The Journal of Turkish Spinal Surgery

2011; 22 (1):25-32

ORJİNAL ÇALIŞMA / *ORIGINAL ARTICLE*

RADIOGRAPHIC ANALYSIS OF DE NOVO SCOLIOSIS

"DE NOVO" SKOLYOZUN RADYOGRAFİK ANALİZİ

Remzi Arif ÖZERDEMOĞLU*, Ufuk AYDINLI, Çağatay ÖZTÜRK***,**
Salim ERSÖZLÜ**, Rasim ŞERİFOĞLU******

SUMMARY:

The objective of this cross-sectional radiological study was to analyze the degenerative process in the lumbar spine in patients with and without scoliosis, in order to determine potential risk factors, which may be related to the development of de novo scoliosis. In 121 adults (≥50 years), analyzed radiological parameters included: listhesis, wedging, and height of each lumbar vertebra, wedging and height of each disc, length of vertebral spurs, lumbar lordosis, lumbosacral, lumbo (L5) horizontal and sacro-horizontal angles, pelvic tilt on A-P X-ray, depth of L5 from the intercrest line, also -if present- pattern of curve, and level presenting with the most obvious degenerative changes (MODC). Uni- and multi-variate statistical tests were used for analysis. Degenerative changes were most obvious in the middle lumbar region. MODC at the L2 vertebra/L2-3 disc and L4 vertebra/L4-5 disc levels were more frequent in cases with scoliosis (p=0.013, p=0.022, respectively). Upon multivariate analysis the presence of scoliosis was closely related to the presence of lateral listhesis of L3, wedging of L3-4 disc, or pelvic tilt (p=0.000, p=0.000, p=0.001, respectively). Cases with MODC at the L3-4 disc level, or a more cranial apex of curve had a higher degree of scoliosis (p=0.009, p=0.017, respectively). Whereas, MODC at the L5-S1 level coexist with a low degree or no scoliosis (p=0.009). Degenerative changes in the middle lumbar region, and pathologic conditions in the hip or lower extremities resulting in pelvic tilt, are frequent findings in cases with de novo scoliosis. Likewise, asymmetric degenerative changes at the L3-4 disc level, and a more cranial apex of curve, were associated with an increased scoliotic curve. However, degenerative changes at the L5 vertebra/L5-S1 disc level carries lower risk in producing scoliosis.

Key Words: *Adult scoliosis, degenerative spine, pathogenesis, pelvic obliquity.*

Level of evidence: *Retrospective clinical study, Level III*

(*) Assist.Prof., Suleyman Demirel University, Medical Faculty, Department of Orthopaedic and Traumatologic Surgery, Isparta.
(**) Prof., Uludag University, Medical Faculty, Department of Orthopaedic and Traumatologic Surgery, Bursa.
(***) Surgeon of orthopaedics, Florans Nightingale Hospital, İstanbul.
(****) Resident, Uludag University, Medical Faculty, Department of Orthopaedic and Traumatologic Surgery, Bursa, TURKEY.

ADDRESS: Remzi Arif Özerdemoglu, M.D.
PK: 90, Merkez Postanesi, 32000 Isparta, TURKEY
Phone (home): *+90 (246) 228-4422 •* ***Phone (office):*** *+90 (246) 211-2323*
Fax / Answering machine: *+90 (246) 227-6955 •* ***E-mail:*** *rezocagatay@hotmail.com*

NOTE: *This work has been orally presented at the Scoliosis Research Society, 36th Annual Meeting, September 19-22, 2001, Cleveland, Ohio, USA*

ÖZET:

Bu radyolojik kesit çalışmasının hedefi, "de novo" skolyoz gelişimine sebep olabilecek potansiyel riskleri belirlemek amacıyla, skolyoz olan veya olmayan lomber vertebrada dejenerasyon sürecini analiz etmektir. 121 erişkinde (>50 yaş) analiz edilen radyolojik parametreler : listezis, kamalaşma, her bir vertebra yüksekliği, her bir intervertebral disk yüksekliği ve kamalaşma, vertebral spur uzunluğu, lomber lordoz, lumbosakral, lumbohorizontal (L5) ve sakrohorizontal açılar, A-P grafide pelvik tilt, ilik tepeler arası çizgiden itibaren L5 derinliği, eğer varsa eğrilik şekli, en belirgin dejeneratif değişiklik seviyesi (MODC)'dir. Analiz için tekli ve çoklu değişken istatistik testleri kullanılmıştır. Dejeneratif değişiklikler en çok orta lomber bölgede belirgindi. Skolyoz ile birlikte olan vakalarda en belirgin dejeneratif değişiklikler (MODC) L2 vertebra/L2-3 disk ve L4 vertebra/L4-5 disk seviyelerinde daha sıktı (p=0,013, p=0,022). Çoklu değişken analizlere göre skolyoz varlığı L3 lateral listezis, L3-4 diskinde kamalaşma veya pelvik tilt ile yakın ilişkiliydi (p=0,000, p=0,000, p=0,001). L3-4 disk seviyesinde MODC ile birlikte veya eğrlik zirvesi daha kranialde olan vakalarda skolyoz derecesi daha yüksekti (p=0,009, p=0,017). Halbuki MODC L5-S1 seviyesinde olanlarda düşük dereceli skolyoz olabiliyor veya hiç skolyoz olmayabiliyor (p=0,009). "De novo" skolyoz olan vakalarda pelvik tilte sebep olan alt ekstremite veya kalça patolojileri ve lomber vertebra dejeneratif değişiklikler daha sık görülüyor. Keza, daha kranial eğrilik zirvesi ve L3-4 disk seviyesindeki asimetrik dejeneratif değişiklikler artmış skolyoz eğrilikleri ile birliktedir. Hernasılsa, L5 vertebra/L5-S1 disk seviyesi dejeneratif değişiklikleri skolyoz oluşumunda düşük risk taşımaktadır.

Anahtar Kelimeler: *Erişkin skolyoz, dejeneratif omurga, patogeneze, pelvic oblisite*

Kanıt Düzeyi: *Retrospektif klinik çalışma, Düzey III*

INTRODUCTION:

De novo scoliosis is the adult onset of coronal deformity in the presence of spondylosis primarily affecting the lumbar spine [3-5]. Its onset occurs in the fifth decade of life in cases without previous scoliosis [3-7]. Although adult degenerative scoliosis is a relatively common entity in the elderly, there is a surprising paucity of adequately controlled, prospective clinical reviews [7-9]. Unlike adolescent scoliosis, in de novo scoliosis there are no established radiographic parameters, no clear diagnostic criteria, useful classification systems, or accepted treatment guidelines [9]. The main purpose of this study was to analyze the degenerative process in the lumbar spine in patients with and without scoliosis, in order to determine potential risk factors, which may be related to the development of de novo scoliosis.

MATERIAL AND METHODS:

This cross sectional study includes 121 adults (≥50 years of age) with or without complaints related to their spine seen at one of our clinics between July 1999 and December 2000. Cases with prior history of scoliosis, trauma, spinal surgery or other surgery related to the pelvis or lower extremities were excluded. Patients with neurofibromatosis, connective tissue diseases, and other diseases or syndromes that may effect the presentation and outcome of the degenerative process of the spinal column were excluded, as well. Furthermore, patients with an endocrine abnormality, metabolic bone disease other than postmenopausal osteoporosis, or other disorders known to affect the bone mineral metabolism were also not included into the study.

All subjects were evaluated by medical history, meticulous physical examination, and standing spinal roentgenograms. Analyzed radiological parameters included: degree of listhesis (%), wedging (%), and height of each lumbar vertebra, also asymmetric disc collapse (%), and height of each disc level, length of vertebral spurs, lumbar lordosis, lumbosacral, lumbo (L5) horizontal and sacro-horizontal angles, pelvic tilt (pelvic obliquity) on A-P X-ray, depth of L5 from the intercrest line, and level presenting with the most obvious degenerative changes (MODC) (Figure-1).

By using the Cobb method, only curves ≥10° were considered as scoliosis. In these cases curve pattern (size of curve, single or multiple curves, side of main curve, length and location (apex, upper and lower end vertebra), apical rotation (based on the method of Nash & Moe)) has been investigated as well. Statistical analysis was performed using SPSS for Windows, Release 8.0.0, copyright© SPSS Inc, 1989-1997 Statistical Software. Quantitative variables were compared by using the Student's t-test, after verification that distribution of the variables was normal. For comparisons of qualitative variables, either Pearson's chi-square test or Fisher's exact test were performed, depending on sample size. The non-parametric Pearson correlation coefficient was used to assess the association between two variables (e.g. degree of pelvic tilt and magnitude of scoliosis). A multivariate logistic regression model was used to identify factors predicting the presence and degree of scoliosis.

RESULTS:

There were 33 male and 88 female with the mean age of 63±7 years (range, 50-93).

Evaluation of degenerative changes in the lumbar spine: Asymmetric disc collapse and spur formation were most obvious at the L3-4 disc level, Table-1. Whereas, on A-P X-rays,

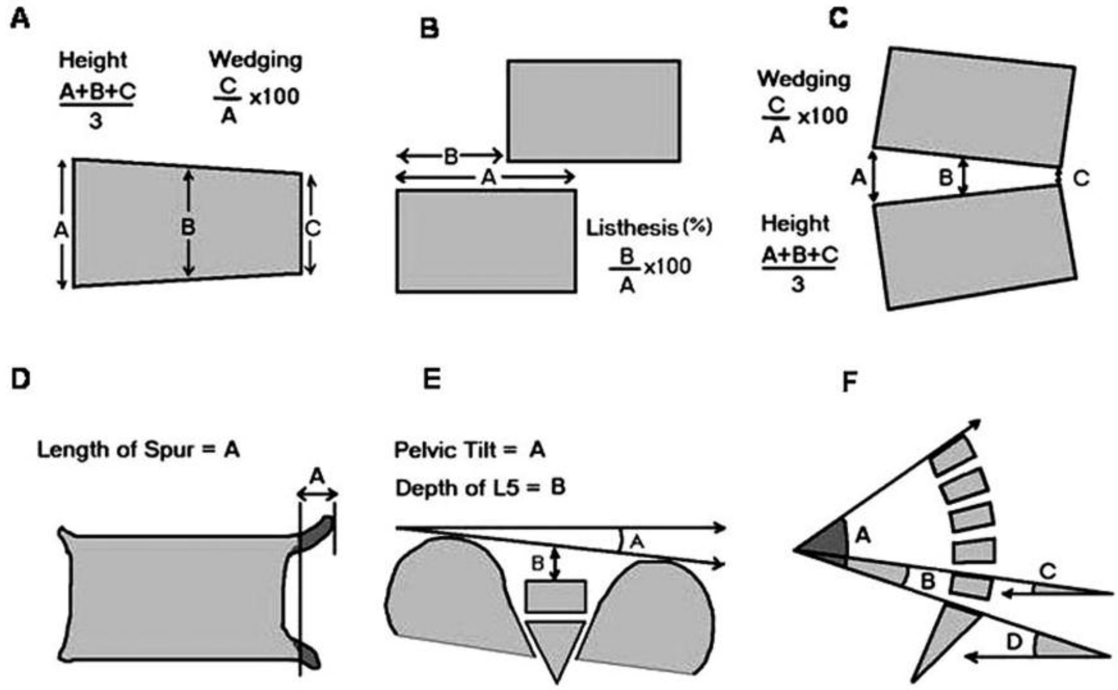

Figure-1. Calculation of some parameters used in this study.

Explanation: **a)** height (mm) and wedging (%) of each lumbar vertebra, **b)** listhesis (%) of each lumbar vertebra, **c)** height (mm) and wedging (%) of each disc level, **d)** length of vertebral spurs (mm) at each disc level, **e)** pelvic tilt (pelvic obliquity) (0) and depth of L5 from the intercrest line (mm) on A-P X-ray, **f)** lumbar lordosis (A), lumbosacral (B), lumbo (L5) horizontal (C), and sacro-horizontal (D) angles.

Table - 1. Spur formation and asymmetric disc collapse (wedging) at each lumbar disc level.

Level	Spur formation on A-P X-ray (mm)	Spur formation on lateral X-ray (mm)	Wedging on A-P X-ray* (%)
L1-2	1.42.0 (0-10) †	1.83.3 (0-20) †	4.113.7 (0-80) †
L2-3	2.12.3 (0-10)	1.93.0 (0-15)	5.014.5 (0-90)
L3-4	3.02.5 (0-12)	2.53.4 (0-14)	10.220.1 (0-99)
L4-5	2.52.8 (0-21)	2.03.1 (0-12)	9.321.0 (0-99)
L5-S1	**	1.02.4 (0-11)	**

* Due to lumbar lordosis, endplates are not parallel on lateral X-rays in normal individuals. Therefore, lumbar lordosis angles for each level have been used instead of disc wedging for analysis on lateral X-rays, table 2.
**Difficult to determine on standing AP X-rays
†mean±std. deviation (min.-max.)

wedging and listhesis were more frequently seen at the L3 vertebra, Table 2. Moreover, on lateral X-rays, anterior wedging of vertebra and a smaller lordosis angle were found in more cranial levels of the lumbar spine, Table-2.

In 38 cases there was not any level (vertebral corpus and/or vertebral disc) representing with MODC according to the remaining lumbar spine. In 74 cases there was one level with MODC, and 9 subjects had 2 separate levels of MODC.

Evaluation of de novo scoliosis: Scoliosis (≥10° Cobb angle) was found in 35 cases (7 male, 28 female), with an average curvature of 15° ± 6° (range, 11-37). There were 31 single curves (21 left and 10 right curves) and 4 double curves.

Mean values of calculated angles and depth of L5 from the intercrest line are shown in Table-3. Upon univariate analysis, only pelvic tilt on the A-P X-ray was found to be significantly higher in cases with scoliosis (p=0.032), Table-3. Likewise, there was also a significant correlation between the degree of pelvic tilt and degree of scoliosis (coefficient=0.320, p=0.000). On the other hand, we could not establish any relationship between the degree of scoliosis and lumbar lordosis, lumbosacral angle, lumbo (L5) horizontal angle, sacro-horizontal angle, and depth of L5 from the intercrest line (p>0.05 for all).

Upon multivariate analysis, the presence of scoliosis showed a close relationship with the

Table - 2. Wedging, listhesis of each vertebra, and lumbar lordosis angle in the lumbar spine.

Level	Wedging on A-P X-ray (%)	Wedging on lateral X-ray (%)	Listhesis on A-P X-ray (%)	Listhesis on lateral X-ray (%)	Lumbar lordosis angle (°)
L1	0.20±1.42 (0-12)	3.0±6.9 (0-38)	0.07±0.73 (0-8)	0.53±2.61 (0-17)	1.2±3.2 (-10-10)
L2	0.14±1.55 (0-17)	1.7±4.4 (0-20)	0.12±1.39 (0-15)	0.93±3.48 (0-26)	4.2±3.5 (-5-14)
L3	0.42±2.93 (0-30)	1.1±5.3 (0-45)	0.89±3,21 (0-18)	0.85±3.42 (0-20)	6.7±4.7 (-20-22)
L4	0.32±2.04 (0-15)	0.6±2.8 (0-17)	0.29±1,98 (0-18)	1,86±7.41 (0-42)	9.1±4.2 (-4-20)
L5	0.33±2.64 (0-25)	0.0±0.0 (0-0)	0.00±0.00 (0-0)	0.56±2.82 (0-20)	15.3±5.7 (0-27)

Values in table are shown as: mean±std. deviation (min.-max.)

Table - 3. Mean values of calculated angles and depth of L5 from the intercrest line according to the presence of de novo scoliosis.

Parameter	De Novo Scoliosis Yes (≥10˚) (n=35)	No(<10˚) (n=86)	p value	TOTAL (n=121)
Lumbar lordosis†	-31.3±16.2 (-60–22)*	-29.8±11.5 (-56–3)	NS**	-30.3±13.0 (-60–22)
Lumbosacral angle†	12.8±6.5 (2–23)	14.9±6.1 (2–30)	NS**	14.3±6.3 (2–30)
Lumbo(L5)horizontal angle†	14.9±15.1 (-38–46)	14.7±10.7 (-14–46)	NS**	14.8±12.1 (-38–46)
Sacro-horizontal angle†	35.0±13.3 (-5–62)	37.7±11.8 (13–70)	NS**	36.9±12.2 (-5–70)
Pelvic tilt on A-P X-ray†	3.1±2.1 (0–10)	2.2±2.0 (0–7)	0.032	2.5±2.0 (0–10)
Depth of L5 from the intercrest line‡	-11.8±10.2 (-33–16)	-9.7±8.1 (-31–7)	NS**	-10.3±8.7 (-33–16)

*mean±std. deviation (min.-max.)

**NS= not significant

† Values are shown in degrees

‡ Values are shown in millimeters. Positive values mean that L5 was cranial to the intercrest line. Negative values are shown that L5 was caudally located to it.

presence of lateral listhesis of L3, asymmetric collapse of L3-4 disc, and pelvic tilt on A-P X-ray (p=0.000, p=0.000, p=0.001, respectively).

MODC at the L2 vertebra/L2-3 disc and L4 vertebra/L4-5 disc levels were significantly more frequent in cases with scoliosis (p=0.013, p=0.022, respectively), Table 4. Upon multivariate analysis, cases with MODC at the L3-4 disc level, or a more cranial apex of curve had a higher degree of scoliosis (p=0.009, p=0.017, respectively). Whereas MODC at the L5-S1 level coexist with a low degree or no scoliosis (p=0.009).

DISCUSSION:

In the lumbar spine, flexion-extension range of motion increases as the level becomes more caudal, while axial rotation is the same at each level, but decreases at the L5-S1 level. Lateral bending, however, is higher in the middle region of the lumbar spine and the most evident at the L3-4 level [4]. In addition, the intervertebral disc provides the main resistance to axial translation and frontal and sagittal plane rotation [1]. With degenerative disease, abnormal motion can occur, which may manifest as either increased or decreased motion at specific levels. Likewise, abnormal translation or rotation in the frontal plane results in lateral listhesis or scoliosis, respectively [1]. Finally, the formation of those deformities, altering the mechanical loading conditions of the spinal column, and can accelerate the degenerative cascade [9].

On the basis of the results of our study, it seems to be reasonable to investigate the degenerative changes in the lumbar spine on two different planes: the sagittal and frontal planes. On the sagittal plane, degenerative changes such as anterior wedging of the vertebra and a decreased lumbar lordosis angle were more obvious in the upper lumbar spine, leading primarily to kyphosis (Table-2). Those degenerative changes can be explained by the fact that the thoracolumbar junction is a transitional region, which puts the upper lumbar spine under greater risk against trauma and degeneration.

In cases with degenerative scoliosis spur formation and listhesis were more prominent in the middle part of lumbar spine on both the sagittal and frontal planes. Consequently, MODC was also found to be more frequent in the middle part of lumbar spine. In addition, we observed that scoliosis represented frequently in cases with lateral listhesis of L3, or an asymmetric collapse of L3-4 disc. All those findings suggest that the degenerative process leading to lateral listhesis or even scoliosis occurs particularly in the middle region of the lumbar spine. This is in accordance with the studies of Grubb and Lipscomb [4], and Isaza et al. [5] in which lateral listhesis particularly at the L3-4 level was

Table - 4. Distribution of levels representing with MODC in the lumbar spine.

Level of MODC	De Novo Scoliosis Yes (≥10°) (n=35)	 No(<10°) (n=86)	p value	TOTAL (n=121)
L1 Vertebra/L1-2 disc	4 (11%)	13 (15%)	NS*	17 (14%)
L2 Vertebra/L2-3 disc	7 (20%)	4 (5%)		0.013 11 (9%)
L3 Vertebra/L3-4 disc	9 (26%)	14 (16%)	NS*	23 (19%)
L4 Vertebra/L4-5 disc	12 (34%)	12 (14%)	0.022	24 (20%)
L5 Vertebra/L5-S1 disc	4 (11%)	13 (15%)	NS*	17 (14%)

*NS = not significant

shown to be the most common finding in cases with de novo scoliosis, and also significantly associated with the severity of curve. Similarly, other studies [6, 8] speculated that degenerative scoliosis might start with instability at the L3-4 and L4-5 disc levels, which may be the key to de novo scoliosis.

Another observation of Grubb et al. [3] was that there were fewer degenerative changes at L5-S1 level in cases with scoliosis. This finding was also observed in our series, as we found that spur formation, wedging and listhesis were all found less frequently in the lower lumbar spine (L5 vertebra and L5-S1 disc level). Likewise, we found that MODC at the L5-S1 level coexist with a lower degree of scoliosis. Those findings may be related to the fact that the L5 vertebra has broad pedicles and large transverse and accessory processes, which reflect its strong muscular and ligamentous support, such as strong iliolumbar and lumbosacral ligaments [6, 8]. Consequently, lateral bending and axial rotation, known to be important in the evolution of scoliosis, are the least at the L5 vertebra in the lumbar spine [10].

In this study, pelvic tilt on A-P X-ray was found to be another parameter frequently present in cases with scoliosis. Taking into consideration that the posture of the lumbar spine is correlated with pelvic parameters, in which the incidence angle is known to be very important for the up-right posture, and pelvic obliquity may cause compensatory scoliosis. A significant difference in leg length may cause scoliosis in the childhood. Similarly, degenerative changes and pathologic conditions in the pelvis, hip or lower extremities developing later in life can cause pelvic tilt, and may also affect the lumbar spine resulting in de novo scoliosis. Although pelvic tilt was not analyzed in the study of Grubb et al. [3] they reported that four of their 21 patients representing with de novo scoliosis had had known degenerative joint diseases of the hip and one had a leg length discrepancy. Likewise, Pritchett and Bortel [6] stated that 20% of their patients with de novo scoliosis had had known degenerative joint disease of the hip or knee. It can also be seen on the published illustrations that their patients had pelvic tilt on AP X-rays. Furthermore, Gillespy et al. [2] stated that leg length discrepancy might play a role in the evolution and increase of scoliosis.

Previous studies [5, 6, 8] reported that radiological parameters predictive for curve progression are: a Cobb angle over 30 degrees, Grade II and III apical rotation, curves that are imbalanced and have a secondary compensatory curve that is sharp and angular at the L4-S1 level, curves in which the apex is at the L2-3 and L3-4 area, a more cranial located L5 vertebra to the intercrest line, and lateral vertebral translation of 6 mm or more. Gillespy et al. [2] stated that degenerative disc disease might be the most important cause of curve progression. Similarly, in our series, patients with MODC at the L3-4 disc level had higher degree of scoliosis. On the contrary, we did not find any relationship between apical rotation and degree of scoliosis. Similarly, we could not demonstrate any correlation between the depth of L5 to the intercrest line and the development or degree of scoliosis, either. This may be related to the fact that our patients had less severe scoliosis than those in other published series [3, 4, 9, 6, 8]. There was only one case with a curve over 30 degrees, and this was also the only case represented with a Grade III apical rotation. This is actually an advantage, as investigating a degenerative process at the beginning, increases the possibility to observe primary causes of deformity rather than secondary changes.

Nevertheless, adult degenerative curves are reported to be shorter (by number of involved spinal segments) and smaller (by curve degree magnitude) than pediatric ones [4, 9].

The role of osteoporosis in the progression of de novo scoliosis is controversial. Robin et al. [7] could not found any relationship between the presence and degree of osteoporosis, and the presence and degree of scoliosis. Similarly, Grubb and Lipscomb [4] reported that there was no evidence of bone demineralization disorder in these patients. Whereas, Gillespy et al. [2] concluded that osteoporosis might increase the risk of the development of scoliosis. Biomechanically, osteoporosis is expected to cause kyphosis rather than scoliosis. We concluded that:

(1) Degenerative changes in the lumbar spine become intense at two regions; on the sagittal plane degenerative changes most obvious in the upper lumbar spine lead primarily to kyphosis. Whereas, the degenerative process in the middle part of the lumbar spine, particularly at L3 vertebra and L3-4 disc level seems to be an important factor in the development of scoliosis.

(2) Degenerative changes at the L5 vertebra/L5-S1 disc level may have lower risk in producing scoliosis, because this region is much stiffer against lateral bending and axial rotation on the frontal plane.

(3) Degenerative changes and pathologic conditions in the pelvis, hip or lower extremities resulting in pelvic tilt (pelvic obliquity), change of the mechanical loading conditions of the spinal column. Therefore, patients with such conditions should be closely followed-up against the potential risk to develop degenerative adult scoliosis in later life.

(4) Patients with asymmetric degenerative changes at the L3-4 disc level, or a more cranial apex of curve presented with larger curves.

REFERENCES:

1. Esses SI, Doherty B. Biomechanics of the spine. In: Esses SI (ed) *Textbook of Spinal Disorders.* JB Lippincott, Philadelphia, 1995; pp: 109-134.
2. Gillespy T III, Gillespy TJr, Revak CS. Progressive senile scoliosis: Seven cases of increasing spinal curves in elderly patients. *Skeletal Radiol* 1985; 13: 280-286.
3. Grubb SA, Lipscomb HJ, Coonrad RW. Degenerative adult onset scoliosis. *Spine* 1988; 13(3): 241-245.
4. Grubb SA, Lipscomb HJ. Diagnostic findings in painful adult scoliosis. *Spine* 1992; 17(5): 518-527.
5. Isaza JE, Londono F, Myers LA, Holt RT, Whitecloud TS. De Novo scoliosis: definition and clinical classification. Scoliosis Research Society 32nd Annual Meeting Final Program, exhibit #24, page 141, St. Louis, Missouri, September 25-27, 1997.
6. Pritchett JW, Bortel DT. Degenerative symptomatic lumbar scoliosis. *Spine* 1993; 18(6): 700-703.
7. Robin GC, Span Y, Steinberg R, Makin M, Menczel J. Scoliosis in the elderly. A follow-up study. *Spine* 1982; 7(4): 355-359.
8. Sapkas G, Efstathiou P, Badekas AT, Antoniadis A, Kyratzoulis J, Meleteas E. Radiological parameters associated with the evolution of degenerative scoliosis. *Bull Hosp Joint Dis* 1996; 55(1): 40-45.
9. Schwab FJ, Smith VA, Biserni M, Gamez L, Farcy JPC, Pagala M. Adult Scoliosis. A quantitative radiographic and clinical analysis. *Spine* 2002; 27(4): 387-392.
10. White AA, Panjabi MM. *Clinical Biomechanics of the Spine.* 2nd ed. JB Lippincott, Philadelphia, 1990: 109-121.