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Lumbar Facet Joint Motion in Patients with Degenerative Spondylolisthesis

Qi Yao, MD[*,†], **Shaobai Wang, PhD**[*], **Jae-Hyuk Shin, MD**[*], **Guoan Li, PhD**[*], and **Kirkham B. Wood, MD**[*]

[*]Bioengineering Laboratory, Department of Orthopaedic Surgery, Massachusetts General Hospital and Harvard Medical School, Boston, MA

[†]Department of Orthopaedic Surgery, Beijing Shijitan Hospital, Capital Medical University, Beijing, China

Abstract

Study Design—Controlled laboratory study.

Objective—To investigate the in vivo biomechanical effect of degenerative lumbar spondylolisthesis (DLS) on the motion of the facet joint during various functional weight-bearing activities.

Summary of Background Data—Although the morphological changes of the facet joints in patients with DLS have been reported in a few studies, no data has been reported on the kinematics of these facet joints.

Methods—Ten patients with DLS at L4–L5 were studied. Each patient underwent a magnetic resonance imaging (MRI) scan to obtain three-dimensional (3D) models of the lumbar vertebrae from L2–L5 as well as a dual fluoroscopic imaging scan in different postures: flexion-extension, left-right bending and left-right torsion. The positions of the vertebrae were reproduced by matching the MRI-based vertebral models to the fluoroscopic images. The kinematics of the facet joint and the ranges of motion (ROMs) were compared with those of healthy subjects and those of patients with degenerative disc diseases (DDD) previously published.

Results—In DLS patients, the range of rotation of the facet joints was significantly less at the DLS level (L4–L5) than that at the adjacent levels (L2–L3 and L3–L4), while the range of translation was similar at all levels. The range of rotation at the facet joints of the DLS level decreased compared to those of both the DDD patients and healthy subjects at the corresponding vertebral level (L4–L5), while no significant difference was found in the range of translation. The ROM of facet joints in DLS and in DDD patients was similar at the adjacent levels (L2–L3 and L3–L4).

Conclusion—The range of rotation decreased at the facet joints at the DLS level (L4–L5) in patients compared to those in healthy subjects and DDD patients. This decrease in range of rotation implies that the DLS disease may cause restabilization of the joint. *The data may help the selection of conservative treatment or different surgical techniques for the DLS patients.*

Correspondence to: Guoan Li, Ph.D., Bioengineering Laboratory, Massachusetts General Hospital/Harvard Medical School, 55 Fruit Street - GRJ 1215, Boston, MA 02114, (gli1@partners.org), Tel: (617) 726-6472, Fax: (617) 724-4392.
Qi Yao and Shaobai Wang contributed equally to this paper.

Approval of the study by our institutional review board was obtained prior to the initiation of this study. Informed consent was obtained from each patient before any testing was performed.

The authors declare no conflict of interest.

Keywords

Degenerative lumbar spondylolisthesis; facet joint kinematics; facet orientation; facet joint osteoarthritis; disc degeneration

INTRODUCTION

Degenerative lumbar spondylolisthesis (DLS) is characterized as the slipping forward of one lumbar vertebra on another with an intact neutral arch. DLS is most commonly seen at the L4–L5 level and affects women more frequently than men [1, 2]. Patients with DLS may suffer from low back pain and other related disabilities [3]. Numerous surgical techniques have been used to treat DLS patients, including decompression, decompression and fusion (with or without an interbody device)[4], and most recently, interspinous spacer devices[5]. Lumbar facet joints play an important role in stabilizing the segmental spine unit [6]. Slippage of the vertebrae occurs when the locking mechanism of the facet joint fails[7]. Therefore, an objective evaluation of the biomechanical functions of the facet joints in DLS patients is critical for improvement of the surgical treatment techniques.

Both kinematics and morphological changes in the facet joints have been related to DLS[8–14]. Several radiographic studies have indicated a correlation between DLS and an increased sagittal orientation of the facet joints at L4–L5 segment[8, 9]. These studies have demonstrated that the pedicle-facet angle, W-shaped facet joint[10], facet joint osteoarthritis[11], the presence of synovial cysts[12], increased fluid signal of the facet joint [13] and facet joint fusion [14] are all linked to DLS. Few studies have used cadaveric specimens or animal models to examine the motion characteristics of normal facet joints[15, 16]. The kinematics of the facet joints were also measured using computed tomography (CT) [17] and kinematic magnetic resonance imaging (MRI) [18] in living human subjects. However, little is known about the kinematics response of the facet joint in pathological spine[19]. There is no study reporting on the motion of facet joints in patients with DLS.

Recently, we validated a combined dual fluoroscopic imaging system (DFIS) to investigate in vivo motion of the lumbar spine, including the facet joints of healthy participants[20] and DDD patients[21]. The system was shown to be robust for investigation of spine kinematics motion during weight-bearing, functional activities. The purpose of this study was to use the DFIS to investigate the 6 degree-of –freedom (DOF) motion of the lumbar facet joint of DLS patients. We hypothesized that the facet joints at the DLS level would demonstrate distinct alterations in motion characteristics during in vivo activities in comparison to those of the healthy participants and DDD patients.

MATERIALS AND METHODS

Patient Characteristics

Ten patients diagnosed with L4–L5 DLS (3 men and 7 women; mean age = 72.6 years; mean height = 162.2 cm; mean weight = 65.2 kg) were recruited from a single academic center. Based on the clinical and radiographic assessments, we graded the vertebral slippage of all patients as I using the Meyerding classification method[22]. Degeneration of the disc was graded using Pfirrmann classification[23] and facet joints was graded using Weishaupt scale[24](Table 1).

Ten DDD patients (7 men and 3 women; mean age = 51.8 years; mean height= 169 cm, mean weight= 65.7kg) and eight healthy participants (3 male and 5 female participant; mean age=54.4years; mean height= 163.5cm; mean weight =63.5kg) tested in our previous studies

were used as comparison controls. We also graded the lumbar discs and the facet joints of the healthy participants and DDD patients using the Pfirmann classification and Weishaupt scales. (Table 1)

Approval by our institutional review board for this study was obtained prior to the initiation of this study. We obtained informed consent from each patient before any testing was performed.

Imaging technique

Each patient was scanned using a 3-T MRI scanner (Siemens Medical Solutions MAGNETOM Trio) with a spine surface coil and a T2-weighted fat-suppressed 3-D spoiled gradient recalled sequence. The MR images of the spinal segments were then imported into a solid modeling software (Rhinoceros® Robert McNeel & Associates, Seattle, Washington) to construct 3-D anatomical vertebral models of L2-L5 using a protocol established in our laboratory[19, 25](Figure 1A). Mesh models of the vertebrae were created from bony contours (Figure 1B).

The lumbar spine of each patient was imaged with different poses of the body using a dual fluoroscopic imaging system (DFIS) (Figure 2A, B). The subject was asked to stand to position the lumbar spine within the views of the two fluoroscopes, and to actively move into different poses: standing position, maximum trunk flexion-extension, maximum left-right bending, and maximum left-right torsion. The subject was asked to hold each pose for about 1 second while the two fluoroscopes took simultaneous images from two orthogonal directions. The poses were monitored by an orthopedic surgeon to reduce variation. Every subject was asked to minimize his/her hip motions to maximize lumbar spine motion.

Lumbar facet joint motion

The in vivo positions of the vertebrae at various weight-bearing body positions were reproduced in the Rhinoceros modeling software using the MRI-based 3D models and the previously captured pair of orthogonal fluoroscopic images of the vertebrae. The 3D vertebral models were introduced into the virtual fluoroscopic system and viewed from the perspectives of the 2 virtual fluoroscopes. A model of the vertebrae can be independently translated and rotated in 6DOF until its outline matches the osseous outlines captured on the fluoroscopic images[19, 25]. Using this technique, we reproduced the vertebral positions during in vivo weight-bearing activities at each selected pose. The accuracy of the technique has been validated to be 0.3 mm and 0.7° in determination of in-vivo spinal translation and rotation[25].

Right-hand Cartesian coordinate systems were created to quantify the 6DOF motions of the facet joints. The origin of the coordinate system was designated at the volumetric center of the facet joint (Figure 3). The x-axis, set perpendicular to the joint surface, represented the mediolateral direction. The z-axis, set in the plane parallel to the facet sliding surface and along the long axis of the facet joint, represented the craniocaudal direction. The y-axis, set in the sagittal plane perpendicular to the z-x plane, represented the anterior-posterior direction. The same coordinate systems were adopted for both the inferior facet of cranial vertebra and the superior facet of the caudal vertebra at the standing position such that the standing position was used as a reference position. After reproducing the in vivo vertebral positions using the 3D anatomic vertebral models, the kinematics of the facet joints at different body positions was directly measured from the coordinated system of the inferior facet joint with respect to that of the superior facet joint. The ranges of motion (ROMs) of the facet joints were then determined during the flexion-extension, left-right bending, and left-right torsion of the body.

Facet orientation

The transverse and longitudal angles of the facet joints were measured in relation to the midsagittal plane of the vertebral body. The orientation and inclination of the facet joints were measured using the method described in the literature [20, 26, 27] (Figure 4, 5). The transverse facet angle was defined as the angle between the projection of the line representing the facet width onto the transverse plane and the anteroposterior axis of the vertebra. The longitudinal facet angle was defined as the angle between the projection of the line representing the facet length onto the sagittal plane and the line of the craniocaudal axis of the vertebra.

Statistical analysis

Two-way repeated measures ANOVA were used to compare the facet ROM and facet orientation at L2–L3, L3–L4 and L4–L5 vertebral levels within each group. A multiway ANOVA was used to compare the kinematics among the healthy subjects, DDD and DLS patients. The subject group was the categorical factor. The vertebral level and the activity were the dependent variables. The level of significance was set at $P<0.05$. When a statistically significant difference was detected, a Newman-Keuls post hoc test was performed. The statistical analysis was performed using the Statistica software (StatSoft version 8.0, Tulsa, Ok).

RESULTS

ROMs of facet joints in DLS patients (Table 2)

Flexion-extension of the trunk—The average range of rotation around all three axes varied from 1.5° to 3.2° at the DLS levels (L4–L5) and 2.2° to 3.0° at the adjacent levels (L2–L3 and L3–L4). The range of coupled rotation along the craniocaudal (z-) axis at the DLS level was significantly less than in the L3–L4 level ($P=0.044$) (Figure 6A).

The average range of translation along all three axes varied from 1.6 to 3.3 mm at the DLS level and 1.4 to 2.6 mm at adjacent levels. Vertebral translations during flexion-extension were not significantly different between the studied levels. (Table 2)

Left-right bending of the trunk—The average range of rotation around all three axes varied from 1.9° to 2.7° at the DLS levels (L4–L5) and 2.1° to 3.1° at the adjacent levels (L2–L3 and L3–L4). The range of coupled rotation along the mediolateral (x-) axis was significantly less at the DLS level than in the adjacent L2–L3 level ($P=0.05$) (Figure 6B).

The average range of translation along all three axes varied from 1.5 to 2.5 mm at the DLS level and 1.4 to 2.1 mm at adjacent levels. Vertebral translations during left-right torsion were not significantly different between the studied levels. (Table 2)

Left-right torsion of the trunk—The average range of rotation around all three axes varied from 1.6° to 2.4° at the DLS levels (L4–L5) and 1.6° to 2.7° at the adjacent levels (L2–L3 and L3–L4). The range of coupled rotation along the anterioposterior (y-) axis was significantly less at the DLS level than in the adjacent L2–L3 ($P=0.01$) and L3–L4 levels ($P=0.04$) (Figure 6C).

The average rangs of translation along the three axes varied from 1.6 to 2.5 mm at DLS level and 1.1 to 1.8 mm at adjacent levels. There was no significant difference between the studied levels. (Table 2)

Comparison with healthy participants and DDD patients

Flexion-extension of the trunk—The primary rotations around the mediolateral (x-) axis at the DLS level (L4–L5) were not significantly different compared to the healthy participants and the DDD patients (Figure 7A). However, the coupled rotations of the DLS patients were significantly smaller around the cranial-caudal (z-) axis, where the DLS patients had a range of rotation of 1.5°±1.2°, the healthy participants had 3.6°±2.3° (P=0.02), and the DDD patients had 3.5°±1.2° (P=0.004).

The DLS patients showed significantly lower range of primary rotation than the healthy subjects at the adjacent levels L3–L4 (DLS: 2.3°± 0.9° *vs.* healthy: 5.7°±1.7° P=0.0001) and L2–L3 (DLS: 2.4°± 1.3° vs. healthy: 6.5°±1.7° P=0.0001). No significant differences were observed between the DLS patients and the healthy subjects in coupled rotations.

Left-right bending of the trunk—The primary rotations around the anteroposterior axis (y-) at the DLS level (L4–L5) were decreased significantly compared to the healthy subjects (Figure 7B). The DLS patients had a range of rotation of 2.0°± 1.3° and the healthy participants had a range of rotation of 4.7°± 1.1°(P=0.001). The coupled rotation of the DLS patients around the mediolateral (x-) axis was significantly smaller compared to the DDD patients (DLS: 1.9°±0.9° *vs.* DDD: 4.3°±2.8° P=0.023).

At the adjacent levels L3–L4 and L2–L3, no significant difference was observed among the DLS, DDD and healthy subjects.

Left-right torsion of the trunk—The primary rotations at the DLS level (L4–L5) were not significantly different from the primary rotations of the DDD patients (Figure 7C), but were significantly lower than those of the healthy participants (DLS: 2.4°± 1.0° *vs.* healthy: 4.4°±1.5° P=0.01). The coupled rotations of the DLS patients around the anterioposterior (y-) axis were significantly smaller compared with those of the DDD patients (DLS: 1.6° ±0.5° *vs.* DDD: 3.6°±2.5° P=0.02).

At the adjacent level L3–L4, no significant difference was observed among the DLS, DDD and healthy subjects. At the L2–L3 level, the rotation around the mediolateral (x-) axis was similar with the DDD patients but significantly larger than the healthy participants (DLS: 2.2°±1.5° *vs.* healthy: 0.6°±0.3° P=0.019).

Translations—The ranges of translation at L2–L3, L3–L4, and L4–L5 were compared among the DLS patients, the DDD patients and the healthy participants (Table 2). The range of translation was between 0.8 and 3.2 mm in the DDD patients, 0.8 and 4.1 mm in the normal participants, and 1.1 and 3.3 mm in the DLS patients. In general, there are no significant differences among the three participant groups. (Table 2).

Facet orientation—The transverse and longitudinal angles for both the superior and inferior facets were presented in (Table 3, 4). In the DLS patients, the transverse orientation of the L4 inferior articular facet angle relative to the coronal plane was more sagittal than the healthy participants (P<0.05). The longitudinal orientation of the facet joints was not significantly different between the DLS patients and the healthy subjects at the L4–L5 level (P>0.05).

DISCUSSION

In this study, we investigated the ROMs of lumbar facet joints in elderly patients with Grade 1 DLS at L4–L5 during functional weightbearing activities and compared the data to those of healthy subjects [20] and DDD patients [21] that have been reported previously. At the DLS

level, no significant difference was found in the range of translation of the facet joint when compared to the range of translation in healthy subjects and DDD patients. However, in general, the range of rotation of the facet joint in the DLS group decreased compared to both DDD patients and healthy subjects. The data on adjacent levels was similar to that observed from DDD patients. These findings indicate that DLS is correlated to the alteration of movement in the facet joint and restabilizes the joints at the involved level.

Few studies have reported on the kinematics of the lumbar facet joints [15, 28]. Svedmark et al. assessed the movement of the lumbar facet joint in healthy participants during flexion-extension using CT scanning and the volume registration techniques [28]. Kozanek et al. described the motion of the facet joints in vivo and found that the motion was different between L4–L5 and the above two levels [20]. Li et al. indicated that rotation increased significantly not only at DDD levels but also at the adjacent levels [21]. No data was reported on the 6DOF kinematics of the facet joints in patients with DLS during in vivo physiologic weight-bearing avtivities.

Kirkaldy-Willis and Farfan proposed a pathway describing DLS development [29], where the advancing segmental degeneration of human spine follows a course from stable to dysfunctional and unstable to restabilized conditions. However, it is difficult to examine this pathway by following a patient group through the entire process of lumbar vertebral degeneration. In this study, we selected a normal subject group and a DDD patient group from our previous studies as comparison groups. The subjects in these two groups had average ages of 54.4 and 51.8 years, respectively. The reported data indicated that segmental motion increased in patients with moderate facet joint and disc degeneration as compared to the normal subjects [21]. The data in this present study further indicated that when disc degeneration progressed to grade 5 and the facet joint to grade 3, segmental motion decreased in DLS patients compared to healthy subjects. The decrease in segmental motion implies that a restablization of the facet joint occurs when DDD progresses to DLS. These results are consistent with previous assumptions on the structural and biomechanical changes in the facet joint that occur with degeneration of the vertebral segments[18, 30]. However, we have to note that the average age of DLS patients was higher than the ages of the normal subjects and the DDD patients. Age may also be another factor that leads to the reduced motion in the facet joint.

The kinematic difference noted in this study may be correlated to the structural change of the lumbar facet. Grobler and Fujiwara et al. indicated that the DLS group had a greater sagittal orientation at the L4 to L5 facet joint than the asymptomatic group [31, 32]. In this present study, a significantly greater sagittal facet orientation was also found when compared to the healthy subjects in L4–L5 level. These results imply that the facet joint motion can be increased in the sagittal plane of the DLS patients. However, the range of rotation of the facet joint in the DLS group decreased compared to the healthy subjects. It is difficult to draw a conclusion whether increasing sagittal orientation is a causative factor or the consequence of DLS. Interestingly, our kinematic data indicated that the range of translation of the facet joint is not significantly increased compared to the normal groups in the sagittal plane. This may indicate that the facet joint geometry is adapted from the DLS disease progress.

The findings of our study may have valuable clinical implications. Decompression only or decompression with spinal fusion, which has been conventionally used in surgical treatments for DLS patients [33]. However, there is an ongoing discussion as to whether additional fusion is superior to decompression surgery alone. Several follow-up outcome studies have shown that decompression plus fusion improved patient outcomes compared to decompression alone[34, 35]. However, there are also reports indicating that a decompression

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could result in similar clinical outcomes as the decompression and instrumented fusion[36]. Segmental instability is an important factor in determining the surgical method. An unstable DLS is usually treated with fusion surgery, which has always been referenced as the gold standard for instability [37]. Current kinematic studies, however, indicate that for elderly patients with Grade 1 DLS, there is no significant instability in the motions of facet joints during active in vivo function of the body. *This information may help the selection of conservative treatment or different surgical techniques for the DLS patients.* Recently, several interspinous devices have been introduced as an alternative to fusion surgeries for elderly patients with Grade 1 DLS [5, 38]. However, the efficiency of these devices in treating DLS has yet to be shown in long term follow up studies.

There are several limitations in this study that need to be noted. The study only focused on an elderly DLS patient population and the sample size was relatively small. However, we specifically selected patients with DLS at the L4–L5 level, who are within the age range of most patients that are commonly treated for degenerative spondylolisthesis. In addition, we only examined the range of motion of the L2–L3, L3–L4, and L4–L5 segments during the three weightbearing functional activities because the size of the field view of the fluoroscopes was limited. Despite these limitations, the present study provides new data on aberrant facet joint motion characteristics in DLS patients with various physiologic loading conditions.

In conclusion, the present study used an in vivo technique to quantify abnormal motion of the lumbar facet joint in DLS patients during various weight-bearing positions. The data could provide baseline information to help identify and characterize the pathologic motion of the facet joint under in-vivo physiological conditions. This information may help develop specified conservative or surgical techniques and evaluate the effect of new surgical modalities for treatment of DLS patients.

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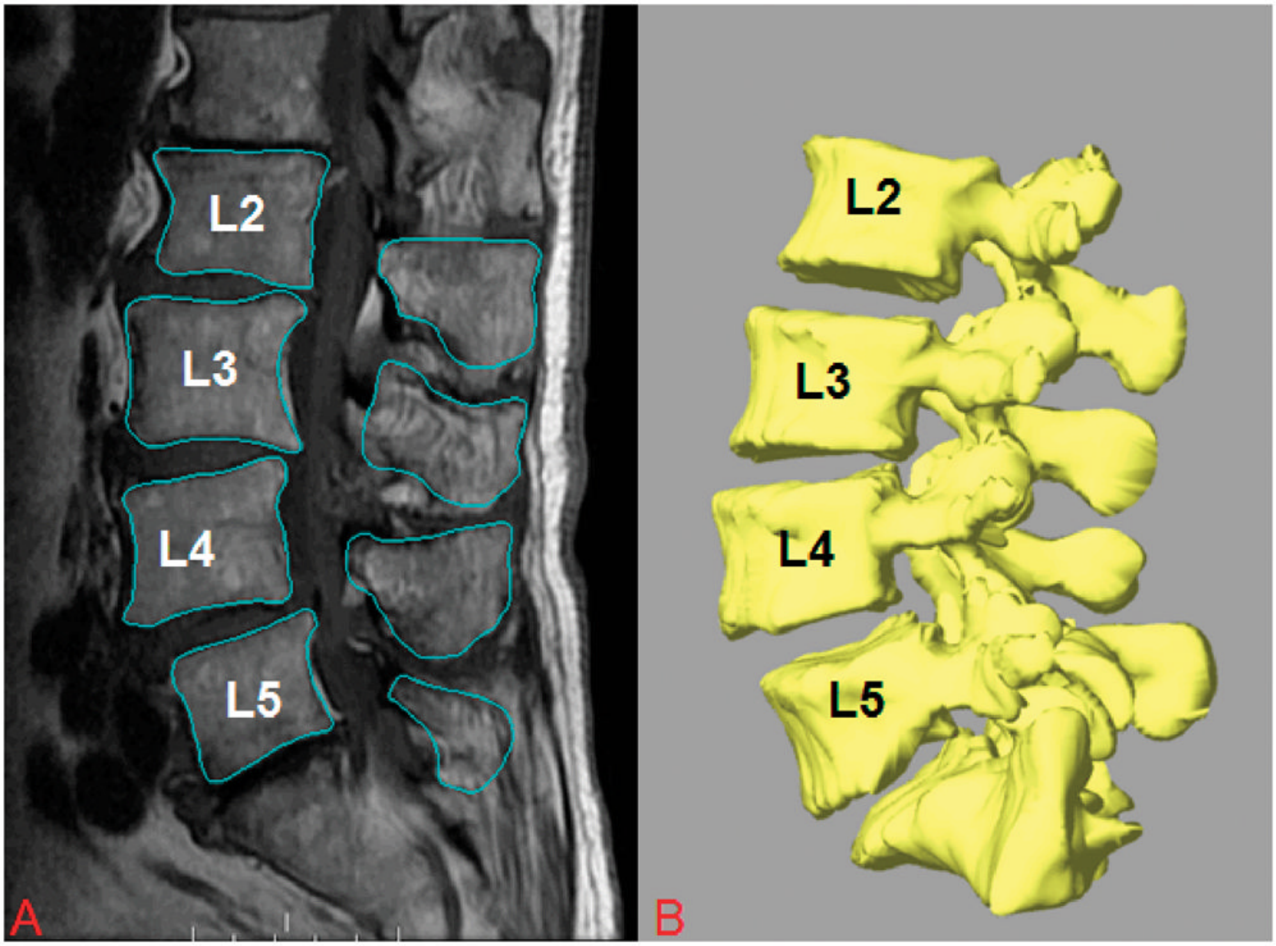

Fig. 1.
A, Digitized contours of lumbar vertebrae of patients with DLS at L4–L5 in the sagittal plane. B, Three-dimensional anatomical vertebral model of L2–L5, constructed from the magnetic resonance imaging.

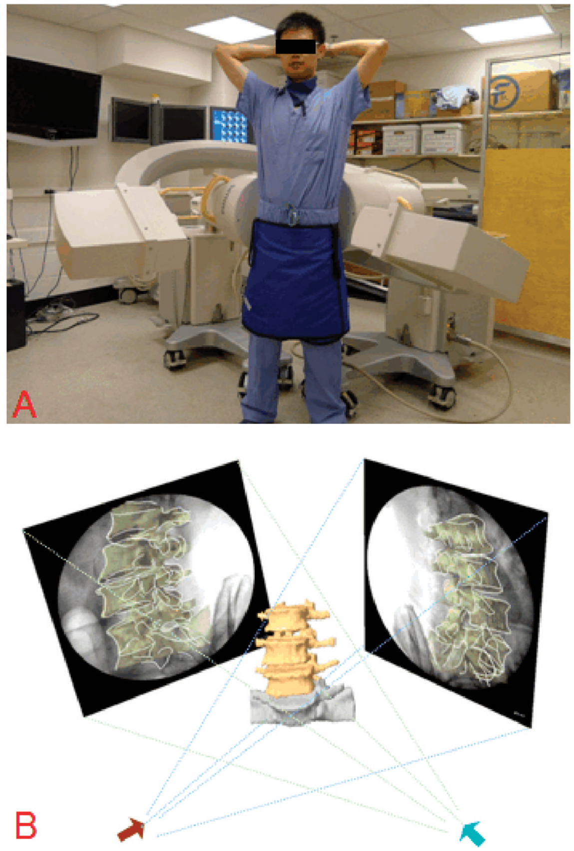

Fig. 2.
A, The experimental setup of the dual fluoroscopic imaging system(DFIS) for capturing the lumbar spine positions of living subjects. B, Virtual reproduction of the DFIS and the vertebral positions..

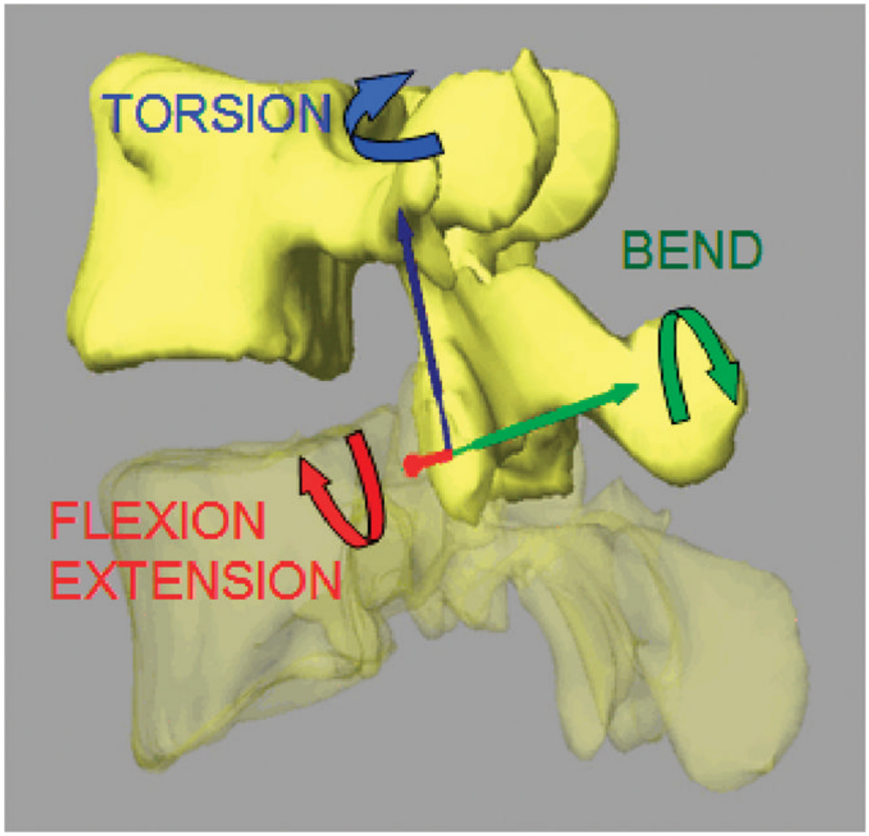

Fig. 3.
Anatomic coordinate system to measure kinematics of the facet joints.

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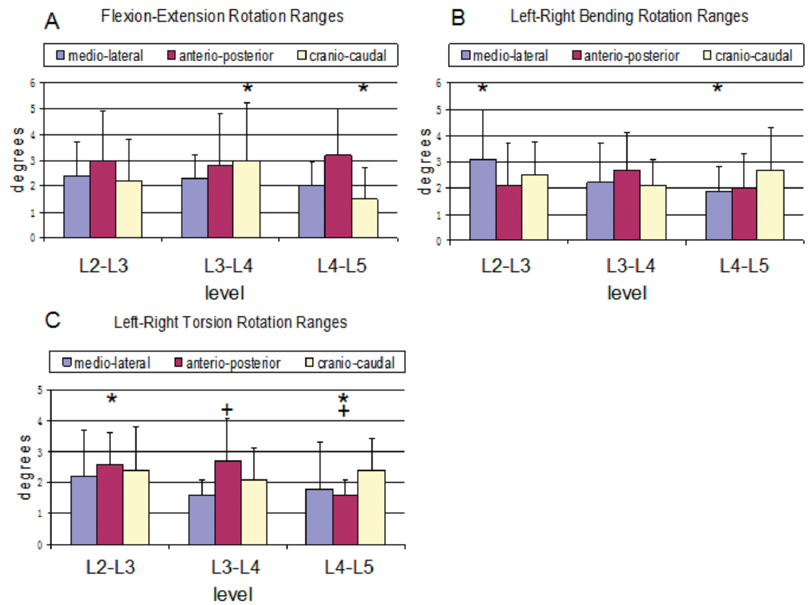

Fig. 4.

The transverse facet angle was defined as the angle between the projection of the line representing the facet width onto the transverse plane and the anteroposterior axis of the vertebra.

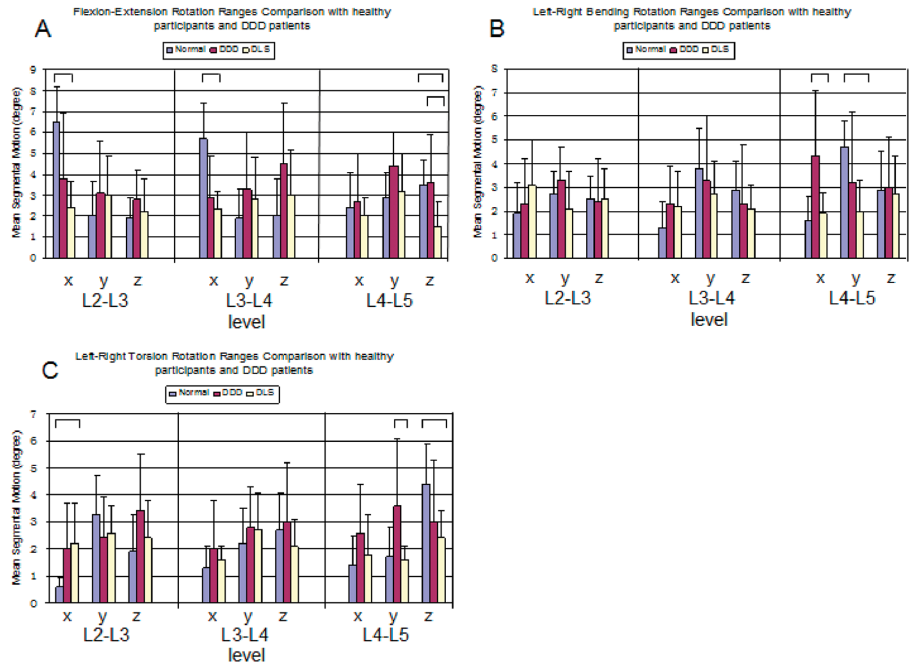

Fig. 5.

The longitudinal facet angle was defined as the angle between the projection of the line representing the facet length onto the sagittal plane and the line of the craniocaudal axis of the vertebra.

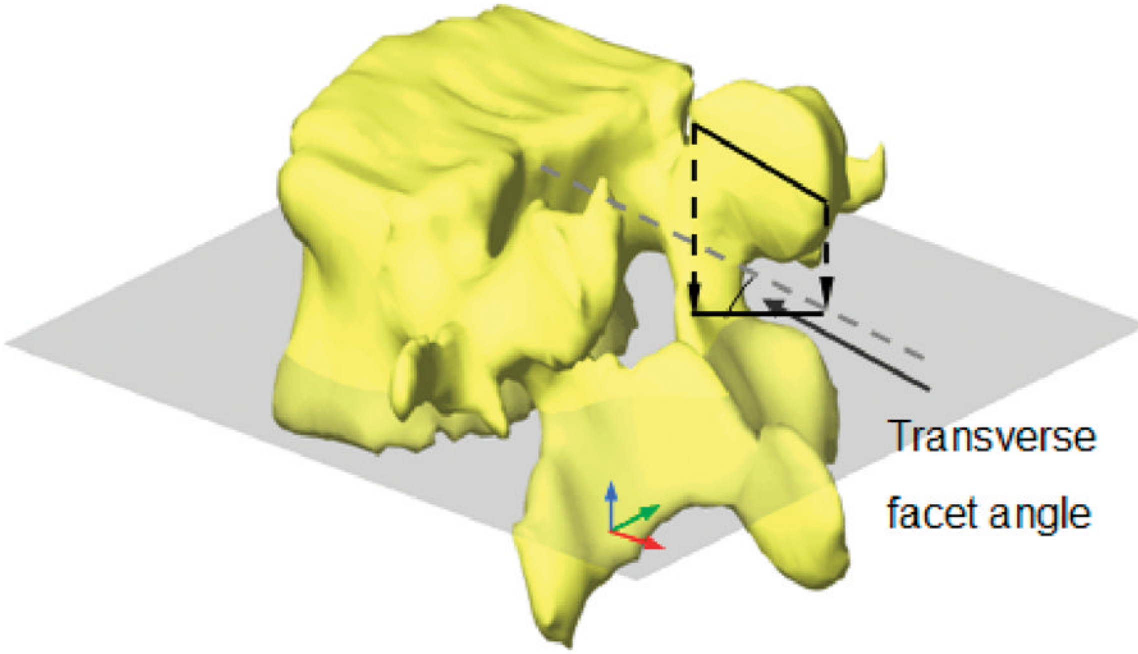

Fig. 6.

Range of facet joint rotations in patients with DLS around three principal axes under (A) torsion, (B) bending, and (C) flexion of the torso. The symbols (*,+) represent statistical significance upon between level comparison (P<0.05).

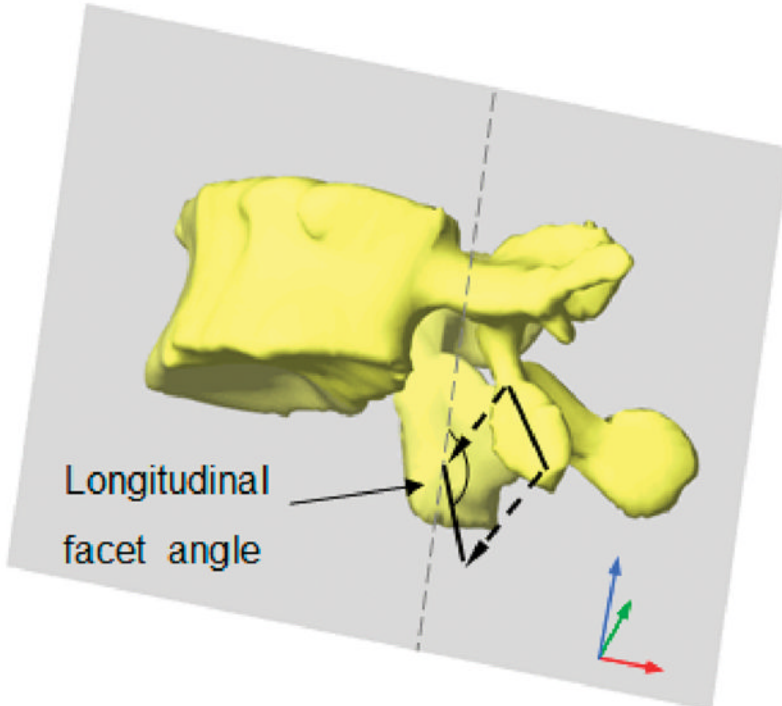

Fig. 7.
Range of facet joint rotation in patients among DLS, DDD and normal subjects around three principal axes under (A) torsion, (B) bending, and (C) flexion of the torso. The bar represent statistical significance upon between group comparison (P<0.05).

Table 1

Mean Facet Joint Osteoarthritis and Disc Degeneration among normal Participants, DDD, and DLS

Level	Group	Disc Degeneration	Range of grade	Left facet joint	Range of grade	Right facet joint	Range of grade
	Normal	1.1(0.4)	1–2	0	0	0	0
L2–L3	DDD	1.4(0.5)	1–2	0.8(0.5)	0–1	0.8(0.5)	0–1
	DLS	2.4(0.7)	1–3	1.4(0.7)	0–2	1.3(0.7)	0–2
	Normal	1.6(0.5)	1–3	0.1(0.4)	0–1	0	0
L3–L4	DDD	1.6(0.8)	1–3	0.8(0.5)	0–1	0.8(0.5)	0–1
	DLS	2.6(1.1)	2–4	1.6(0.5)	1–2	1.5(0.5)	1–2
	Normal	1.9(0.6)	1–3	0.1(0.4)	0–1	0.1(0.4)	0–1
L4–L5	DDD	4.2(0.8)	3–5	2.5(0.8)	1–3	2.4(0.7)	1–3
	DLS	4.7(0.8)	4–5	2.8(0.5)	1–3	2.6(0.5)	1–3

Normal=normal subject (N=8)

DDD=degenerative Disc Disease (N=10)

DLS=degenerative lumbar spondylolisthesis (N=10)

The value were presented as mean (SD)

Table 2

Comparison of Translation Ranges Among normal Participants, DDD, and DLS

	L2–L3			L3–L4			L4–L5		
	ML	**AP**	**CC**	**ML**	**AP**	**CC**	**ML**	**AP**	**CC**
Left-right torsion									
Normal	1.2(0.7)	1.1(0.8)	1.2(0.6)	1.3(0.8)	1.1(1.0)	1.4(0.9)	2.2(0.6)	1.3(0.7)	2.3(1.0)
DDD	1.2(0.9)	1.5(0.8)	1.5(1.4)	1.9(1.1)	0.8(0.8)	1.7(1.3)	2.5(1.4)	1.5(1.1)	1.7(1.5)
DLS	1.8(1.0)	1.1(1.0)	1.6(1.3)	1.5(1.3)	1.2(0.7)	1.3(0.7)	2.5(1.0)	1.6(0.5)	1.6(1.4)
Left-right bending									
Normal	1.0(0.7)	1.3(0.8)	1.5(1.4)	1.5(1.3)	1.4(1.1)	1.4(0.9)	1.6(1.2)	1.5(1.1)	1.7(1.4)
DDD	0.8(0.7)	1.0(0.7)	2.0(1.8)	1.9(1.7)	1.2(0.7)	2.0(1.9)	1.8(1.2)	1.4(1.2)	2.0(1.6)
DLS	1.4(0.6)	1.5(0.8)	1.5(0.7)	2.1(1.8)	1.6(0.7)	1.4(0.9)	2.5(1.5)	2.0(1.6)	1.5(0.9)
Flexion-extension									
Normal	1.2(0.7)	1.3(0.6)	3.6(2.4)	1.4(0.9)	1.3(1.0)	4.1(1.4)	1.8(1.1)	1.3(0.9)	2.4(1.4)
DDD	1.4(0.7)	1.2(0.5)	2.6(2.2)	2.2(1.7)	1.3(1.2)	2.4(2.0)	2.1(1.5)	1.0(0.9)	3.2(1.7)
DLS	1.7(1.0)	1.4(1.2)	2.3(1.5)	1.6(1.4)	2.3(1.3)	2.6(1.8)	2.2(1.5)	1.6(1.0)	3.3(1.1)

Translation around axis: ML, AP and CC.

The values were presented as mean (SD) in millimeter.

ML, mediolateral; AP, indicate anterioposterior; CC, craniocaudal.

DDD=degenerative disc disease, DLS=degenerative lumbar spondylolisthesis, Normal=normal subject

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Table 3

Transverse Orientation of Lumbar Facets in degree Comparison with the normal participants

vertebra	Left superior		Right superior		Left inferior		Right inferior	
	DLS	**Normal**	**DLS**	**Normal**	**DLS**	**Normal**	**DLS**	**Normal**
L2					22(10)	22(13)	21(10)	21(11)
L3	22(6)	18(6)	24(7)	21(8)	27(11)	29(16)	27(10)	30(12)
L4	25(9)	27(10)	28(6)	29(7)	28(8)*	40(16)*	28(9)+	39(13)+
L5	31(9)	38(16)	32(8)	41(12)				

The values for orientation are mean (standard deviation)

(*,+) L4 superior articular facet angle relative to the coronal plane was more sagittal than healthy participants ($P<0.05$)

Table 4

Longitudinal Orientation of Lumbar Facets in degree Comparison with the normal participants

vertebra	Left superior		Right superior		Left inferior		Right inferior	
	DLS	Normal	DLS	Normal	DLS	Normal	DLS	Normal
L2					165(7)	170(6)	165(7)	170(5)
L3	167(6)	167(7)	168(7)	168(5)	164(7)	166(4)	163(6)	166(5)
L4	165(6)	167(7)	167(7)	167(8)	162(6)	163(6)	164(5)	163(6)
L5	166(7)	168(5)	166(6)	168(5)				

The values for longitudinal orientation are mean (standard deviation)