INTRODUCTION Pedicle screw fixation procedures using rods, hooks, and wires instrumentation are considered as the most popular and versatile methods of spinal stabilization. Oversized or misaligned screw insertion leads to pedicle wall penetration, which in turn causes serious surgical complications. Cross-sectional morphology of the pedicle is generally assumed as elliptical and it becomes oblique to the vertical in the lower levels. Although morphometry of lumbar pedicles have been reported in several articles, to the best of our knowledge, there are no reports of in-vivo 3D measurements of the human lumbar pedicle in the literature. The objective of the present study was to obtain lumbar pedicle isthmus 3D geometry isthmus using a novel in-vivo CT-based 3D measuring technique.

METHODS A total of 89 subjects (46 males and 43 females, age range 23-59 years, mean: 36.5±10.0 years) were used in this study (IRB approved). 3D point-cloud models of L1-L5 were created from CT images. A custom-written C++ program was used to determine the following parameters (Fig.1). Two points were set at approximately centers of anterior and posterior ends of the tubular pedicles in 3D space. Along this axis line, pedicle cross sections were determined at approximately 0.5 mm intervals. A spherical coordinate system was centered at each intersection point of the line and the cross sections (Point O), which served as pivot point for a virtual cone with a vertex angle of 10°. The cones were rotated 10° about O in 10° increments and the points with least distances within the cone were chosen as boundary points of the cross-section of the pedicle. For each cross section, the centroid, the longest axis and the shortest axis were calculated. The shortest axis was determined by the line which connected 2 points with the least distance and cross near the centroid. The cross-section having the smallest shortest axis was defined as the isthmus. The shortest axis and the longest axis in the transverse plane was defined as Pedicle Isthmus Width (PIW) and Pedicle Isthmus Height (PIH), respectively. The angle between the PIW and a transverse plane (perpendicular to the posterior wall) of each vertebral body was defined as the Isthmus Angle (IA) (Fig.1). To show the differences caused by using planar images, the largest width of the pedicle (Transverse Plane Width-TPW) was measured from a plane transverse CT image and used to compute the TPW/PIW ratio. Distance between the gravity centers at right and left pedicles was defined as Interpedicular Distance (IDP). The shortest distance between right and left isthmus of the pedicle was defined as Shortest Distance between Pedicles (SDBP) (Fig.1). These parameters were compared among levels, genders and ages with ANOVA and Fisher’s post-hoc tests. Significant level was set up at p<0.05.

RESULTS Pedicle isthmus width (PIW) increased with each successive lower level (Fig.2). The male PIW at all levels were greater than those of female (p<0.02) (Table 1). PIW increased with age (Differences were shown in the following comparisons: 20 vs.30, 40, 50 at L1; 20 vs.30, 40 at L2; L5: 20 vs.40, 50 at L5, p<0.037 ) (Fig.3). Pedicle Isthmus Height (PIH) was greatest at L5 and greater in male at all levels (Table 1). PIH increased with age (Differences were shown between 20 vs.50 at L1; 20 vs.30, 40 at L2, 20, 30 vs.40 at L5, p<0.044). Transverse Pedicle Width (TPW) showed the same pattern as the PIW. TPW/PIW ratio was increased with each successive lower level, the largest values being 140.9 % in female and 147.2 % in male at L5 (Fig.4). Isthmus Angle (IA) was largest at L5 for both genders (Fig.5a,b). There were no statistical differences among different age groups. Interpedicular Distance (IDP) was greatest at L5 and greater in male at all levels (Table 1). There were no statistical differences among different age groups. Shortest Distance between Pedicles (SDBP) was greatest at L5. Statistical differences were not shown between genders. SDBP in 20’s was greatest at all levels.

DISCUSSION The present study demonstrated that the isthmus is larger in males and increases with age and with each subsequent lower level. Most of the parameters at L5 were different from those at other levels. These results are consistent with previous studies. However, the 3D shortest axis at the isthmus, which was measured by using the automatic searching algorithm of the least distance in 3D space developed in the present study, has never been measured in vivo to our knowledge.

The diameters of the pedicle measured in the conventional way using the transverse CT images were up to 44% larger than the least diameter of the pedicle measured in the present study due to inclination of the axis from the transverse plane. This finding supports the fact that determination of the size of pedicle screws using the transverse CT images may cause overestimation of the screw diameter, although the present study did not measure inner diameter of the pedicle. In a future study, data on bone density will be incorporated to the analysis as a way to measure the inner diameter of the pedicle.

In-Vivo Three-Dimensional Morphometric Analysis of the Lumbar Pedicle Isthmus
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