Introduction: Facet joint osteoarthritis has been considered as an important source of mechanical low back pain (LBP) in addition to intervertebral disc degeneration. Facet orientation and area of joint surface may have a significant effect on loading and stress transfer across the facet joints and the development of facet joint osteoarthritis [1]. These anatomic variations of the lumbar facet joints are not well delineated in the literature, let alone factors such as age, sex, level effect, and symptoms of low back pain [2]. The facet joint surface area is not well-known largely due to the complicated three-dimensional (3D) geometry of the facet joint surface. We have established a non-invasive, CT-based methodology to measure 3D orientation and joint surface area of the facet joint [3]. The purpose of the current study was to investigate the 3D orientation and area of the facet joint surface in the different age and gender groups with and without chronic low back pain using the 3D in vivo measurement technique.

Materials and Methods: A total of 90 volunteers were included in the study (IRB approved). The subjects were grouped by gender, age, and existence or not of chronic LBP (Table 1). CT images from L1 to proximal half of the sacrum in a supine position were used for the current study. The CT images were reconstructed in 3D and then surface point cloud models were created. Polygon models of each facet joint surface were created from the point cloud models. A normal vector and area of each polygon were calculated. A mean normal vector was determined by averaging all normal vectors in each facet joint. Since orientation of each vertebra differs by level, local coordinates were determined for each level to determine the facet joint orientation. The local coordinate of each vertebra was determined by eigenvectors calculated from the point-cloud model of the vertebral body. The orientation of the facet joint surface was defined by angles from the eigenvectors. The facet joint orientation was presented by “x-angle”, “y-angle”, and “z-angle”, which correspond to the angles from sagittal, coronal and transverse planes, respectively. It should be noted that these sagittal, coronal, and transverse planes were defined within each vertebra. Comparison between two groups (symptomatic vs. non-symptomatic and male vs. female) was done by unpaired t-tests. Comparison between two anatomical sites (right vs. left and superior vs. inferior) was done by paired t-tests. Level and age effects were sought by ANOVA with a Fischer’s post-hoc test.

Results: Area: The facet area in male (174.1±176.5mm²) was greater than that in female (157.0±64.2mm², p<0.05). The symptomatic group (174.8±75.3mm²) had greater facet area compared with the non-symptomatic group (158.9±60.2mm², p<0.05). The facet joint area is greater in the lower compared to higher lumbar segments (p<0.05) and is greater in the older age groups (Fig 1). Also, symptomatic group tends to have wider facet (Fig 1). At L3/4, L4/5 and L5/S1, symptomatic group showed a tendency toward larger facet area compared with the asymptomatic group (L3/4:p=0.06, L5/S5/L5/S1:p<0.01).

Orientation: In terms of the x-, y- and z-angle, there was no statistical difference between female and male or between right and left sides. The x-angle decreased with age (Fig 2). Symptomatic group had larger x-angle (40.4±10.0) than the non-symptomatic group (38.4±10.5). The x-angles of the superior and inferior facets decreased with caudal level up to L4/5 (p<0.01). On the other hand, the y and z-angles of superior and inferior facets increased with caudal level (p<0.05). The y-angle at L4/5 was greater (p<0.01) and the z-angle at L4/5 was smaller (p<0.05) compared with those at L5/S1, respectively (Fig 2).

Discussion: This study has shown that the 3-D anatomy of the lumbar facet joints can be accurately measured in vivo by this non-invasive CT-based methodology. As expected, males had larger joint surface area compared to females. The joint surface area was greater in the lower levels as reported by Panjabi et al.[4]. The facet joint surface area grew with age and in the symptomatic group, which may suggest adaptation to the higher load transmission through the facet joints with aging and disc degeneration. Another interesting finding of this study was that the higher x-angle or sagittal orientation of the facet joint was found in the symptomatic group. Several other studies reported that the sagittally oriented facet joint associated with degenerative changes in the facet joint and anterior-posterior instability [5,6]. In conclusion, this study has shown that 3D facet joint anatomy includes surface area and joint orientation varies with age, sex, and level, and certain changes such as larger surface area and sagittal angulation are associated with LBP symptoms. In future studies, kinematic analysis of the motion segment may be helpful to understand the relationship between the sagittal orientation facet joint and other anatomical features with motion and symptoms of mechanical LBP. With current interest in motion preservation techniques in the field of spine surgery, anatomy, kinematics, and pathomechanics of the facet joints should be carefully followed in the future.

[4] Clinical biomechanics of the spine

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