP: preoperative, POST-OP: postoperative, n: number, FVC: forced vital capacity, FEV1: forced expiratory volume in one second)

Group II				thoracal curve			lumbar curve			kyphosis			lordosis			pulmonary function tests	
n	age	blood (cc)	follow up (months)	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	PRE-OP	POST-OP	final	FVC (%)	FEV1 (%)
1	12	1000	71	60	42	44	70	35	35	12	28	44	32	36	32	80	86
2	13	1000	63	39	0	0	22	0	0	32	36	36	56	66	66	78	82
3	13	1000	34	70	0	0	32	0	0	70	56	56	40	47	47	85	79
4	11	1000	69	42	25	25	38	18	18	70	50	50	70	36	36	81	83
5	13	1000	62	42	18	35	20	5	42	22	32	30	34	38	40	86	88
6	13	500	47	47	10	10	26	10	10	45	38	44	53	44	46	87	90
7	13	1000	68	49	23	26	5	5	26	20	40	40	42	43	48	82	84
8	12	1000	23	65	26	26	0	5	5	60	38	38	52	44	44	83	84

According to the surgical classification of AIS by the Lenke et al⁽⁶⁾ system, the number of the patients in Group I were: 9 for Type 1 (main thoracic, 82 %), 2 for Type 3 (double major, 18 %). Four patients had a lumbar A modifier, one lumbar B modifier and 6 lumbar C modifier. Five patients had a normokyphotic sagittal modifier (T5-T12, +10° to +40°). Six patients had a hyperkyphotic sagittal modifier (T5-T12, >+40°) (Figure-1).

**Figure-1.** Preoperative AP view (Group I)

According to the surgical classification of AIS by the Lenke et al⁵ system, the number of the patients in Group II were: 7 for Type 1 (main thoracic, 87 %) and 1 for Type 6 (major thoracolumbar / lumbar and minor thoracic structural, 13 %). One patient had a lumbar A modifier, 4 lumbar B modifier and 3 lumbar C modifier. Three patients had a normokyphotic sagittal modifier (T5-T12, +10° to +40°). Four patients had a hyperkyphotic sagittal modifier (T5-T12, >+40°). One patient had a hypokyphotic sagittal modifier (T5-T12, <+10°) (Figure-2).

**Figure-2.** Preoperative AP view (Group II)

All of the operations in both groups were performed under general anesthesia and patients in a prone position using posterior midline incision. In Group I pedicle screws were used on both the concave and convex sides at all levels of instrumentation. All pedicle screws were inserted by free-hand technique and they were confirmed by intra-operative fluoroscopy. In group II, pedicle screws were used in thoracolumbar junction and lumbar region where the bilateral pediculotransverse claw hook configuration at the cranial end of instrumentation and compressive hook on the convex side was used. Concave rod derotation maneuver and appropriate compression and / or distraction were performed in order to correct the spinal deformity posteriorly. Spinous process autograft and allograft spongious chips were used in both groups for all patients. Blood loss during the operations in both groups was noted. (Figure-3, 4, 5, 6)



Figure-4. Follow-up lateral view (Group I)

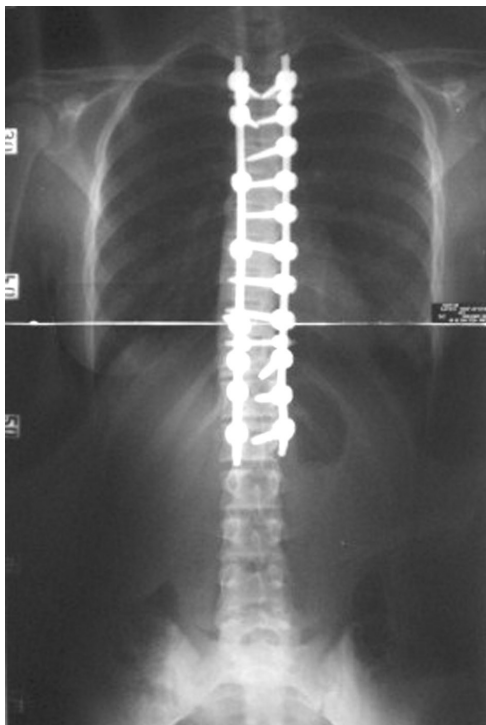


Figure-3. Follow-up AP view (Group I)



Figure-5. Follow-up AP view (Group II)



Figure-6. Follow-up lateral view (Group II)

After surgery, none of the patients in either group was immobilized in a brace. They were initially engaged in a supervised rehabilitation programme in the department and were let to stand-walk on the next postoperative day.

Radiographic measurements were made on 36-inch long-cassette coronal and lateral radiographs of the spine with the patient standing. All of the radiographic measurements were made by the first three authors. Thoracic and lumbar curve measurements were performed using Cobb method. Curve flexibility was determined on the preoperative supine side bending films. Global coronal balance was measured as the distance between the C7 plumb line and center sacral vertical line (CSVL). On the

lateral radiographs, global sagittal balance was measured as the distance from the C7 plumb line to the perpendicular line drawn from the superior posterior endplate of S1 vertebral body (sagittal sacral vertical line-SSVL). If the C7 plumb line fell behind SSVL, global sagittal balance was negative. If the C7 plumb line fell in front of SSVL, global sagittal balance was positive. Thoracic kyphosis was measured from the upper endplate of T5 to the lower endplate of T12, and the lumbar lordosis was measured from the lower endplate of T12 to the upper endplate of S1.

All of the patients in both groups had been performed pulmonary function tests at the last follow-up. For purposes of analysis and comparison; the forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC ratio were used.

The data were analyzed using SPSS for Windows 11.5.0 software package (6 Sep. 2002, LEAD Technologies Inc.). For the comparison of age, blood loss, follow-up period and pulmonary function tests Mann Whitney U test was used. For the comparison of; preoperative-postoperative-follow-up thoracic and lumbar curve magnitudes, kyphosis, and lordosis Pillai's Trace test was used via general linear models in repeated measures method. p values smaller than 0.05 were accepted as being statistically significant.

RESULTS:

The average follow-up period was 43 months (range 22-71 months) in Group I and 54.6 months (range 23-71 months) in Group II. (p=0.116) The mean age at the operation time in Group I was 12 (range 10-13). The mean age in Group II was 12.5 (range 11-13). (p=0.247) In Group I, 12.7 levels (range 11-

16) were fused and in Group II 11.3 levels (range 9-14) were fused ($p>0.05$).

The mean preoperative thoracic major curve in Group I was 57.6° (range $32^\circ-90^\circ$). Then it improved to 19.1° (range $0^\circ-44^\circ$) in the early postoperative period. Finally it was measured as 19.7° (range $0^\circ-44^\circ$) at the latest follow-up period. The mean preoperative thoracic major curve in Group II was 51.7° (range $39^\circ-70^\circ$). Then it improved to 18° (range $0^\circ-42^\circ$) in the early postoperative period. Finally it was measured as 20.7° (range $0^\circ-44^\circ$) at the latest follow-up period ($p=0.627$).

The mean preoperative lumbar major curve in Group I was 32.8° (range $0^\circ-62^\circ$). Then it improved to 13.7° (range $0^\circ-28^\circ$) in the early postoperative period. Finally it was measured as 13.2° (range $0^\circ-28^\circ$) at the latest follow-up period. The mean preoperative lumbar major curve in Group II was 26.7° (range $0^\circ-70^\circ$). Then it improved to 9.8° (range $0^\circ-35^\circ$) in the early postoperative period. Finally it was measured as 17° (range $0^\circ-42^\circ$) at the latest follow-up period ($p=0.279$).

The mean preoperative thoracic kyphosis in Group I was 41.5° (range $10^\circ-71^\circ$). Then it decreased to 36.5° (range $23^\circ-62^\circ$) in the early postoperative period. Finally it was measured as 36.5° (range $23^\circ-83^\circ$) at the latest follow-up period. The mean preoperative thoracic kyphosis in Group II was 41.4° (range $12^\circ-70^\circ$). Then it decreased to 39.8° (range $28^\circ-56^\circ$) in the early postoperative period. Finally it was measured as 42.3° (range $30^\circ-56^\circ$) at the latest follow-up period. ($p=0.780$)

The mean preoperative lumbar lordosis in Group I was 37.7° (range $20^\circ-53^\circ$). Then it decreased to 35° (range $20^\circ-55^\circ$) in the early postoperative period. Finally it was measured as 37.8° (range $27^\circ-57^\circ$) at the latest follow-up period. The mean preoperative lumbar

lordosis in Group II was 47.4° (range $32^\circ-70^\circ$). Then it decreased to 44.3° (range $36^\circ-66^\circ$) in the early postoperative period. Finally it was measured as 44.9° (range $32^\circ-66^\circ$) at the latest follow-up period ($p=0.783$).

In Group I, 8 patients had normal global coronal balance preoperatively where 2 patients had imbalance to the right (14mm, 11 mm) and one had imbalance to the left (12 mm). In the latest follow-up, 9 of 11 patients had normal global coronal balance, but 2 patients had residual coronal imbalance to the left (8mm, 13 mm). In the same group, 6 patients had normal global sagittal balance where one had (+) and 4 had (-) global sagittal imbalance preoperatively. In the latest follow-up, 7 of 11 patients had normal global sagittal balance, but 4 patients had still (-) global sagittal imbalance.

In Group II, 4 patients had normal global coronal balance preoperatively where 2 patients had imbalance to the right (13mm, 12 mm) and 2 had imbalance to the left (12 mm, 14 mm). In the latest follow-up, all of the patients had normal global coronal balance. In the same group, 5 patients had normal global sagittal balance where 3 had (-) global sagittal imbalance preoperatively. In the latest follow-up, 7 of 8 patients had normal global sagittal balance, but one patient had still (-) global sagittal imbalance ($p>0.05$).

The mean blood loss during the operative procedure in Group I was 1800 cc (range 500 cc-4000 cc) and it was 900 cc (range 500 cc-1000 cc) in Group II. ($p<0.02$) In the early postoperative period, transient hemolytic reaction due to transfusion was seen in a patient of Group I. In the late follow-up period, introduction of new curves in the lumbar region of 2 patients of both groups were the complications noted ($p=1$).

The average postoperative FVC in Group I was 84.2 % (range 78 % - 90 %). The mean FEV1 in the same group was 85 % (range 73 % - 92 %). The average postoperative FEV1/FVC ratio was 1.02 (range 0.9-1.06). The average postoperative FVC in Group II was 82.7 % (range 78 % - 87 %). (p=0.534) The mean FEV1 in the same group was 84.5 % (range 79 % - 90 %). (p=0.534) The average postoperative FEV1/FVC ratio was 1.02 (range 0.93-1.08). (p=0.771)

As a result, both pedicle screw and hybrid posterior instrumentation in the surgical treatment of adolescent idiopathic scoliosis displayed similar clinical and radiographic results, but hybrid instrumentation caused significantly less bleeding during the procedure when compared with pedicle screw instrumentation respectively.

DISCUSSION:

The goals of surgical treatment in AIS have remained constant despite evolving concepts, techniques and approaches for scoliosis³. Treatment must achieve a solid arthrodesis and prevent progression of the spinal deformity while preserving distal motion segments, maintaining balance and alignment in both coronal and sagittal planes during the correction of the deformity⁽¹⁾.

Recent clinical research suggests that thoracic pedicle screw instrumentation (all-screw instrumentation) is more effective than hybrid lumbar screw thoracic hook instrumentation in correcting spine deformity⁴. In a retrospective cohort study, all pedicle screw versus hybrid thoracic hook lumbar screw instrumentation were compared with each other in terms of coronal and sagittal plane correction in AIS. There was no

statistically significant difference comparing the two groups, although a trend was observed toward better correction of the main thoracic curve in the all-screw instrumentation group, but hybrid instrumentation was comparable to all-screw instrumentation in the correction of coronal plane deformity and sagittal balance⁽⁷⁾.

In an other matched cohort study from the literature, authors compared the clinical and radiographic results of AIS treatment using all pedicle screw instrumentation versus hook/hybrid implants⁽⁹⁾. Pedicle screw fixation was found to be safe and effective⁽⁹⁾. Additionally, when compared to hook/hybrid implantation, these patients displayed significantly improved correction of the major curve (even in the absence of anterior releases), maintenance of thoracic kyphosis and a lower revision rate⁽⁹⁾. Similar Scoliosis Research Society (SRS) scores and blood loss were noted⁽⁹⁾.

In the comparison study of Karatoprak et al.; correction rate, postoperative coronal and sagittal balance, operation time, blood loss and number of fixation points were not significantly different between the all-screw and hybrid instrumentation groups, but correction durability and apical vertebral de-rotation was better with pedicle screw instrumentation where apical vertebral translation was better achieved via hybrid system instrumentation⁽⁴⁾.

According to other retrospective matched cohort study from literature, pedicle screw instrumentation offered a significantly better major curve correction and postoperative pulmonary function values without neurologic problems compared with hybrid implantation⁽⁸⁾. Both instrumentation methods offered similar junctional change, lowest instrumented

vertebra, operative time and postoperative SRS-24 outcome scores in the operative treatment of AIS ⁽⁴⁾.

In the study of Yu et al. a total number of 48 patients surgically treated for AIS were evaluated retrospectively⁸. Thirty patients were treated with hook-screw-rod type internal fixation and 18 patients via screw-rod (all pedicle screws) type internal fixation. They concluded that both all pedicle screws and hybrid instrumentation could offer good correction results of the thoracic and lumbar curve in posterior selective thoracic fusion in patients with AIS while with all pedicle screws, the correction results of the thoracic and lumbar curve are both better than those with hybrid instrumentation without increased decompensation rate ⁽⁹⁾.

Di Silvestre et al compared pedicle screws versus hybrid instrumentation in posterior fusion only for thoracic AIS of more than 80° and concluded that the pedicle screw group showed a significantly greater final correction and a significantly better maintenance of the initial correction of the main thoracic curve ⁽²⁾. However, even hybrid instrumentation may be certainly considered for the treatment of severe scoliosis; severe curves may be amenable to hybrid systems which have provided results similar to those of screw-only instrumentation with regards to patient satisfaction ⁽²⁾.

On a biomechanical basis, Jones et al. used human cadaveric thoracic spine segments in order to determine whether a hybrid implantation using a combination of pedicle screws and lamina hooks was equivalent to pedicle screw instrumentation in a short-segment thoracic spine fixation model ⁽³⁾.

They concluded that there was no difference in stiffness between the implantations in compression, flexion, extension or lateral bending, but in axial pullout testing, a construct consisting of pedicle screws was significantly stiffer and more resistant to implant failure than a hybrid instrumentation consisting of lamina hooks and pedicle screws ⁽³⁾.

In the current study, there was not a significant difference between the parameters of both pedicle screw and hybrid instrumentation groups in terms of age, follow-up period, respiratory function tests, curve correction and correction durability, complications, thoracic kyphosis, and lumbar lordosis. The blood loss during the procedure in Group I was significantly higher than Group II ($p < 0.02$). Additionally, even it was not significant according to the statistical analysis, the durability of lumbar curve correction in hybrid group deteriorated much more than pedicle screw group during the follow-up period which should be considered to be of value clinically. On the other hand; retrospective data collection, relatively less number of patients and the lack of objective clinical assessment tools may be considered as the weak points of our study.

As a conclusion, both pedicle screw and hybrid posterior instrumentation in the surgical treatment of adolescent idiopathic scoliosis are valid and safe methods displaying similar clinical and radiographic results, but hybrid instrumentation causes significantly less bleeding during the procedure when compared with pedicle screw instrumentation respectively.

REFERENCES:

- 1- Akbarnia BA, Segal LS. Infantile, juvenile and adolescent scoliosis, in Spivak JM(Ed): *Orthopaedic Knowledge Update Spine 3*. Rosemont, IL, AAOS Press, 2006; pp: 443-457.
- 2- Di Silvestre M, Bakaloudis G, Lolli F, Vommaro F, Matrices K, Parisini P. Posterior fusion only for thoracic adolescent idiopathic scoliosis of more than 80°: pedicle screws versus hybrid instrumentation. *Eur Spine J* 2008; 17: 1336-1349.
- 3- Jones GA, Kayanja M, Milks R, Lieberman I. Biomechanical characteristics of hybrid hook-screw constructs in short-segment thoracic fixation. *Spine* 2008; 33(2): 173-177.
- 4- Karatoprak O, Unay K, Tezer M, Ozturk C, Aydogan M, Mirzanli C. Comparative analysis of pedicle screw versus hybrid instrumentation in adolescent idiopathic scoliosis surgery. *Inter Orthop* 2008; 32: 523-528.
- 5- Kim YJ, Lenke LG, Kim J, Bridwell KH, Cho SK, Cheh G, Sides B. Comparative analysis of pedicle screw versus hybrid instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis. *Spine* 2006; 31(3): 291-298.
- 6- Lenke LG, Betz RR, Harms J, Bridwell KH, Clements DH, Lowe TG, Blanke K. Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. *J Bone Joint Surg* 2001; 83-A (8): 1169-1181.
- 7- Lowenstein JE, Matsumoto H, Vitale MG, Weidenbaum M, Gomez JA, Lee FY, Hyman JE, Roye DP Jr. Coronal and sagittal plane correction in adolescent idiopathic scoliosis: a comparison between all pedicle screws versus hybrid thoracic hook lumbar screw constructs. *Spine* 2007; 32 (4): 448-452.
- 8- Rose PS, Lenke LG, Bridwell KH, Mulconrey DS, Cronen GA, Buchowski JM, Scwend RM, Sides BA. Pedicle screw instrumentation for adult idiopathic scoliosis: an improvement over hook/hybrid fixation. *Spine* 2009; 34 (8): 852-857.
- 9- Yu B, Zhang JG, Qui GX, Wang YP, Zhao Y, Shen JX, Zhao H, Yang XY. Posterior selective thoracic fusion in adolescent idiopathic scoliosis patients: a comparison of all pedicle screws versus hybrid instrumentation. *Chin Med Sci J* 2009; 24(1): 30-35.