Characteristic findings on imaging of cervical spondylolisthesis: Analysis of computed tomography and X-ray photography in 101 spondylolisthesis patients

Ryoma Aoyama[1], Tateru Shiraishi[2], Masahiro Kato[3], Junichi Yamane[4],

Ken Ninomiya[1], Kazuya Kitamura[5], Satoshi Nori[1] and Takahito Iga[1]

1) Department of Orthopaedic Surgery, Tokyo Dental College Ichikawa General Hospital, Tokyo, Japan
2) Shiraishi Spine Clinic, Tokyo, Japan
3) Department of Orthopaedic Surgery, Saiseikai Utsunomiya Hospital, Tochigi, Japan
4) Department of Orthopaedic Surgery, Murayama Medical Center, Tokyo, Japan
5) Department of Orthopaedic Surgery, Saiseikai Tobu Yokohama Hospital, Kanagawa, Japan

Abstract:

Introduction: The characteristics of cervical spondylolisthesis are not currently fully understood, because of the shortage of reports covering the large population of patients with cervical spondylolisthesis. The purpose of this study was to elucidate the characteristics of cervical spondylolisthesis by examining a relatively large number of cases.

Methods: We analyzed 101 cases with more than 2 mm of vertebral listhesis as determined from X-ray or computed tomography (CT) images among 731 patients who underwent surgery at a single institute. We considered the C2-7 angle, range of motion, and C2-7 sagittal vertical axis on lateral X-ray images. From sagittal CT images, classifications into five grades based on the slipped disc and adjacent caudal levels were made. We examined the orientation of facet joints at the slipped level using axial CT images.

Results: Spondylolisthesis was recognized in 101 cases at 124 levels. Anterior and posterior spondylolisthesis were detected in 68 and 40 cases, respectively. Anterior spondylolisthesis developed predominantly at C3 or C4, usually at the level adjacent to the narrowed disc, or at C7, adjacent to the stiffened thoracic spine. The disc height was relatively preserved at the anterior slipped level. Posterior spondylolisthesis developed predominantly at the level of the significantly narrowed disc associated with advanced intervertebral osteoarthritis. At the segment with listhesis in the lower cervical spine, the direction of the facet joint in the axial plane tended to be posteromedial.

Conclusions: Cervical degenerative spondylolisthesis was classified into two types. The first and more common listhesis occurred adjacent to stiffened levels, and anterior slippage was common in this type. The second and less common listhesis occurred within progressively degenerated segments, and posterior slippage was prominent. We have uniquely described the morphological changes in orientation of the cervical facet joints at the slipped level in the transverse plane.

Keywords:
cervical facet joint, spondylolisthesis, imaging, CT, X-ray

Introduction

The characteristics of cervical spondylolisthesis are not currently fully understood, because of the shortage of reports covering the large number of patients with cervical spondylolisthesis. Since the first description of cervical spondylolisthesis by Perlman and Hawes in 1951[1], only one study has reported the evaluation of more than 100 cases of cervical spondylolisthesis[2]. In 2003, Tani et al. described the functional importance of degenerative spondylolisthesis in cervical spondylotic myelopathy (CSM) by analyzing 47 spondylolisthesis patients[3]. In 2007, Kawasaki et al. studied 79 patients with cervical spondylolisthesis and reported that degenerative cervical spondylolisthesis of 3.5 mm or more

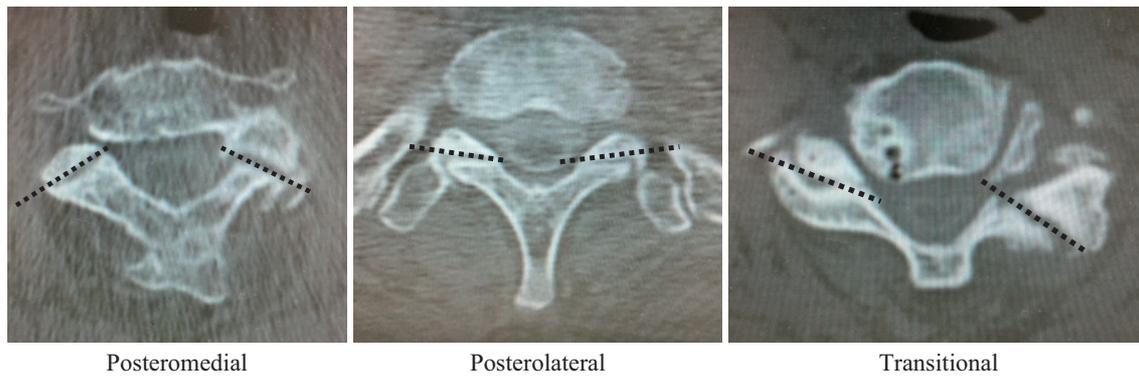| Posteromedial | Posterolateral | Transitional |

Figure 1. Classification of the orientation of facet joints in the axial plane.
We categorized the orientation of the facet joints in relation to the transverse plane into the posteromedial, postero-
lateral, and transitional groups.

occurred in as many as 30% of older CSM patients[4]. In 2009, Dean et al. analyzed 58 degenerative spondylolisthesis patients and identified two types of cervical degenerative anterior spondylolisthesis[5]. In 2013, Park et al. studied the natural history of 27 patients with degenerative cervical spondylolisthesis and reported that they seemed to remain stable from 2 to nearly 8 years of follow-up[6]. Reports concerning cervical spondylolisthesis have increased, but the research is still insufficient to clarify the pathology and proper treatment choice for this disease. The purpose of this study was to determine the characteristics of cervical spondylolisthesis by analyzing 101 patients with cervical spondylolisthesis.

Materials and Methods

Between 2008 and 2013, 731 patients underwent operations for cervical spinal disorders at a single spine center. All patients underwent conventional radiographic examinations of the cervical spine preoperatively, including lateral imaging in flexion and extension. A plain computed tomography (CT) or myelogram-CT image was taken of each patient. We defined cervical spondylolisthesis as anteroposterior vertebral slipping of more than 2 mm, identified on lateral standing X-ray images in a neutral position or on sagittal CT images according to the criteria describes in previous papers[3,6-8]. Motion of 1 mm or greater on flexion-extension views was considered to represent instability, according to a previous paper[5]. The clinical records and radiographs of spondylolisthesis patients were independently reviewed. We recruited a total of 100 asymptomatic volunteers between January 2010 and June 2010 at one radiology clinic (Utsunomiya Central Clinic). There were 20 subjects in each decade of age from the 20s to the 60s. Interestingly, there was no subject who had cervical spondylolisthesis when stood in a neutral position. We selected 20 asymptomatic volunteers in their 60s, who had plain X-ray images and magnetic resonance images of the cervical spine taken, to serve as the control group.

We evaluated intervertebral disc height according to the revised Matsumoto method[9]. We defined disc height grade as the percent of height reduction compared with the most adjacent normal disc on sagittal CT images, graded from 0 to 4: grade 0, no narrowing of the disc space; grade 1, less than 25% loss of height; grade 2, 25%-50% loss of height; grade 3, 50%-75% loss of height; and grade 4, more than 75% loss of height.

We classified the cervical curvature of spondylolisthesis patients and asymptomatic volunteers into five groups according to Takeshima's method[10]: Group A, lordosis; Group B, straight; Group C, kyphosis; Group D, sigmoid with cranial lordosis; and Group E, sigmoid with cranial kyphosis. We evaluated subchondral bone cyst formation in vertebral endplates on the segment of slippage using sagittal CT images.

Sagittal alignment of the cervical spine was measured at C2-7, using the Cobb method, on lateral radiographs of patients stood in a neutral position. Neck range of motion (ROM) was assessed based on the differences in C2-7 angles from flexion to extension. We measured the C2-7 sagittal vertical axis (SVA), which was defined as the deviation of the C2 plumb line (extending from the centroid of the C2 vertebra) from the posterior superior corner of the vertebral body of C7, with positive sagittal alignment defined as an anterior deviation.

The orientation of the superior articular surfaces from C3 (C2/3 zygapophyseal joint) to T1 was analyzed using axial CT slices according to Pal's method[11]. He studied dry macerated bones taken from 30 adult human male vertebral columns. He reported that, at the C2/3 facet joint level, all columns showed posteromedially facing superior articular facets, and, at the C7/T1 facet joint level and below, all columns had posterolaterally facing superior articular facets. The level at which a change in orientation from posteromedially to posterolaterally facing superior articular facets occurred was not constant. In short, he categorized facet joint orientation in relation to the transverse plane into the posteromedial, posterolateral, and transitional groups (Fig. 1).

Table 1. Epidemiology of Listhesis Classified according to Disease Cause.

	A	B	C	D	E	F
Number of cases	17	123	487	64	17	24
Number of cases with listhesis	0	6	89	1	4	1
Ratio of slippage (%)	0	4.9	18.3	1.6	23.5	4.2
Average age (yrs)						
without listhesis	47.9±20.6	61.1±9.9	62.8±12.6	49.0±10.6	60.8±13.0	58.4±19.1
with listhesis	N/A	67.7±8.1	70.5±9.8	64	63.0±6.1	71

A: Tumor of the spinal cord or vertebrae, B: Ossification of the longitudinal ligament, C: Cervical spondylotic amyotrophy or myelopathy, D: Cervical spondylotic radiculopathy or cervical disc herniation, E: Rheumatoid arthritis or destructive spondyloarthropathy, F: Miscellaneous diseases

Table 2. Comparison of Patients with and without Listhesis.

	Total without listhesis	Total with listhesis	Anterior listhesis	Posterior listhesis
Number of cases	630	101	68	40
Average age (yrs)	61.8±13.2	70.0±9.6	71.2±7.9	67.8±8.0
Male: female	464:168	68:33	42:26	30:10
Total levels of listhesis	N/A	124	81	43

Statistical analysis

We used one-way analysis of variance (ANOVA) followed by Bonferroi/Dunn's post hoc test for analyzing statistical differences in the data obtained from the X-ray images. We used the Kruskal-Wallis test followed by Bonferroi/Dunn's post hoc test for analyzing statistical differences in the disc height data. Chi-square tests were used to compare the proportions of diseases and the ratio of bone cyst formation. All statistical analyses were performed with commercially available software programs (R version 3.0.2; The R Foundation for Statistical Computing, Vienna, Austria, and StatView version 5; SAS Institute Inc., Cary, NC, USA).

Results

Epidemiology (Table 1)

We organized 731 patients into six groups according to disease type: group A, tumor of the spinal cord or vertebrae; group B, ossification of the longitudinal ligament; group C, cervical spondylotic amyotrophy or CSM; group D, cervical spondylotic radiculopathy or cervical disc herniation; group E, rheumatoid arthritis or destructive spondyloarthropathy; and group F, miscellaneous diseases.

The prevalence rate of slippage was significantly higher in groups C and F (Chi-square test, $p < 0.0001$). The average age of patients with spondylolisthesis was higher than that of those without spondylolisthesis in all groups.

Anterior and posterior spondylolisthesis (Table 2)

The average age of patients with spondylolisthesis was significantly higher than that of those without spondylolis-

thesis. Instability was identified in 48 levels out of a total of 81 levels for anterior spondylolisthesis, whereas it was identified in 21 levels out of a total of 43 levels for posterior spondylolisthesis. The rate of instability was statistically the same for anterior and posterior spondylolisthesis. The numbers of cases with each slippage level are shown in Fig. 2. The numbers of duplications of listhesis are presented in Table 3. The male to female ratio is shown in Fig. 3. There was a higher female to male ratio of patients with anterior spondylolisthesis between C2 and C4 than at the other levels.

Disc height grade at a segment with slippage and at the adjacent caudal segment (Fig. 4)

In patients with anterior listhesis, the disc height at a segment with slippage was significantly higher than that at an adjacent caudal segment. Also, the disc height at an adjacent caudal segment was significantly lower than the corresponding disc height of the 20 asymptomatic subjects. This meant that anterior listhesis happened adjacent to a narrowed disc and the disc height remained higher at the segment with slippage. In patients with posterior listhesis, the disc height at a segment with slippage was significantly lower than that at an adjacent caudal segment. The disc heights at an adjacent caudal segment were not significantly different between the patients with anterior listhesis and those with posterior listhesis. This meant that disc height at a segment with posterior listhesis was significantly narrowed. Interestingly, there were no segments with slippage in the asymptomatic subjects (Fig. 4). The disc heights of patients with slippage were significantly lower than those of asymptomatic subjects (Kruskal-Wallis test, $p < 0.0001$).
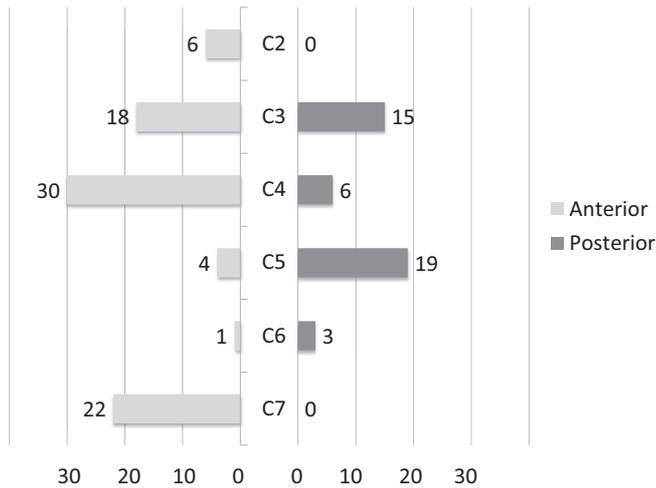
Figure 2. Numbers of patients with anterior and posterior listhesis classified by the level of slippage.

Figure 3. Male to female ratio in anterior and posterior listhesis classified by the level of slippage.

Table 3. Numbers of Duplications of Listhesis.

Duplication of listhesis	Number of cases
1 level	78 cases
2 levels	18 cases
3 levels	5 cases
Anterior+posterior	7 cases

Cervical alignment (Fig. 5)

The ratio of subjects with malalignment, such as kyphosis and sigmoid curvature, was significantly higher among patients with anterior or posterior spondylolisthesis. Cervical malalignment significantly occurred in patients with anterior or posterior spondylolisthesis compared with asymptomatic subjects.

Subchondral bone cyst formation of vertebral endplates at a segment of slippage (Table 4)

Subchondral bone cyst formation of vertebral endplates was identified more frequently on segments with posterior slippage (Chi-square test, $p < 0.0001$).

C2-7 angle and C2-7 SVA (Table 4)

There was no statistically significant difference in the C2-7 angle among the three groups (ANOVA, $p = 0.127$). The C2-7 SVA in patients with anterior listhesis was significantly higher than that of both asymptomatic volunteers and patients with posterior listhesis (ANOVA, $p = 0.003$).

Neck ROM and C2-7 angle in flexion and extension (Table 4)

The ROM was significantly lower in a group of patients where each patient exhibits anterior listhesis or posterior listhesis (ANOVA, $p < 0.0001$). The C2-7 angle in flexion was higher in patients with posterior listhesis, without a statistical difference (ANOVA, $p = 0.26$), while the C2-C7 angle in
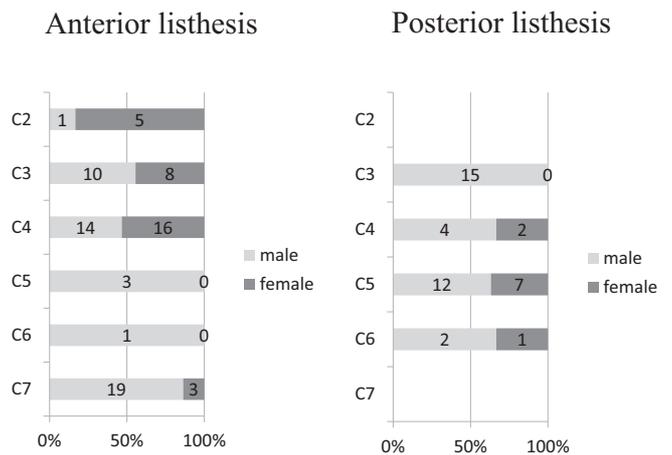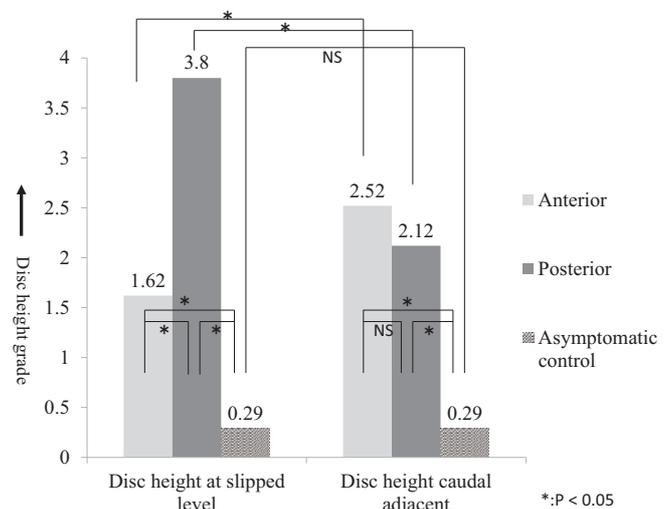

Figure 4. Average disc height grade in the three groups.

extension was significantly lower in patients with anterior listhesis (ANOVA, $p = 0.007$). This shows that neck flexion was limited in patients with posterior slippage and neck extension was limited in patients with anterior slippage.

Direction of facet joints in the transverse plane (Fig. 6)

We referred to Pal's results as control data for the direction of the facet joints.

Below C6, the ratio of subjects with posteromedially facing facets was significantly higher for both anterior and posterior listhesis than that in Pal's report. At the segment with anterior or posterior listhesis in the lower cervical spine, the direction of the facet joint in the axial plane tended to be posteromedial.

Discussion

Spondylolisthesis was well recognized in old patients (mean age 70) in our study, regardless of the type of underlying disease. An earlier report stated that spondylolisthesis
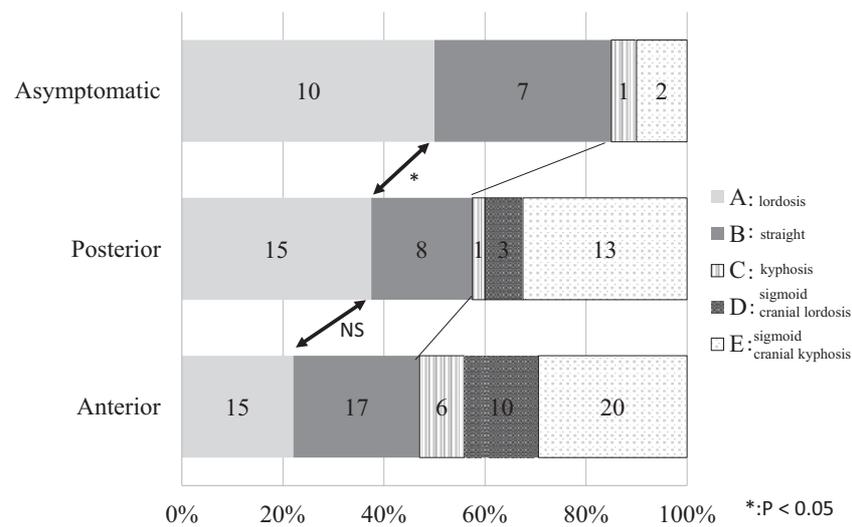
Figure 5. Types of alignment and the numbers of cases of each alignment in the three groups.

A: lordosis, B: straight, C: kyphosis, D: sigmoid with cranial lordosis, E: sigmoid with cranial kyphosis.

The ratio of subjects with malalignment, such as kyphosis and sigmoid curvature, was significantly higher among patients with anterior or posterior spondylolisthesis.

Table 4. Radiographic Findings for Anterior Listhesis Patients, Posterior Listhesis Patients, and Asymptomatic Volunteers.

	Anterior listhesis	Posterior listhesis	Asymptomatic volunteer
C2-7 angle (°)	6.2±14.7	11.9±15.2	6.9±15.9
C2-7 SVA (mm)	30.4±16.2	22±15.9	20.1±10.5
C2-7 angle in flexion (°)	-13.0±13.4	-10.4±16.2	-16.8±9.9
C2-7 angle in extension (°)	20.7±12.6	24.7±15.6	31.7±11.5
ROM (°)	34.0±11.8	34.6±11.8	48.6±12.6
Bone cyst formation	29.6%	86.0%	N/A

SVA: sagittal vertical axis, ROM: range of motion

occurred in as many as 30% of elderly CSM patients[4]. The findings in this study and our study suppose that spondylolisthesis was mainly induced by the degenerative cascade. Kirkaldy-Willis described the phases of lumbar spine degeneration, such as dysfunction, instability, and stabilization, which he called the degenerative cascade[12]. He described how the progressive degeneration of discs and facet joints leads to stretching of the adjacent capsules and ligaments; uni- or multisegmental instability then produces rotational and translational subluxation, and this finally results in degenerative spondylolisthesis or scoliosis. The mechanism of the formation of cervical spondylolisthesis may be similar to that of the lumbar form.

We clarified that anterior spondylolisthesis at C7 is a relatively common lesion. In previous papers, the most common level for cervical listhesis was reported to be C3/4 or C4/5. Spondylolisthesis below C5/6 was reportedly rare[3-5,13]. In our study, we demonstrated that anterior spondylolisthesis at C7/T1 and posterior spondylolisthesis at C5/6 were relatively common. Our usage of CT images might have allowed us to detect spondylolisthesis at C7/T1 in a way that was not pos-

sible for studies reported in previous papers. There was only one study which used magnetic resonance imaging (MRI) for detecting the slippage, and the researchers stated that anterior spondylolisthesis at C7 was a relatively common lesion[14]. CT imaging or MRI is considered to be necessary to detect the slippage at C7/T1 in many cases. The cervicothoracic junction is structurally unstable, because the mobile cervical spine connects with the relatively immobile thoracic spine[15]. This precariousness might accelerate degenerative changes in the disc and then induce slippage. Similar to other studies[3,4], C3/4 was the most common segment for listhesis identified in our study. The pseudosubluxation in the midcervical spine reported by Penning might promote spondylolisthesis at C3/4[16].

Considering the results of disc height at the slipped level, we can say that anterior spondylolisthesis generally occurs at the level adjacent to the stabilized level where the disc space is narrowed, and the disc height of the slipped level is usually preserved, which allows the vertebra to slip down in flexion.

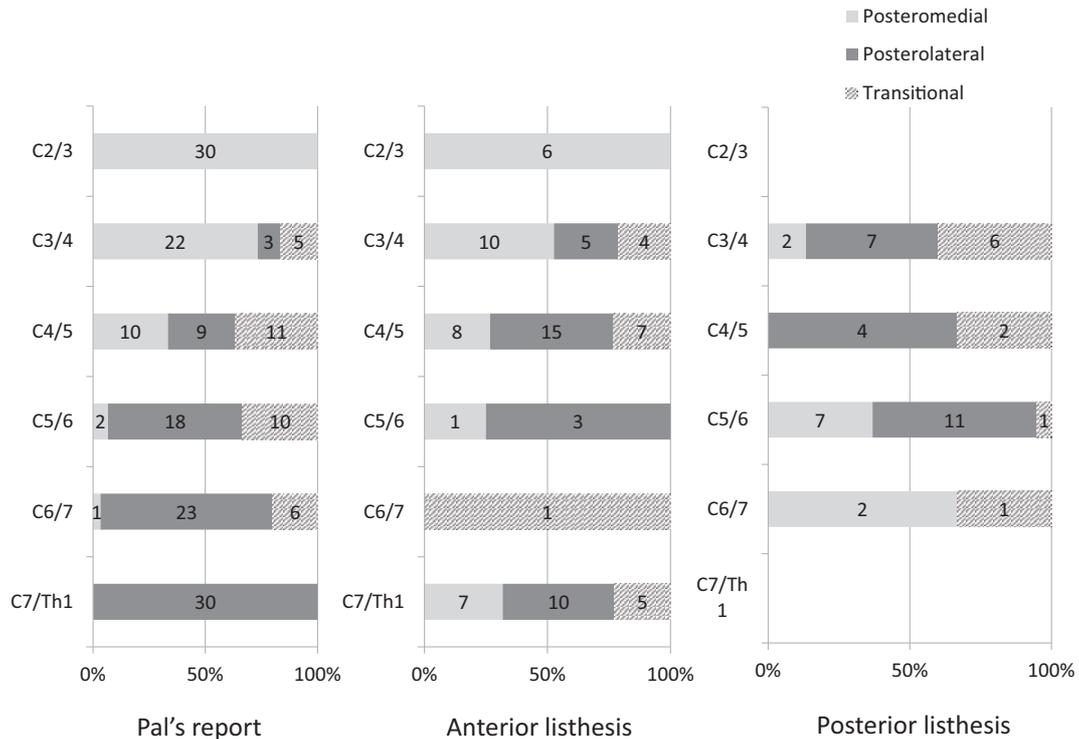Some reports described that anterior spondylolisthesis oc-

- Posteromedial
- Posterolateral
- Transitional

Pal's report | **Anterior listhesis** | **Posterior listhesis**

Figure 6. Direction of the facet joints at the slipped level in the transverse plane classified by the level and direction of listhesis compared with the distribution in Pal's report.

curred adjacent to stiff levels, because of compensatory abnormal subluxation above stiff levels[5,17,18]. In contrast to anterior spondylolisthesis, posterior spondylolisthesis occurred predominantly at the level where the disc height significantly narrowed and bone cyst formation was well recognized. This implies that posterior spondylolisthesis is a result of advanced disc degeneration. An earlier report described the typical radiological appearance of degenerative retrolisthesis, including the narrowing of an intervertebral disc, which is occasionally associated with degenerative changes of the involved facets[7].

We can say that cervical degenerative spondylolisthesis could be classified into two types. The first and more common listhesis occurred adjacent to stiffened levels, and anterior slippage was common in this type. The second and less common listhesis occurred within progressively degenerated segments, and posterior slippage was prominent. There is so far only one previous report which has mentioned two types of anterior cervical spondylolisthesis[5].

We have uniquely described the morphological changes in the orientation of cervical facet joints at the slipped level in the transverse plane for cervical spondylolisthesis. In contrast to papers concerning the cervical spine, there are many papers which have described predisposing factors for degenerative lumbar spondylolisthesis, such as the sagittal orientation of lumbar facet joints, hormonal factors, ligament hyperlaxity, and iliolumbar morphology[19]. When there is a morphological difference between the cervical facet joints at each level, the motion pattern of each level differs according to the facet joint shape[11]. The unusual shape of the facet

joints inhibits natural movement or causes abnormal movement, which finally may induce spondylolisthesis. However, the observed morphological differences in the cervical facet joints were possibly only the consequence of deformities induced by slippage. To discover whether the morphological differences in the facet joints are the cause or the outcome, a longitudinal study is necessary.

Limitations

As with any study, this investigation has several limitations. First, it is a retrospective study including a small number of patients and asymptomatic volunteers. Our research would be improved by performing a prospective study that utilizes a large number of subjects. Second, we did not describe in detail the clinical presentation and treatment options. To understand the precise pathology of spondylolisthesis, we have to clarify information such as what symptoms patients presented with and what types of surgery are effective for treating spondylolisthesis. We will elucidate the importance of cervical listhesis on surgical outcomes in the future. Third, the diversity of diseases included in this study might have influenced the outcome of our study. Fourth, we selected patients who underwent surgery only. To elucidate the overall characteristics of spondylolisthesis, we should include some of the many cases of mild spondylosis or even asymptomatic subjects. Fifth, our study insufficiently considered dynamic factors. Dynamic translation of the spine is indispensable in understanding the pathology of cervical spine diseases. Nevertheless, we defined spondylolisthesis by using neutral lateral X-ray images, because it

was an adequate way to identify symptomatic spondylolisthesis. Of the 100 asymptomatic volunteers, no one had cervical spondylolisthesis while standing in a neutral position; therefore, we reasoned that examining spondylolisthesis with patients stood in a neutral position was appropriate for our investigation. The cervical spine is an inherently mobile organ[16]; therefore, the determination of cervical instability is a difficult problem. Cervical spondylolisthesis in a flexed or extended neck position possibly suggests inherent instability of the cervical spine. In order to elucidate the importance of dynamic listhesis, we need to conduct further study, utilizing a large number of subjects. Addressing these aspects would improve our research.

Conclusion

Anterior spondylolisthesis tended to occur at the level adjacent to the stabilized level, where the disc space was narrowed due to degeneration, or at the cervicothoracic junction, where the thoracic spine is naturally stiffened. The disc height of the slipped level was usually preserved, thus presenting an opportunity for the vertebra to slip down in flexion. Posterior spondylolisthesis tended to occur at the level where the disc space was significantly narrowed and cyst formation was often detected. This suggests that posterior spondylolisthesis is related to intervertebral disc degeneration. Furthermore, the direction or orientation of the facet joints may influence spondylolisthesis.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

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