Degenerative retrolisthesis
Is it a compensatory mechanism for sagittal imbalance

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- ABSTRACT –

Degenerative retrolisthesis

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Study Design: Retrospective analysis of a prospectively collected patient database.

Objective: to investigate the spinopelvic morphology and global sagittal balance of degenerative retrolisthesis, and to determine whether retrolisthesis is a result of spinopelvic morphology or a compensatory mechanism of global sagittal balance.

Summary of Background Data: We investigated the spinopelvic morphology and global sagittal balance of patients with a degenerative retrolisthesis or anterolisthesis. A total of 269 consecutive patients with a degenerative spondylolisthesis were included in this study. There were 95 men and 174 women with a mean age of 64.3 years (SD 10.5; 40 to 88). A total of 106 patients had a pure retrolisthesis(R group), 130 had a pure anterolisthesis (A group), and 33 had both (R+A group).

Results: A backward slip was found in the upper lumbar levels (mostly L2 or L3) with an almost equal gender distribution in both the R and R+A groups. The pelvic incidence and sacral slope of the R group were significantly lower than those of the A (both $p < 0.001$) and R+A groups (both $p < 0.001$). The lumbar lordosis of the R+A group was significantly greater than that of the R ($p = 0.025$) and A groups ($p = 0.014$). The C7 plumb line of the R group was located more posteriorly than that of the A group ($p = 0.023$), but was no different from than that of the R+A group ($p = 0.422$). The location of C7 plumb line did not differ between the three groups ($p = 0.068$). The spinosacral angle of the R group was significantly smaller than that of the A group ($p < 0.001$) and R+A group ($p < 0.001$).

Conclusions: Our findings imply that there are two types of degenerative retrolisthesis: one occurs primarily as a result of degeneration in patients with low pelvic incidence, and the other occurs secondarily as a compensatory mechanism in patients with an anterolisthesis and high pelvic incidence.

Keyword : spinopelvic morpgology, sagittal balance, degerative retrolistesis, anterolisthess, pelvic incidience

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I. INTRODUCTION

Spondylolisthesis is the slippage of one vertebra in relation to an adjacent vertebra. The slippage observed in the degenerative spine is thought to be a forward displacement of thesuperior vertebra resulting from the lumbosacral configuration and the caudal–ventral vector of gravity and muscle forces. (Bergmark, 1989; Sengupta DK and Herkowitz HN, 2005) However, backward displacement has also been found to occur, and has been termed retrolisthesis in order to distinguish it from anterior spondylolisthesis or anterolisthesis. (Iguch T et al, 2002; Berlemann U et al, 1999; Barrey C et al, 2011)

Retrolisthesis has been seen to occur in degenerative conditions (Rothman SL et al, 1985; Lee C et al, 1986) after injury (Cohn SL et al, 1989; Ahmed A et al, 2005) and next to fused levels. (Hambly MF et al 1998; Park P et al, 2004) While numerous studies have addressed anterolisthesis (Sengupta DK and Herkowitz HN, 2005; Tsirikos AI and Garrido EG, 2010; Hu SS et al, 2008; Bassewitz H and Herkowitz H, 2001; Wiltse LL, 1962) and since its original description by the Belgian obstetrician Herbinaux in 1782, (Herbinaux G, 1782) little is known about it epidemiology, etiology and clinical significance.

Spinopelvic morphology and global sagittal balance are important factors in understanding the biomechanical pathogenesis of sagittal imbalance disorders. (Mardjetko S et al, 2005; Roussouly P and Pinheiro-Franco JL, 2011) Pelvic incidence, pelvic tilt, sacral slope, and lumbar lordosis have each been found to be significantly increased in both developmental and degenerative spondylolisthesis, (Labelle H et al, 2004; Schuller S et al, 2011) suggesting that spinopelvic morphology may predispose patients to anterolisthesis. Pelvic incidence (PI) is defined as the angle subtended by a line from the centre of rotation of the hip to the mid-point of the endplate of S1 and perpendicular to the endplate of S1 at its midpoint. Sacral slope (SS) is defined as the angle between the superior endplate of S1 and the horizontal plane. Pelvic tilt(PT) is defined as the angle between a line joining midpoint of the superior endplate of S1 to the centre of rotation of the hip, and the vertical plane (Fig. 1).

If a high PI predisposes patients to anterolisthesis, then retrolisthesis cannot be accompanied by a high PI. Conversely, retrolisthesis is thought to attempt to compensate for sagittal imbalance in degenerative spondylolisthesis. (Barrey C et al, 2011; Barrey C et al; 2007) If retrolisthesis does occur as the result of a degenerative anterolisthesis, it should be accompanied by a high PI.

The aim of the present study was to investigate the spinopelvic morphology and global sagittal balance of degenerative retrolisthesis, and to determine whether retrolisthesis is a result of spinopelvic morphology or a compensatory mechanism of global sagittal balance.

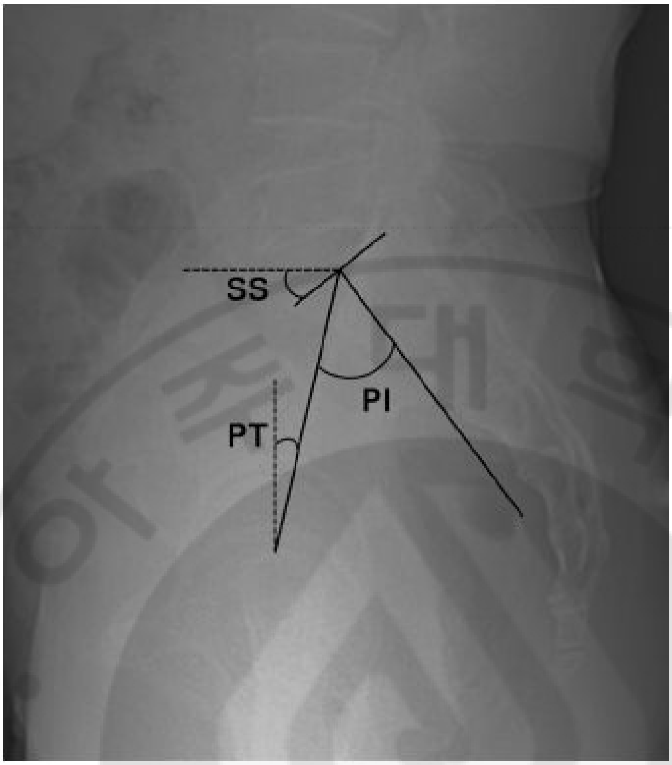

Fig. 1. Radiograph showing the measurement of pelvic parameters. pelvic incidence (PI) is defined as the angle subtended by a line connecting the centre of rotation of the hip joint to the midpoint of the endplate of S1 and a perpendicular to the endplate of S1 at its midpoint; sacral slope (SS) is defined as the angle between the superior endplate of S1 and the horizontal plane; pelvic tilt (PT) is defined as the angle between a line joining the midpoint of the superior endplate of S1 and the centre of rotation of the hip with the vertical plane.

Ⅱ. MATERIALS AND METHODS

The ethical committee of the hospital reviewed and approved the design of the study. Between March 2009 and June 2012 a total of 300 consecutive patients with a spondylolisthesis (anterolisthesis or retrolisthesis) were prospectively evaluated. Spondylolisthesis was defined as a forward or backward slip ≥ 3 mm on a standing lateral lumbar radiograph. Patients with other spinal diseases resulting from trauma, tumors, scoliosis > 10°, isthmic lysis, hip pathology, age < 40 years and a history of spinal surgery (including vertebroplasty or kyphoplasty) were excluded (n = 31).

This left a total of 269 patients in the study (95 men and 174 women, mean age 64.3 years (SD 10.5; 40 to 88)), who underwent a standing lateral radiograph of the whole spine with the arms in the fists-on-clavicles position with their knees and hips fully extended. (Faro FD et al, 2004) All radiographs were taken using vertical 35.4 × 83.7 cm film and a digital radiography system (Fuji IP Longview cassette; Fuji Photo Film Co.,Tokyo, Japan).

A total of 106 patients were identified as having a pure retrolisthesis (R group), 130 patients a pure anterolisthesis (A group), and 33 both (R+A group) (Fig. 2).

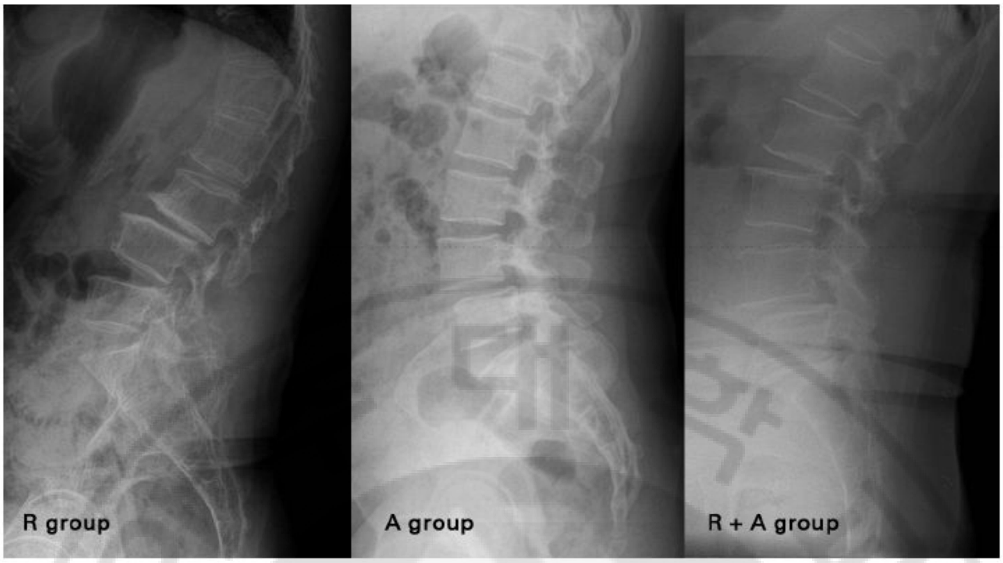

Fig. 2. Radiographs showing the three study groups of degenerative spondylolisthesis categorised according to the direction of the slip(s). The retrolisthesis (R) group was defined as having a pure backward slip(s); the anterolisthesis (A) group was defined as having a pure forward slip(s); and the combined (R+A) group was defined as having both retro- and anterolisthesis.

The pelvic parameters, including PI, SS and PT, were measured as described by Legaye et al. (Legaye et al, 1998) The spinal parameters, including lumbar lordosis and thoracic kyphosis were measured as described by Berthonnaud et al. (Berthonnaud et al, 2005) The spine was regarded as three distinct anatomical areas (cervical, thoracic and lumbar), and the neutral point, i.e., the point at which the two different curvatures change direction, was determined. The lumbar lordosis was determined by Cobb's method (Cobb JR,

1948) and measured between the sacral plate and upper endplate of the most inclined vertebra at the thoracolumbar junction, corresponding to the neutral point where the spine moves from lordosis into kyphosis. The thoracic kyphosis was measured between the neutral point of the thoracolumbar junction and that of the cervicothoracic junction. The configuration of the lumbar lordosis was classified into four types as described by Roussouly and Pinheiro-Franco (Table 1). (Roussouly P et al, 2011)

Table 1. Classification of lumbar lordosis according to Roussouly and Pinheiro-Franco. (Roussouly P and Pinheiro-Franco JL, 2011)

Type	Sacral slope (SS)	Description
1	< 35°	Short and small lordosis, long kyphosis exceeding the thoracolumbar transition zone, reaching lower thoracic spine
2	< 35°	Long and flat lordosis
3	35° ≥ SS < 45°	Normal length and angle of lordosis
4	> 45°	Very curved lordosis, higher extension and angle

Global sagittal balance was evaluated by measuring the C7/sacrofemoral distance (SFD) ratio and spinosacral angle as described by Roussouly and Pinheiro-Franco. (Roussouly P et al, 2011) Briefly, the SFD is defined as the horizontal distance between the centre of rotation of the hip and a vertical line passing through the posterior corner of the sacrum. The horizontal distance between the posterior corner of the sacrum and the C7 plumb line was measured. The ratio between this measurement and the SFD was calculated (C7/SFD ratio). The C7/SFD ratio was equal to 0 when the C7 plumb line was exactly on the posterior corner of the sacrum and equal to 1 when the C7 plumb line was exactly on the hip axis. The ratio was negative when the C7 plumb line was posterior to the sacrum and more than 1 when the C7 plumb line was anterior to the hip axis. The spinosacral angle was defined as the angle between the sacral plate and a line running from the centre of C7 to the centre of the sacral plate.

No further information about transitional vertebrae was obtained. The lowest vertebra that was not fused to the sacrum was considered to be L5. All radiological measurements were performed by one spinal surgeon (JUP) using a picture archiving and communication system (PiViewer-STAR; INFINITT, Seoul, Korea), which was equipped with an integrated digital measurement facility.

Descriptive statistics are summarised as frequencies and percentages for categorical variables, and as means and standard deviations (SDs) for continuous variables. Each continuous variable between each study group was compared using one-way analysis of variance (ANOVA) with Tukey's post-hoc analysis. Each categorical variable between each study group was compared using Fisher's exact test with Bonferroni's correction. Statistical analyses were carried out using SPSS v16.0 software (SPSS Inc., Chicago, Illinois). A p-value < 0.05 was considered to be statistically significant.

Ⅲ. RESULTS

The characteristics of the study groups are shown in Table II. There were no statistically significant differences between the groups regarding gender distribution or mean extent of slip in either direction, but the R group was significantly younger than the A and R+A groups (both $p < 0.001$) (Table 2). In the 106 patients in group R, the most common level affected was L3/4 (62 of 140 slips,44%) followed by L2/3 (50 slips, 36%). In the 130 patients in group A, the most common level affected was L4/5 (79 of 133 slips, 59%) followed by L5/S1 (39 slips, 29%). In the R+A group the most common combination of levels was retrolisthesis at L2/3 with anterolisthesis at L4/5 in nine patients (27%), followed by retrolisthesis and anterolisthesis at L1/2 and L4/5, respectively (in five patients, 15%).

Table III summarises the measurements of spinopelvic morphology and global sagittal balance of the study groups. The R group had a significantly lower mean PI and SS than the A group (both $p < 0.001$) and the R+A group (both $p < 0.001$), with no difference between the A and R+A groups ($p = 0.231$ and 0.982, respectively) (Table 3). There was only a significant difference in pelvic tilt between the R and A groups ($p = 0.010$). The mean lumbar lordosis in the R+A group was significantly higher than that of the R and A groups ($p = 0.025$ and $p = 0.014$, respectively). The mean thoracic kyphosis of the A group was significantly lower than that of the R group ($p = 0.039$), but not significantly different to that of the R+A group ($p = 0.191$). The mean thoracic kyphoses of the R and R+A groups were not significantly different ($p = 0.995$) (Table 3, Fig. 3).

Table 2. Demographics of the study groups (R, retrolisthesis; A, anterolisthesis)

Characteristic	Group			p-values		
	R (n = 106)	A (n = 130)	R+A (n = 33)	R *vs* A	R *vs* R+A	A *vs* R+A
Mean age (yrs) (SD; range)	61.3 (12.2; 40 to 85)	66.4 (9.3; 44 to 88)	65.5 (6.2; 52 to 76)	< 0.001	< 0.001	0.485
Male (n, %)	54 (*50.9*)	25 (*19.2*)	16 (*48.5*)	< 0.001	0.806	0.001
Slip type (n, %)				< 0.001	< 0.001	< 0.001
1-segment	75 (*70.7*)	127 (*97.7*)	-			
2-segment	28 (*26.4*)	3 (*2.3*)	18 (*54.5*)			
≥ 3-segment	3 (*2.8*)	-	15 (*45.5*)			
Mean slip extent (mm) (SD; range)						
Retrolisthesis	4.3 (1.6; 3.0 to 11.11)	-	6.5 (2.5; 3.0 to 11.81)	-	0.597	-
Anterolisthesis	-	4.7 (1.7; 3.0 to 12.81)	4.1 (1.1; 3.0 to 12.01)	-	-	0.665
Number of slips (n)	140	133	-			
Level (n, %)				< 0.001	-	-
L5/S1	0	39 (*29.3*)	-	-	-	-
L4/5	19 (*13.6*)	79 (*59.4*)	-	-	-	-
L3/4	62 (*44.3*)	15 (*11.3*)	-	-	-	-
L2/3	50 (*35.7*)	0	-	-	-	-
L1/2	8 (*5.7*)	0	-	-	-	-
T12/L1	1 (*0.7*)	0	-	-	-	-
Combined slip pattern (n, %)						
L4/5 (R) + L3/4 (A)	-	-	4 (*12.1*)	-	-	-
L3/4 (R) + L5/S1 (A)	-	-	3 (*9.1*)	-	-	-
L3/4 (R) + L4/5 (A)	-	-	2 (*6.1*)	-	-	-
L2/3 (R) + L5/S1 (A)	-	-	4 (*12.1*)	-	-	-
L2/3 (R) + L4/5 (A)	-	-	9 (*27.3*)	-	-	-
L2/3 (R) + L3/4 (A)	-	-	3 (*9.1*)	-	-	-
L1/2 (R) + L4/5 (A)	-	-	5 (*15.2*)	-	-	-
L1/2 (R) + L3/4 (A)	-	-	2 (*6.1*)	-	-	-
T12/L1 (R) + L3/4 (A)	-	-	1 (*3.0*)	-	-	-

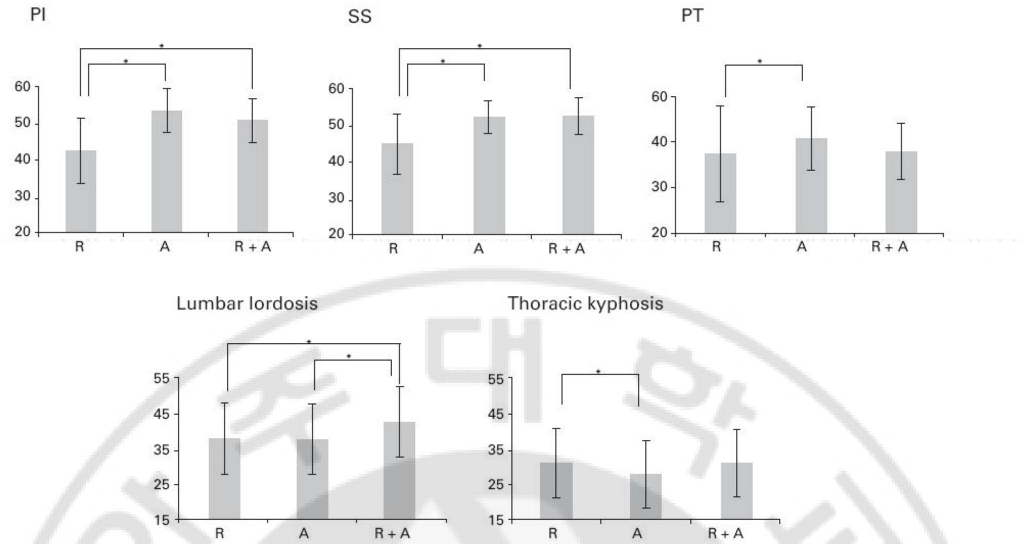

Fig. 3. Bar charts showing the mean pelvic and spinal parameters in each of the study groups. Error bars represent the standard deviation. An asterisk denotes a statistically significant difference (see Table 3 for p-values) (R, retrolisthesis; A, anterolisthesis; PI, pelvic incidence; SS, sacral slope; PT, pelvic tilt).

The configuration of the lumbar lordosis in the R group differed significantly from that of the A group ($p < 0.001$) and R+A group ($p = 0.030$), although there was no difference between the A and R+A groups ($p = 0.355$). The C7/SFD ratio did not differ between the three groups ($p = 0.068$) (Fig. 4). The mean spinosacral angle of the R group was significantly lower than that of the A group ($p < 0.001$) and R+A group ($p < 0.001$), again with no difference between the A and R+A groups ($p = 0.597$).

Table 3. Spinopelvic morphology and global sagittal balance of the study groups

	Group			p-values		
	R (n = 106)	A (n = 130)	R+A (n = 33)	R *vs* A	R *vs* R+A	A *vs* R+A
Mean (SD) pelvic parameters						
Pelvic incidence (°)	42.6 (8.9)	53.4 (6.2)	51.0 (6.0)	< 0.001	< 0.001	0.231
Sacral slope (°)	25.2 (8.2)	32.8 (4.7)	33.0 (5.0)	< 0.001	< 0.001	0.982
Pelvic tilt (°)	17.5 (10.5)	20.7 (6.8)	18.0 (6.1)	0.010	0.935	0.242
Mean (SD) spinal parameters						
Lumbar lordosis (°)	37.9 (10.1)	37.6 (8.1)	42.5 (6.8)	0.977	0.025	0.014
Thoracic kyphosis (°)	31.4 (10.3)	28.2 (9.9)	31.6 (9.8)	0.039	0.995	0.191
Spinopelvic configuration (n, %)				< 0.001	0.030	0.355
Type 1	81 (*76.4*)	60 (*46.2*)	20 (*60.6*)	-	-	-
Type 2	16 (*15.1*)	29 (*22.3*)	3 (*9.1*)	-	-	-
Type 3	8 (*7.5*)	41 (*31.5*)	9 (*27.3*)	-	-	-
Type 4	1 (*0.9*)	0	1 (*3.0*)	-	-	-
Mean (SD) global sagittal balance						
C7/SFD* ratio	0.38 (0.94)	0.64 (0.75)	0.53 (0.89)	0.061	0.422	0.473
Spinosacral angle (°)	114.5 (10.6)	120.4 (7.3)	122.1 (7.0)	< 0.001	< 0.001	0.597

* SFD, sacrofemoral distance

The configuration of the lumbar lordosis in the R group differed significantly from that of the A group ($p < 0.001$) and R+A group ($p = 0.030$), although there was no difference between the A and R+A groups ($p = 0.355$). The C7/SFD ratio did not differ between the three groups ($p = 0.068$) (Fig. 4). The mean spinosacral angle of the R group was significantly lower than that of the A group ($p < 0.001$) and R+A group ($p < 0.001$), again with no difference between the A and R+A groups ($p = 0.597$).

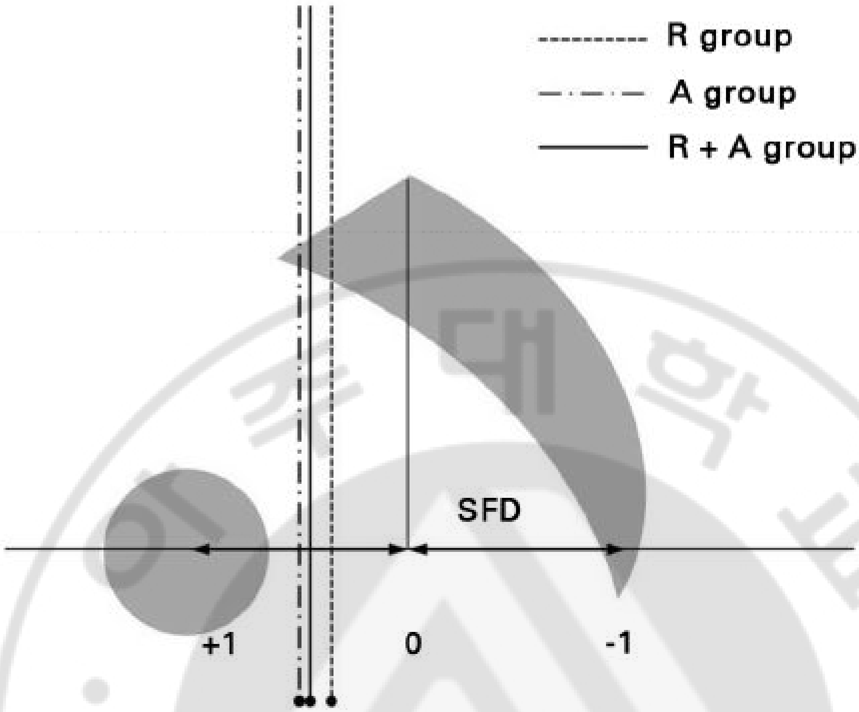

Fig. 4. Diagram showing a comparison of the C7 plumb line between the groups. The C7 plumb lines of the three groups are all located between the centre of rotation of the hip and the posterior corner of the sacrum.

Ⅳ. DISCUSSION

Although numerous reports on spondylolisthesis exist in the literature, little attention has been paid to retrolisthesis because it was regarded as a rare and insignificant condition. (Shen M et al, 2007) Recent studies have, however, shown that it may exist more commonly than was previously believed and with significant symptoms. (Sengupta DK and Herkowitz HN, 2005; Barrey C et al, 2007; Shen M et al, 2007) Iguchi et al. (Igucho T et al, 2002) reported 83 cases (2.6%) of degenerative retrolisthesis among 3259 outpatients with low back pain. Their series included 39 patients with a single-level retrolisthesis, with multilevel retrolisthesis and 19 with a retrolisthesis combined with an anterolisthesis. Shen et al. (Shen M et al, 2007) reported a 23.2% incidence of L5 retrolisthesis among 125 individuals with L5- S1 disc herniations.

In the present study of 269 consecutive patients with a degenerative spondylolisthesis, we identified 106 patients (39.4%) with a pure retrolisthesis, 130 (48.3%) with a pure anterolisthesis, and 33 (12.3%) with a combined retrolisthesis and anterolisthesis. The number of patients with a retrolisthesis was similar to the number of patients with an anterolisthesis, implying that degenerative retrolisthesis is not a rare condition.

There were two types of degenerative retrolisthesis (R type and R+A type): both types of retrolisthesis were found at the upper lumbar levels (mostly L2 or L3) with an almost equal gender distribution. The mean amount of backward slip did not differ between the two types ($p = 0.597$). However, the mean age was significantly higher in patients with combined forward and backward displacement than in patients with a pure retrolisthesis ($p < 0.001$). Our results concerning the demographic characteristics were very similar to those in a previous report. (Iguchi T et al, 2002)

We compared the spinopelvic morphology and global sagittal balance in the two types of retrolisthesis. The spinopelvic morphology determines the mechanical stress at the lumbosacral junction. (Labelle H et al, 2011) Degenerative anterolisthesis was reported to have a higher PI, SS, and lumbar lordosis. (Schuller S et al, 2011; Barrey C et al, 2007; Shen M et al, 2007) By contrast, degenerative retrolisthesis was associated with a lower lumbar lordosis and SS. (Iguchi T et al, 2002 and Berlemann U et al, 1999) We hypothesised that there is a different biomechanical cause for the two types of degenerative retrolisthesis; one mechanism is the natural occurrence of backward displacement. Rothman et al. (Rothman SL et al, 1985) stated that degenerative retrolisthesis is primarily a disease of the intervertebral disc, whereas anterolisthesis is a disease of the posterior joints. When the lumbar spine is hyperlordotic, the contact force on the posterior joints and the intervertebral tilt will increase, thereby increasing the forward sliding force. By contrast, the contact force on the anterior intervertebral disc will increase with hypolordosis, subsequently decreasing the intervertebral tilt. (Roussouly P and Pinheiro-Franco JL, 2011) As hypolordosis is related to a lower SS, and subsequently lower PI, (Schwab F et al, 2009; Mac-Thiong JM et al, 2007) backward displacement could occur in patients with a low PI for this reason. This condition may be relevant to the R group in the present study.

The other mechanism of backward displacement is as compensation for a kyphotic imbalance disorder, which includes degenerative spondylolisthesis. (Barrey C et al, 2011; Barrey C et al, 2007) In kyphotic imbalance disorders, the axis of gravity moves anteriorly. Inorder to compensate for it, there is a reduction in the thoracic kyphosis, intervertebral hyperextension, retrolisthesis, pelvis back tilt, knee flexion and ankle extension. (Barrey C et al, 2011) By this mechanism, retrolisthesis could occur secondarily after degenerative anterolisthesis, which is usually associated with high PI. (Barrey C et al, 2007) We suggest that this condition may be relevant to the R+A group in the present study.

The PI, SS and lumbar lordosis were significantly lower in the R group than in the R+A group ($p < 0.001$, $p < 0.001$ and $p = 0.025$, respectively). The distribution of the lumbar lordosis configuration was also significantly different between the two groups ($p = 0.030$). Given that the PI is a morphological constant that varies between individuals, we can conclude that the two different biomechanical conditions exist depending on the PI: one occurs spontaneously in patients with a low PI, and the other occurs secondarily in patients with an anterolisthesis and a high PI. Furthermore, the spino-sacral angle of the R group was significantly lower than that of the A group ($p < 0.001$) and R+A group ($p < 0.001$). Considering that the spinosacral angle is also a morphological constant variable of each individual, (Roussouly P et al, 2011) we can reaffirm the different spinopelvic morphology between the natural and compensatory retrolisthesis.

We acknowledge several methodological flaws in the present study. As the radiological assessments were not followed longitudinally over time, there is no way to prove our hypothesis. Clinical information such as back pain, leg pain, disability and treatment outcomes were not assessed. Other radiological studies such as magnetic resonance imaging or dynamic radiographs were not analysed. We simply divided degenerative retrolisthesis into two types according to the direction of the slip. This dichotomous discrimination may have a favourable reliability; however, the validity of this discrimination was not exclusively provided. Furthermore, this simple discrimination overlooked the various subtypes of spinopelvic morphology. The PI value of anterolisthesis was initially believed to be high. However, subtype analysis found that there are anterolisthesis patients with a low PI, which suggests a different mechanism of slippage. (Labelle H et al, 2011) There were six patients (5.7%) with a high PI (≥ 60°) in the R group, and four patients (12.1%) with a low PI (< 45°) in the R+A group.

Ⅴ. CONCLUSION

In conclusion, our findings imply that there are two types of degenerative retrolisthesis: one occurs primarily as a result of degeneration in patients with low pelvic incidence, and the other occurs secondarily as a compensatory mechanism in patients with an anterolisthesis and high pelvic incidence. Additional studies that address the clinical relevance, treatment outcome and subgroup analysis are warranted.

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- 국문요약 -

퇴행성 척추 후방 전위증

시상 불균형에 의한 보상작용으로 발생하는가

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연구 목적 : 척추 전방전위증 환자와 척추 후방전위증 환자의 척추골반 형태와 전반적인 시상 균형을 조사하고, 척추 후방 전위증이 척추골반의 형태 또는 글로벌 시상 균형의 보상 메커니즘의 결과로 발생하는지 조사한다. 내원한 환자의 정보를 바탕으로 후향적 연구 방법으로 분석 하였다.

연구 대상 및 방법: 척추골반 형태 및 퇴행성 척추 후방전위증 또는 척추 전방전위증 환자의 전반적인 시상 균형을 조사 하였다. 퇴행성 척추 전방 전위증을 가진 총 269 명의 환자를 대상으로 하였다. 남성은 95 명, 여성은 174 명 이었고 이들의 평균 연령은 64.3 세 였다 (SD 10.5; 40 to 88). 106 명의 환자가 순수 척추 후방전위증 (R 그룹), 130 명은 순수 척추 전방 전위증 (A 그룹)을 가지고 있었으며, 33 명 (R + A 그룹)은 모두 가지고 있었다.

결과: 척추체의 후방 미끄러짐은 R 및 R + A 그룹 모두에서 거의 동일 성별 분포 하에 상부 요추(대부분 L2 또는 L3) 에서 발견되었다. R 그룹의

골반 입사각과 천추 경사면 값은 A 및 R + A 그룹(모두 $P < 0.001$) 보다 유의하게 낮았다. R+ A 그룹의 요추 전만도는 R 그룹($p = 0.025$) 및 A 그룹($p = 0.014$)보다 유의하게 높았다. 제 7 경추체 중심에서 내린 수선(C7 plumb line)은 R 그룹의 경우 A 그룹($p = 0.023$) 보다 더 후방에 위치하였지만, R +A 그룹 ($p = 0.422$)과는 유의한 차이가 없었다. C7 의 수직 라인의 위치는 세 그룹 ($P = 0.068$) 사이에 차이가 없었다. R 그룹의 요천추 각도는 A 그룹 ($p < 0.001$) 과 R + A 그룹 ($p < 0.001$)보다 유의하게 더 작았다.

결론 : 본 연구 결과는 퇴행성 후방전위증에는 두 가지 유형이 있다는 것을 의미한다. 하나는 낮은 골반 입사각을 갖는 환자에서 퇴행의 결과로 일차적으로 발생하는 것이고 다른 하나는 척추전방전위증과 높은 골반 입사각을 갖는 환자에서 보상 작용으로 이차적으로 발생한다.

핵심어 : 척추골반 형태, 시상균형, 척추 후방전위증, 척추 전방전위증, 골반 입사각