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The Relationship between Facet Joint Morphology and Flexion-extension Movement

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ABSTRACT. Previous studies reported on the relationship between facet tropism and disc degeneration and disc herniation, but results were conflicting. Nineteen fresh cadaveric spines were used. A total of 25 motion segments were studied. The frozen lumbar motion segments were imaged in the direct axial and sagittal projections in a CT scanner. The motion segments were loaded to 5.7 Nm in flexion or extension. After flexion or extension loading, the specimens were frozen. The frozen motion segments were imaged again by CT scan. A total of 6 parameters were digitized and measured directly from the CT images. The facet joints were more sagittally oriented proximally and gradually became more coronal in the lower lumbar spine. The facet joints were also more horizontal proximally and gradually became more vertical in the lower lumbar spine except at L4 - L5 level. The facet joints at L4 - L5 were significantly more horizontal than adjacent levels. The facet tropism was statistically associated with translation at L1 - L2 and L3 - L4. The facet joints at L4-L5 were more horizontal than other levels, and might account for the higher incidence of degenerative spondylolisthesis at this level. Facet tropism was found to be associated with translation at L1-L2 and L3-L4 but not at the lower lumbar levels. probably because of increased degeneration of the lower lumbar spine.

Key words: lumbar spine — facet joint morphology — facet tropism — segmental instability

Tropism was defined as asymmetry in the lumbar and lumbosacral facet joint orientations. Putti[1] in 1927 was the first to comment on the significance of facet tropism in the pathogenesis of low back pain and sciatica. Farfan and Sullivan[2] found a high correlation between facet tropism, disc pathology and the side of the disc prolapse. Many studies reported on the relationship between facet tropism and disc degeneration and disc herniation, but results were conflicting.[2-10]

In a biomechanical study, Farfan[11] had described that a malalignment of the facets decreases torsional stability. Other studies reported on the important role of the facet joint in limiting the rotation.[12-15] Cyron and Hutton[16] reported that cadaver specimens with tropism tend to rotate toward the more

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oblique facet after an axial loading.

In degenerative spondylolisthesis, a significantly more sagittal facet orientation was found at L4-L5 level when compared to the normal population.[17] Grobler et al[17] concluded that patients developing degenerative spondylolisthesis are predisposed by a developmental sagittal orientation of the L4-L5 facet joints.

To our knowledge, there have been no quantitative studies on the relationship between the facet joint morphology and segmental instability. The purpose of this study is to investigate the relationship between flexion-extension movements and the facet joint morphology.

MATERIALS AND METHODS

Nineteen fresh frozen human cadavers with an age range from 39 to 87 years (mean age = 68.6 ± 13.5 years) were used in this study. From a cadaver, either the L2-L3 and L4-L5 or the L1-L2, L3-L4 and L5-S1 motion segments were obtained. The extraneous soft tissues were removed carefully so that the ligaments, facet capsule and disc remained infact. A total of 25 motion segments including five L1-L2, seven L2-L3, seven L3-L4, three L4-L5 and three L5-S1 were studied at random. The pathological changed specimens were not studied. The remaining specimens were used in other studies. The motion segments were sealed in plastic bags to prevent dehydration and stored frozen at −20℃.

The inferior vertebra of each motion segment was secured in the base mold and a specially designed loading frame was attached to the superior vertebra. Following fixation in poly-methymethacrylate, the specimens were frozen at −20℃. The frozen lumbar motion segments were imaged in the axial and sagittal projections in a CT scanner (General Electric Medical Systems High-speed Advantage 9800, Milwaukee, WI) using 120 kV, 200 mA, and 1 mm slice thickness.

The lumbar motion segments were thawed at room temperature in sealed plastic bags. The lumbar motion segments were loaded to 5.7 Nm using 1,100

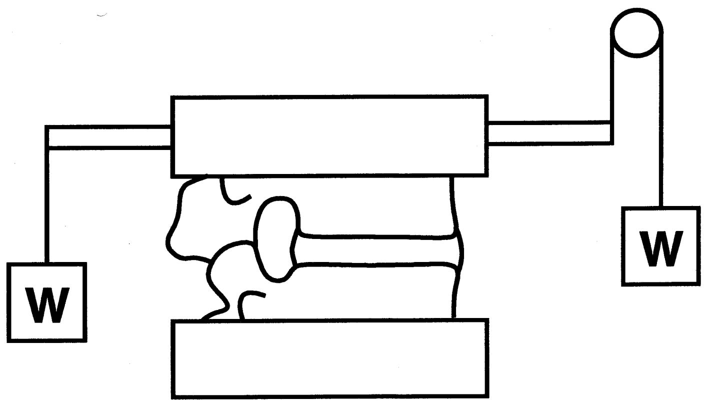

Fig 1. Diagram showing the experimental set-up of the extension:
The motion segment was secured in the base mold, and loaded to 5.7 Nm using 1,100 grams dead weight.

grams dead weights attached to the arm on the top vertebra (Fig 1). Flexion was loaded by hanging the weight directly to the anterior loading rod, and through the pulley to the posterior loading rod in 13 specimens. Extension was loaded by hanging the weight directly to the posterior loading rod, and through the pulley to the anterior loading rod in 12 specimens.

Following flexion or extension loading, the specimens were frozen using dry ice and liquid nitrogen. The frozen motion segments were imaged again by CT scan using the same parameters as in the pre-loading scan. There were 25 sections of facet joints including five L1-L2, seven L2-L3, seven L3-L4, three L4-L5, three L5-S1.

The axial CT images at the level of the intervertebral disc were analyzed (Fig 2). The parasagittal CT images just medial to the tip of the superior articular process were analyzed (Fig 3). To assess the relationship flexion-extension movements and the facet joint morphology, measurements were made on the pre- and post-loading CT images.

A total of 3 parameters on the axial CT images was measured directly from CT scan software (General Electric Medical System). The parameters included the facet joint orientation, facet joint depth, and facet joint length (Fig 4). The facet tropism was measured as a difference in facet orientations between the right and left side.

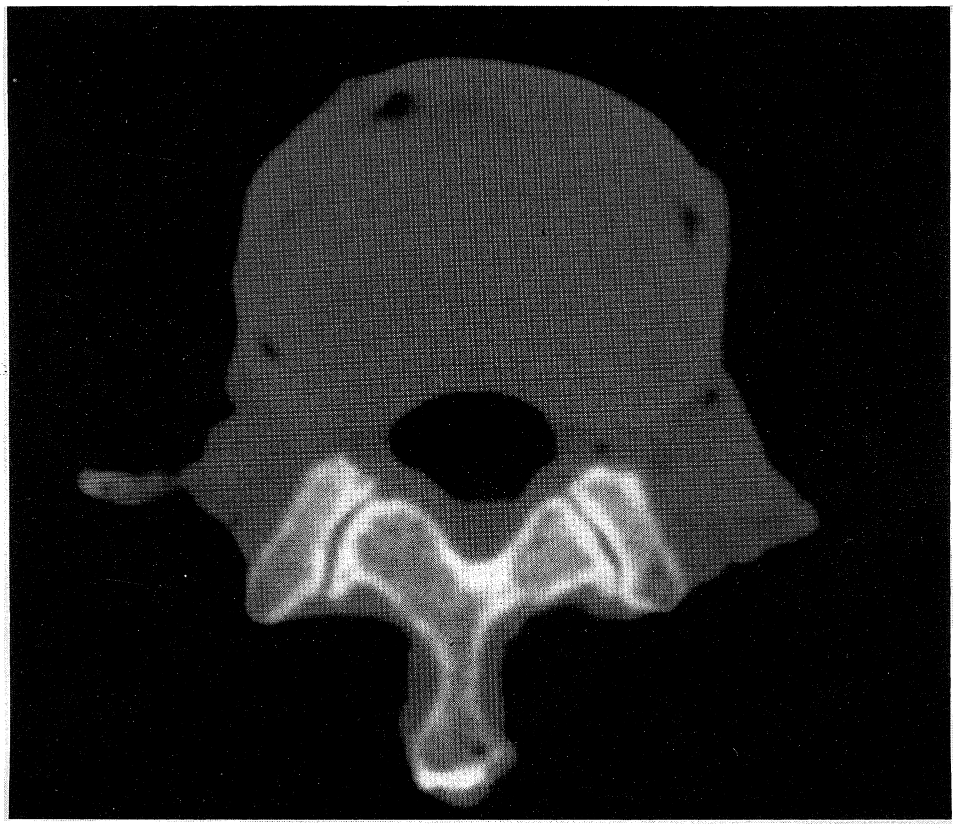

Fig 2. The axial CT

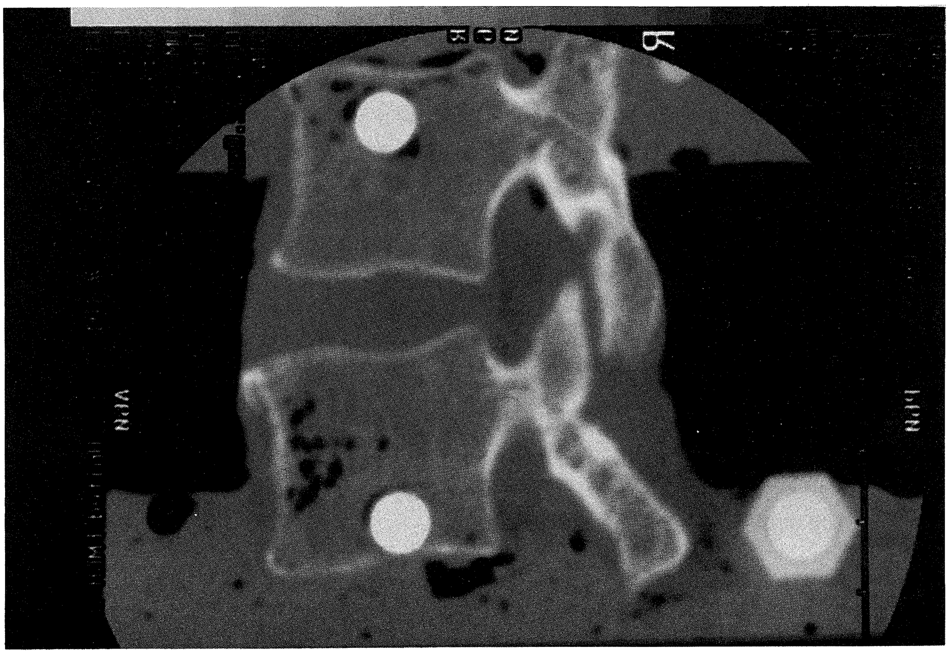

Fig 3. The parasagittal CT

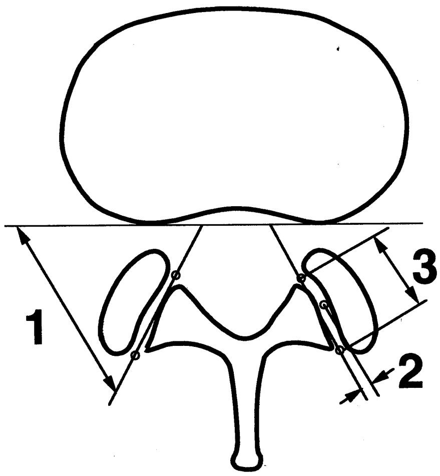

Fig 4. Diagram showing the measurements made on the axial CT
1 : facet joint orientation, 2 : facet joint depth, 3 : facet joint length

A total of 3 parameters was measured on the parasagittal CT images, including the sagittal facet orientation, vertebral body angle, and vertebral translation (Fig 5).

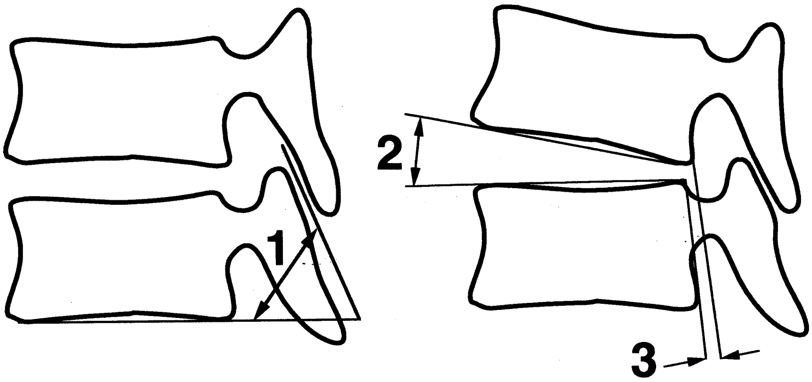

Fig 5. Diagram showing the measurements made on the parasagittal CT
1 : sagittal facet orientation, 2 : vertebral body algle, 3 : vertebral translation

Correlations coefficients and statistical significance was determined with the Stat View software (Abacus Concepts, Inc. Berkeley, CA) using ANOVA.

RESULTS

The measurements of the facet orientation, facet tropism, sagittal facet orientation, facet depth, facet length, and facet thickness are shown in Table 1.

TABLE 1. Values for the parameters that were measured

	L1-L2	L2-L3	L3-L4	L4-L5	L5-S1
Facet orientation (degree)	68.7 ± 7.3	54.7 ± 8.9	54.9±12.8	46.8±12.2	39.7 ± 7.2
Facet tropism (degree)	6.2 ± 3.3	8.6 ± 4.7	7.7± 7.1	4.3± 3.2	7.3 ± 3.2
Sagittal facet orientation (degree)	78.3 ± 7.7	81.4 ± 9.8	85.5± 7.3	74.8± 9.4	93.3 ± 5.5
Facet depth (mm)	1.3 ± 0.7	1.3 ± 0.8	2.1± 1.0	3.3± 1.8	2.3 ± 0.5
Facet length (mm)	10.8 ± 2.6	14.6 ± 2.2	14.5± 1.7	14.3± 1.6	19.5 ± 0.8

The facet joint orientation ranged from 30° to 86° (54.8±13.0°). The facet joint orintation of L1 - L2 was significantly larger than other levels ($p<0.05$), and L5-S1 was significantly smaller than other levels ($p<0.005$) except L4-L5 level. The facet tropism varied from 1° to 21° (mean 7.2±4.8°). The sagittal facet joint orientation ranged from 52° to 97° (mean 82.6±9.5). The sagittal facet joint orientation of L1-L2 was significantly smaller than L3-L4 level ($p<0.05$), and L5-S1 was significantly larger than L1-L2, L2-L3, and L4-L5 ($p<0.001$), and L4 - L5 was significantly smaller than L3 - L4 and L5 - S1 ($p<0.05$). The facet joint depth measured from 0 mm to 6 mm (mean 1.9±1.2 mm). The facet joint depth of L1-L2 was significantly smaller than L4-L5 and L5-S1 ($p<0.05$), and L2-L3 was singificantly smaller than L3-L4, L4-L5, and L5-S1 ($p<0.05$), and L3 - L4 was significantly smaller than L4 - L5 ($p<0.05$). The facet joint length measured from 6 mm to 21 mm (mean 14.4±3.1 mm). The facet joint length of L1 - L2 was significantly smaller than other levels ($p<0.005$), and L5-S1 was significantly larger than other levels ($p<0.0001$).

The facet tropism was statistically associated with translational changes at L1-2 ($r=0.89$, $p<0.0005$) and L3-4 ($r=0.55$, $p<0.05$). No correlation was observed between other dimensions and angulational changes.

DISCUSSION

The facet joint is formed by the inferior articular surface of cephalad vertebra and the superior articular surface of caudad vertebra. CT is an excellent method for studying the facet joint, and has improved the understanding of facet joint morphology.[18] Van Schaik *et al*[19] reported that the transverse interfacet-joint angle are 74.2° at L3-L4, 96.4° at L4-L5, and 106.2° at L5-S1. They found that the facet joints at L3-L4 are oriented more sagittally, while L5-S1 joints are oriented in a coronal orientation.

Grobler *et al*[17] found an association between the increased facet orientation and degenerative spondylolisthesis at L4-L5 level. Boden *et al*[20] reported that the facet joint orientation greater than 45° is 24 times more likely to have a degenerative spondylolisthesis at L4-L5 level. The increased facet orientation may be the result rather than the cause of degenerative spondylolisthesis.

In our study, the facet joints were more sagittally oriented proximally and gradually became more coronal in the lower lumbar spine. No previous reports described the facet joint orientation in the sagittal plane. Our study also showed that the facet joints are more horizontally oriented proximally and gradually became more vertical in the lower lumbar spine except at L4-L5 level. The facet joints at L4-L5 were more horizontal than other levels. This horizontal orientation may be a factor in the development of degenerative spondylolisthesis at L4-L5 level.

Reports on facet tropism are conflicting and could be divided into four groups. The first group[2,7] reported that there is a high correlation between facet tropism and unilateral disc herniation. The second group[5,9] reported that there is a correlation between facet tropism and early disc degeneration. The third group[4,6,10] reported that there is no clear correlation between facet tropism and disc herniation. The fourth group[20] reported that is an association of increased tropism with disc herniation at L4-L5 level but no association with disc degeneration.

Duncan and Ahmed[21] reported that facet asymmetry does not influence the coupled motions. But they found that facet asymmetry increase only the coupled flexion in a finite-element analysis. In our study, facet tropism was found to be associated with translation at the upper lumbar levels but not at the lower lumbar levels, probably because of increased degeneration of the lower lumbar spine. Severe disc degeneration is known to limit motions and stabilize the spine.

Several limitations were inherent in our study design. First, the number of specimens was small in that when one analyzes the data from the same level, the statistical significance becomes less. Secondly, the specimens were of the older population with significant degenerative changes, particularly in the lower lumbar spine. Disc degeneration is another confounding variable that may affect flexion-extension movements. Finally, our study was limited by two-plane anatomy of the facet joints, and future studies may include morphology in three dimensions.

At any rate, our study showed that the facet joints at L4-L5 were more horizontally oriented than other levels, which is a new finding. Facet tropism is still controversial issue, and further research may give more insights on the possible relationship between facet tropism and translational instability that was found at the upper lumbar levels. The effect of disc degeneration on instability is another issue that should be explored in the future.

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REFERENCES

1) Putt V : On new conceptions in the pathogenesis of sciatic pain. Lancet **2** : 53-60, 1927
2) Farfan HF, Sullivan JD : The relation of facet orientation to intervertebral disc failure. Can J Surg **10** : 179-185, 1967
3) Ahmed AM, Duncan NA, Burke DL : The effect of facet geometry on the axial torque-rotation response of lumbar motion segments. Spine **15** : 391-401, 1990
4) Cassidy JD, Loback D, Yong-Hing K, Tchang S : Lumbar facet joint asymmetry : Intervartebral disc herniation. Spine **17** : 570-574, 1992
5) Farfan HF, Huberdeau RM, Dubow HI : Lumbar intervertebral disc degeneration. The influence of geometrical features on the pattern of disc degeneration : A post mortem study. J Bone Joint Surg **54-A** : 492-510, 1972
6) Hägg O, Wallner A : Facet joint asymmetry and protrusion of the intervertebral disc. Spine **15** : 356-359, 1990
7) Loback D, Yong-Hing K, Cassidy D, Tchang S : The relationship between facet orientation and lumbar disc herniation : The role of torsion in intervertebral disc failure. Orthop Trans **9** : 560, 1985
8) Murtagh FR, Paulsen RD, Rechtine GR : The role and incidence of facet tropism in lumbar spine degenerative disc disease. J Spinal Dis **5** : 383-389, 1992
9) Noren R, Trafimow J, Andersson GBJ, Huckman MS : The role of facet joint tropism and facet angle in disc degeneration. Spine **16** : 530-532, 1991
10) Vanharanta H, Floyd T, Ohnmeiss DD, Hochschuler SH, Guyer RD : The relationship of facet tropism to degenerative disc disease. Spine **18** : 1000-1005, 1993
11) Farfan HF : Effects of torsion on the intervertebral joints. Can J Surg **12** : 335-341, 1969
12) Adams MA, Hutton WC : The relevance of torsion to the mechanical derangement of the lumbar spine. Spine **6** : 241-248, 1981
13) Farfan HF, Cossette JW, Robertson GH, Wells RV, Kraus H : The effects of torsion on the lumbar intervertebral joints : The role of torsion in the production of disc degeneration. J Bone Joint Surg **52-A** : 468-497, 1970
14) Liu YK, Goel VK, Dejong A, Njus G, Nishiyama K, Buckwalter J : Torsional fatigue of the lumbar intervertebral joints. Spine **10** : 894-900, 1985
15) Markolf KL : Deformation of the thoracolumbar intervertebral joints in response to external loads : A biomechanical study using autopsy material. J Bone Joint Surg **54-A** : 511-533, 1972
16) Cyron BM, Hutton WC : Articular tropism and stability of the lumbar spine. Spine **5** : 168-172, 1980
17) Grobler LJ, Robertson PA, Novotny JE, Pope MH : Etiology of spondylolisthesis : Assessment of the role played by lumbar facet joint morphology. Spine **18** : 80-91, 1993
18) Carrera GF, Haughton VM, Syvertsen A, Williams AL : Computed tomography of the lumbar facet joints. Radiology **134** : 145-148, 1980
19) Van Schaik JPJ, Verbiest H, Van Schaik FDJ : The orientation of laminae and facet joints in the lower lumbar spine. Spine **10** : 59-63, 1985
20) Boden SD, Riew KD, Yamaguchi K, Branch TP, Schellinger D, Wiesel SW : Orientation of the lumbar facet joint : Association with degenerative disc disease.

J Bone Joint Surg : **78-A** : 403-411, 1996
21) Duncan NA, Ahmed AM : The role of axial rotation in the etiology of unilateral disc prolapse : An experimental and finite-element analysis. Spine **16** : 1089-1098, 1991