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Facet orientation in patients with lumbar degenerative spondylolisthesis

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Abstract

Background Several studies have indicated a correlation between lumbar degenerative spondylolisthesis (DS) and increased sagittal orientation of the facet joints. Although the sagittalization of the lumbar facet joints is a major cause of DS, a majority of the studies of lumbar facets were performed in the axial plane. We tried to explore the spinal morphological characteristics by examining the axial, oblique and sagittal views in DS patients and compared these parameters to those of patients with lumbar spinal canal stenosis (LCS) and low back pain (LBP).

Methods We analyzed 119 patients with various spinal dysfunctions. We divided them into 3 groups based on the clinical and imaging findings. There were 42 patients with DS, 39 with LCS, and 38 with LBP. The following parameters were measured from the L2 to S1 levels: axial facet angle (AFA) in an axial orientation, oblique facet angle (OFA) and lamina angle (LA) in sagittal orientations.

Results The AFA of the DS group was significantly smaller than that of the LCS and LBP groups at the slippage level, but there were no significant differences between DS and LCS at other non-slippage levels. In the oblique plane, the DS and LCS groups had a more horizontal facet angles than those of the LBP group. However, LA of the DS group revealed no significant difference compared with LCS group at all levels. In the DS group, there was little correlation among the axial, oblique, and lateral planes ($r = -0.14$-0.11).

Discussion and Conclusion In the axial plane, patients with DS had more sagittally oriented facets than patients in the other 2 groups at the slippage level. These results correspond with previous studies. The AFA orientations of the DS group were not sagittalized compared with those of the LCS group at the other 3 levels. The facet angles of the DS and LCS groups were not significantly different in the sagittal plane. These results showed that the sagittal orientation of the facet joints is more likely due to a secondary remodeling of the joint orientation rather than a pre-existing morphologic feature. Comparing the morphology of the facet joints among DS, LCS and LBP by measuring three different parameters, the facet sagittalization was the only characteristic parameter related to DS in axial plane, whereas the changes in other planes (OFA and LA) may be due to aging.

Introduction

The degenerative process in facet joints is known to be affected by the stability of the lumbar motion segment. While facet joint orientation, facet joint osteoarthritis, synovial cyst and facet joint effusion have been considered to be associated with degenerative spondylolisthesis (DS), the precise etiology of DS is uncertain[1)2)]. In particular, the outcomes of lumbar decompression surgery with or without instrumented fusion for grade I DS are controversial[3)4)]. Previous studies have stated that the sagittal orientation of facet joints is one of the risk factors for DS in the axial plane[5-9)]. However, the slippage stress could affect both the axial and sagittal

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planes[5)6)]. Since the facet joint surface is 3-dimensional and its orientation changes from cephalad to caudad, we measured the facet orientation of the axial, lateral and oblique views, and compared these angles within the groups of patients with DS, lumbar spinal canal stenosis (LCS), and young adult low back pain (LBP).

Materials and methods

In this study, we performed a retrospective analysis of the lumbar facet angles in a sample of 119 patients with LCS or LBP. The patients were divided into the following 3 groups based on the clinical and imaging findings : DS group, 42 patients (15 men, 27 women, mean age±SD : 62.2±8.8 years) ; LCS (without slippage) group, 39 patients (28 men, 11 women, mean age±SD : 66.6±10.1 years) ; and the LBP (without slippage or neurological symptoms) group, 38 patients (24 men, 14 women, mean age±SD : 35.5±10.3 years) (Table 1). All patients in the DS and LCS groups underwent surgery at our department. The facet angles were measured in 336 joints of the 42 patients with DS, in 312 joints of the 39 patients with LCS, and in 304 joints of the 38 patients with LBP from L2-L3 to L5-S1 levels.

The DS was classified as a Grade I DS at the single L4 level, and the patients had symptomatic LCS. Patients with trauma, inflammatory disorders, scoliosis of more than 10°, facet tropism of more than 10°, lumbar kyphosis or multiple operated back were excluded.

The orientation of the axial facet joints (AFA) was measured on axial CT scans using the method described by Noren et al[10)], whereby a facet line is drawn between the anteromedial and posterolateral points of each facet. A midsagittal line through the disc was considered the sagittal line. The angle formed by the left (or right) facet line and the sagittal line was measured and recorded in degrees (Fig. 1a). The 2 angles were averaged to obtain the orientation of the facet joints. Simultaneously, the oblique facet angle (OFA)[11)] was measured ; this was defined as the angle between a straight line connecting the midpoints of the anterior and posterior vertebral cortices and a straight line positioned parallel to the facet joint on an oblique plane X-ray (Fig. 1b). The lamina angle (LA) was defined as the angle between a line connecting the tip of the superior facet with the base of the inferior facet and a line connecting the midpoints of the anterior and posterior vertebral cortices on a lateral plane X-ray[11)] (Fig. 1c). The images were taken using CT scan (Light speed VCT, GE Healthcare) and radiography system (Toshiba, Japan). All the parameters have been measured once by first author (W.A.).

This study was approved by the International Review Board of our institution. Statistical analyses were performed using the Dr. SPSS II for Windows (standard version). One-way ANOVA was used to analyze the differences in the spinal parameters ; Correlations were analyzed by Pearson's correlation coefficient. P-values less than 0.05 were considered to indicate a statistically significant difference. Values were expressed as mean±standard deviation (SD). The study was approved by the Ethics Review Committee of Tokyo Medical University (IRB No.1310).

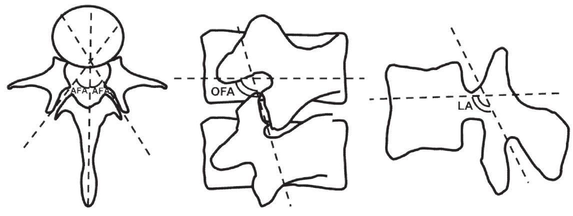

Fig. 1 (a) Axial facet angle (AFA) : A facet line was drawn between the anteromedial and posterolateral points of each facet. A midsagittal line through the disc was considered as the sagittal line. The angle formed by the left (or right) facet line and the sagittal line was measured and recorded in degrees.
(b) Oblique facet angle (OFA) : An angle between a straight line connecting the midpoints of the anterior and posterior vertebral cortices and a straight line positioned parallel to the facet joint on an oblique plane X-ray.
(c) Lamina angle (LA) : An angle between a line connecting the tip of the superior facet with the base of the inferior facet and a line connecting the midpoints of the anterior and posterior vertebral cortices on a lateral plane X-ray.

Results

The mean age of DS and LCS had significant differences compared with LBP, respectively (P<0.01) (Table 1)

1) AFA

The AFAs at the L4-L5 level were 29.0±8.4°, 36.5±11.5°, and 44.5±10.5° in patients with DS, LCS, and LBP, respectively (P<0.01). The AFA of the DS group was significantly smaller than that of the LCS and LBP groups at the slippage level. Regarding the L2-L3 and L3-L4 levels, the AFAs of the DS and LCS groups were significantly smaller than that of the LBP group. At the L5-S1 levels, the AFA was the same in all the groups (Table 2).

2) OFA

The OFA of the DS and LCS groups had no significant differences at any of the levels. However, regarding the L3-L4 and L4-L5 levels, the OFA of the DS and LCS groups were significantly larger than that of the LBP group. At the L5-S1 level, the OFA was similar among all groups (Table 3).

Table 1 Patient characteris

	DS	LCS	LBP
N	42	39	38
Gender (male/female)	15/27	28/11	24/14
Age (years)	62.2±8.8	66.6±10.1	35.5±10.3

*P < 0.01

Table 2 Facet angle on axial plane (AFA)

	DS	LCS	LBP
L2-L3	24.1±6.5°	26.4±7.3°	30.6±8.0°
L3-L4	28.3±7.3°	31.1±10.0°	39.4±8.4°
L4-L5	29.0±8.4°	36.5±11.5°	44.5±10.5°
L5-S1	40.7±12.0°	46.1±9.4°	51.8±11.0°

*P < 0.01, †P < 0.05

Table 3 Facet angle on oblique plane (OFA)

	DS	LCS	LBP
L2-L3	97.6±3.5°	97.1±4.9°	95.2±2.2°
L3-L4	99.5±3.9°	99.5±5.5°	96.0±2.3°
L4-L5	103.2±5.9°	101.2±5.1°	98.1±3.0°
L5-S1	103.0±6.9°	101.4±5.7°	102.6±6.7°

*P < 0.01, †P < 0.05

Table 4 Lamina angle on lateral plane (LA)

	DS	LCS	LBP
L2	121.0±7.3°	121.7±5.9°	116.9±4.5°
L3	121.2±8.3°	123.2±9.4°	117.3±4.2°
L4	120.1±6.2°	120.0±7.4°	117.5±6.3°
L5	119.2±7.7°	120.7±7.5°	120.6±4.1°

*P < 0.01

3) LA

From the L2 to L4 levels, the LA of the DS and LCS groups had a tendency to be larger than that of the LBP group, but we did not find any significant differences. At the L5 level, the LA was similar among all groups (Table 4).

4) Correlations among AFA, OFA and LA

There were no correlations among the axial plane, oblique plane and lateral plane in DS group (r = − 0.14-0.11) (Fig. 2).

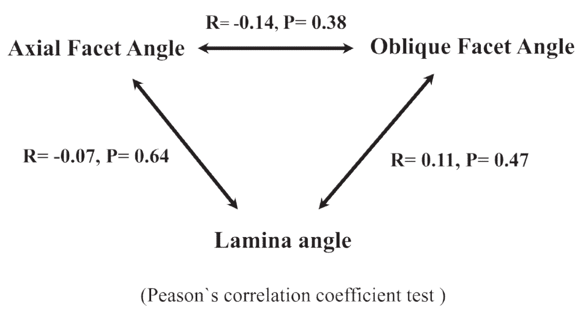

Fig. 2 Correlations in the degenerative spondylolisthesis (DS) group (Pearson's correlation coefficient test)

Discussion

Facet joints play an important role in stabilizing the segmental spine unit. With the onset of degeneration in the lumbar spine, increased stress is experienced posteriorly resulting in alterations in the mechanical properties of the facet joints[12-14]. Many studies have shown that the progression of DS slippage was affected by the facet morphology[5)8)15-18]. In order to determine the prognosis of DS or predict the outcome of non-fused decompression surgery, the facet orientation should be analyzed in detail. Previous studies focused on the facet shape only in the axial plane on CT or MRI. However, from the mechanical point of view, the information obtained from oblique and sagittal examination should also be considered.

According to previous studies, the predisposing factors of DS were identified as having sagittal-shaped facet joints, age, gender, lamina and oblique facet orientation[2)5)8)15-19]. In the DS group, the articular facet joints of the lower lumbar vertebrae were more sagittally oriented than in the normal condition, thus facilitating their forward slippage, particularly at the L4 level[5)8)15-18]. This study focused on the lumbar facet morphology by measuring axial, oblique and sagittal planes.

Patients with DS had more sagittally oriented facet joints in the axial plane than patients in the other 2 groups at L4/5 (slippage) level, but at the other L2/3, L3/4 (non-slippage) levels we didn't find significant differences between DS and LCS group (Table 2). These results correspond with those of previous studies[5)8)15-18)]. Additionally, we found that AFA at L4/5 of DS was about 1.7 times smaller than 48° which had been defined as sagittal shaped AFA in a former study by White et al[19)]. The facet angles (AFA) in the DS and LCS groups were smaller than those in the LBP group at all levels (Table 2). These data support the concept that facet sagittalization is also affected by aging[20)].

At the L3-L4 and L4-L5 levels, the facet joint angles in the DS and LCS groups were significantly larger than those in the LBP group in an oblique plane (P<0.01 or P<0.05) (Table 3). These findings do not support the suggestion that the existence of a horizontal lamina and oblique facet lend a developmental predisposition to the occurrence of DS[18)]. In this study, the oblique facet orientation revealed horizontalization in the DS and LCS groups, thus the horizontalization of OFA may be associated with changes in an aging spine.

The LA has also been reported as an important factor in cases of DS[18)], but there were no significant differences between DS and LCS at any level measured in this study, suggesting that horizontalization of LA may not be a representative morphologic feature of DS (Table 4).

The mechanism of morphological changes in facet orientation remains controversial[7)20)21)]. According to Toyone et al[21)] such spatial differences in the facet joints were part of the pre-existing morphology and not an independent secondary result of spondylolisthesis. On the other hand, Berlemann et al[7)] did not identify sagittally oriented facet joints in 31 patients under age 35 and concluded that the sagittal orientation of facet joints was more likely due to a secondary remodeling of the joint orientation rather than a pre-existing morphologic feature. In the present study, sagittal facets were not observed at any level in the subjects of LBP group (Table 2). Although sagittalization was generally seen in aged group (both DS and LCS), significant difference in AFA was only observed at slippage level in DS, suggesting that changes in AFA are related to DS. Since this was not a longitudinal study, it was impossible to conclude if this change in AFA is a result or a cause of the DS.

Our results demonstrated that both the facet sagittalization in the axial plane and the horizontalization in the oblique plane were affected by the aging process, including osteoarthritis which is one of the major spine conditions in elderly people. The patients with DS and LCS were older than those with LBP (Table 1).

Our results revealed that the 3 different planes were independent (Fig. 2), and that the AFA was most pronounced in the presence of DS. It was reported that the sagittally oriented lumbar facets facilitate the anteroposterior movement (flexion and extension of the spine) while limiting axial rotation[21)]. Considering this report and our results, sagittalization of AFA is associated with and characteristic feature of DS. It would be important to take the AFA into account when non-fused lumbar operations are performed to avoid the risk of slippage in future.

This study has some limitations. The number of subjects was relatively small, the study was not longitudinal, and the patients with degenerative scoliosis or facet tropism were excluded. We had no access to the initial imaging data of patients with DS, as most of the patients took the radiographs on hospital visits, after the spinal vertebra slippage occurred. Moreover, to minimize radiation exposure we used images which had been taken at former clinical examination. This led to compare CT images with X-ray in the current study. Despite these limitations, we believe that the current results could contribute to understand the morphological characteristics of DS at different planes. In future studies, the outcomes of non-fused surgical decompression surgery for DS should be evaluated.

Conclusion

Comparing the morphology of the facet joints among DS, LCS and LBP by measuring three different parameters, the facet sagittalization was the only characteristic parameter related to DS in axial plane, whereas the changes in other planes (OFA and LA) may be due to aging.

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腰椎変性すべり症における椎間関節の形態学的研究

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背景と目的 : 腰椎変性すべり症（DS）は、すべり椎間の椎間関節が横断面で矢状化していることがすべり発症に関与していることが知られているが、立体的な影響について不明である。今回、我々は DS 患者の椎間関節の形態的特徴を X 線斜位像と側面像にて研究を行った。

対象と方法 : 対象は L4/5 椎間の DS 群 42 例（平均年齢 : 62.2± 8.8 歳）、腰部脊柱管狭窄症群（LCS）39 例（平均年齢 : 66.6± 10.1 歳）、腰痛群（LBP）38 例（平均年齢 : 35.5± 10.3 歳）で、L2 から S1 レベルまで測定した。椎間関節形態は、腰椎 CT 横断面において axial facet angle（AFA）、腰椎 X 線斜面像において oblique facet angle（OFA）; 側面像にて lamina angle（LA）を計測した。

結果 : DS 群で L4/5 AFA は、LCS 群 LBP 群より有意に小さかった、他椎間レベルで LCS と有意差を認めなかった。DS 群と LCS 群の OFA は LBP 群より大きく、水平化していた。また、DS 群の LA は LCS、LBP と有意差を認めなかった。DS 群で AFA、OFA、LA は、それぞれの間で相関関係を認めず、椎間関節の横断面での矢状化形状は、斜位像、側面像での形状と無関係であった。

考察 : 今回の検討において先行研究と同様に横断面で DS 群の椎間関節は L4/5 レベルで他の 2 群より矢状化していた。しかし、他椎間において DS と LCS 群の椎間関節角度は有意差を認めなかった。以上より横断面での椎間関節矢状化は、加齢とメカニカルストレスによる椎間関節の退行性変化の影響を強く受けている可能性が高いことが示された。

結論 : DS, LCS, LBP 患者の椎間関節の形態学的特徴を 3 種類のパラメーターで比較検討を行った結果、横断面における椎間関節の矢状化が、変性すべり症と関連した唯一のパラメーターであり、斜位像、側面像の変化はむしろ加齢によるものと推察された。

〈キーワード〉　変性脊椎すべり症、椎間関節、腰部脊柱管狭窄症、腰痛