We have analysed a number of radiological measurements in an attempt to clarify the predisposing factors for degenerative spondylolisthesis of the lumbosacral junction. We identified 57 patients with a slip and a control group of 293 patients without any radiological abnormality apart from age-related changes. The relative thickness of the L5 transverse process, the sacral table angle and the height of the iliac crest were measured and evaluated. The difference in these measurements between men and women was analysed in the control group.

We found that the transverse process of L5 was extremely slender, the sacral table more inclined, and the L5 vertebra was less deeply placed in the pelvis in patients with a slip compared with the control group. The differences in these three parameters were statistically significant.

We believe that the L5 vertebra is predisposed to slip when these factors act together on a rigidly-stabilised sacrum. This occurs more commonly in women, probably as a result of constitutional differences in the development of the male and female spine.

Anterior translation of a lumbar vertebra without a defect in the neural arch was first reported by Junghanns in 1930 and the term ‘degenerative spondylolisthesis’ was introduced by Newman in 1955 to describe it. It is said to be six to nine times more common at L4-5 than at adjoining levels, and is four times more common in women than in men. Many studies have been undertaken in an attempt to determine its cause but this remains elusive. At L4-5 a degenerative slip is more likely to be present when the L5 vertebra is ‘sacralised’. A sagittally-placed facet joint, a widening lumbosacral angle, and a high iliac crest have also been suggested as predisposing factors.

We hypothesised that the cause of a lumbosacral slip must be related to decreased stability of the motion segment and that this stability is determined by: 1) the tethering of the fifth lumbar vertebra by the iliolumbar ligament, 2) the degree of obliquity of the sacral end-plate and 3) the position of the fifth lumbar vertebra in relation to the pelvis, namely, whether it is deeply or shallowly seated in the pelvis. We then attempted to establish whether any combination of these radiological factors could explain the relative instability of the lumbosacral junction and to suggest a reason as to why a slip should occur.

Patients and Methods
We identified 57 patients (45 women, 12 men; group I) with degenerative spondylolisthesis of the fifth lumbar vertebra from 17 500 patients in whom lumbar spinal radiographs had been taken at Nagoya Daini Red Cross Hospital between 1983 and 1998. Their mean age was 68.2 years (42 to 93). No patient with a transitional vertebra or a congenital spondylolisthesis of L5 (Newman’s group I) was included in this study. These were compared with a randomly-selected group of 293 patients (173 women and 120 men; group II) in whom radiographs were normal apart from age-related changes. Their mean age was 46.8 years (21 to 69).

Radiological measurement. Each patient had anteroposterior (AP), lateral and oblique radiographs taken in the standing position. We measured the relative thickness of the L5 transverse process, the sacral table angle, the degree of obliquity of the sacral end-plate, and the position of the fifth lumbar vertebra in relation to the pelvis, namely, whether it is deeply or shallowly seated in the pelvis. We then attempted to establish whether any combination of these radiological factors could explain the relative instability of the lumbosacral junction and to suggest a reason as to why a slip should occur.

The relative thickness of the L5 transverse process was estimated from the following measurements (Fig. 1): the interpedicular distance, the length of the transverse process from the medial margin of the pedicle to the
tip of the process and the thickness of the process, namely the craniocaudal width at the junction of its middle and lateral thirds. The thickness was expressed as a percentage of the interpedicular distance to give the relative thickness.

The sacral table angle (Fig. 2) was determined by drawing a line along the cranial end-plate of the sacrum and a line along the posterior aspect of the first sacral vertebral body (θ) S1 (reproduced with permission from Lippincott Williams & Wilkins, 2002). The position of the L5 vertebra on a lateral radiograph, in relation to the height of the iliac crest was recorded in the manner described by Ohmori et al.¹⁵ (Fig. 3). The midpoint between the two projections of the iliac crests was measured in relation to the L4-5 disc and the posterior margins of the L4 or L5 which were divided into thirds for the purpose. These were then scored as shown in Figure 3.

The orientation of the lumbosacral facet joints was assessed using the method described by Sato et al.⁸ When both joint spaces could be clearly seen on the AP radiograph, the joints were deemed to be orientated in the sagittal plane.

We measured the degree of lumbosacral slip and excluded the patients whose slip was less than 5% and those with slips at more than one level.

**Statistical analysis.** Data were expressed as the mean and SD. Statistically significant differences between two unpaired values were estimated by the t-test using StatView software (Abacus Concepts, Berkeley, California). The data were analysed by analysis of variance followed by Fisher’s protected least significant difference test, with a *post hoc* test for multiple comparison. A p-value < 0.05 was considered to be significant.

**Results**

**Analysis of parameters predisposing the L5 vertebra to slip.** The number of patients, the age at the first visit, the relative thickness, sacral table angle, and the height of the iliac crest are shown in Table I.

**Facet joint morphology.** A sagittally-orientated joint morphology of the L5-S1 segment was observed in three of the
57 patients (5.3%) in group I and in 11 of the 293 (3.7%) in group II. This difference was not significant. The mean degree of slippage in group I was 14.59% (5% to 30.48%).

Gender differences. To clarify the gender difference the 293 control patients in group II were examined. The results are shown in Table II. All were statistically significant (unpaired t-test, p < 0.01). The mean relative thickness of the L5 was 54.13% in women and 58.04% in men (p = 0.0006). The mean sacral table angle was 98.58° in women and 99.77° in men (unpaired t-test, p = 0.0009) and the mean iliac crest height was -1.45 in women and -0.58 in men (unpaired t-test, p = 0.0001). These differences were also statistically significant (Table II).

Correlations among parameters. Correlation coefficients were calculated to identify any correlations among the relative thickness, sacral table angle and iliac crest height. The results are shown in Table III. There were no close correlations in these parameters.

Discussion
We found a statistically significant difference in the relative thickness, sacral table angle and height of the iliac crest in the two groups.

The transverse process of L5 was markedly slender in patients with a lumbosacral slip (Fig. 4), suggesting that the L5-S1 segment may be relatively unstable, and that the tetherring force of the iliolumbar ligaments on the L5 vertebra may be reduced in patients with a spondylolisthesis (Fig. 4).

There was a statistically significant difference in the sacral table angle in the groups in that the obliquity of the sacral end-plate was more pronounced in patients with a slip. The question is whether the lessening of the sacral table angle took place before or after the slip. We are unable to answer this since only patients with an established slip were studied. However, the sacral table angle did not change in eight patients with L5 spondylolysis who were followed for a mean of 7.9 years (4 to 13). This confirmed that the sacral table angle rarely changes after skeletal maturity, even if the superior vertebra is translated forward to a mild degree.

The mean height of the iliac crest was noticeably less in patients with a slip indicating that there was a shallow seating of the L5 vertebra in the pelvis. As the L5-S1 disc space narrows, the iliac crest appears to rise in relation to the spine. This also occurs as the L5 vertebra slips down the increased slope of the sacral end-plate in patients with spondylolisthesis. Hence it may be speculated that the position of the L5 vertebra in patients with a slip must have been even shallower in the pelvis before the onset of the slip.

There was no significant difference in the prevalence of sagittally-orientated facet joints between the two groups.
Consequently, these cannot be implicated in the aetiology of a slip. None of these parameters could be correlated with the degree of slip. We considered the differences in radiological measurements between the genders. Although the differences were relatively small, those measurements were all significantly lower in grade in women than in men. These were thought to be developmental in origin rather than acquired.

We believe that a degenerative slip at the lumbosacral junction is due to a failure of the L5 tether combined with a slender transverse process of L5 and a shallow position of the vertebral body in the pelvis. The increased tilt of the sacral end-plate increases the shear stress across the L5-S1 disc. Because the sacrum is rigidly fixed, there is no way of dissipating the resultant force other than through the lumbosacral disc which fails and slips.

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References