Does the iliolumbar ligament prevent anterior displacement of the fifth lumbar vertebra with defects of the pars?

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We studied 23 patients with spondylolysis of the fifth lumbar vertebra (L5) and 20 with spondylolytic spondylolisthesis at this level. All were more than 40 years of age. The transverse processes at L5 were significantly wider in the former group than in the latter. We also dissected 56 cadavers to study the morphological relationship between the transverse process of L5 and the iliolumbar ligament, and found that the wider transverse process is associated with increased width of the posterior band of the iliolumbar ligament.

If a patient with pars defects has wide transverse processes at L5, the lumbosacral junction may be stabilised by wide posterior bands of the iliolumbar ligament and the fifth lumbar vertebra by the ligament, preventing anterior displacement.

Patients and Methods

Clinical study. We examined the lumbar spine in 23 patients with spondylolysis of L5 and 20 with spondylolytic spondylolisthesis at this level. All had bilateral, radiologically verified defects of the pars of the fifth lumbar vertebra. Further classification into isthmic or congenital (dysplastic) spondylolytic types was not attempted since it is sometimes difficult to distinguish between them.

All were more than 40 years of age and did not have lumbosacral transitional vertebrae. There were 13 men (mean age, 53.2 years) and ten women (mean age, 53.2 years) with spondylolysis, and ten men (mean age, 58.3 years) and ten women (mean age, 60.3 years) with spondylolisthesis. Although the ages of the men and wom-

The iliolumbar ligament binds the transverse process of the fifth lumbar vertebra to the ilium, stabilising each (Fig. 1). There have been a number of reports concerning its anatomy and biomechanics. Shellshear and Macintosh described the part played in stabilisation of the lumbosacral region in spondylolisthesis. Leong et al stated that it is difficult to ascertain its significance in vivo but, in isthmic spondylolysis of L5 and congenital spondylolisthesis of L5 on S1, the integrity of the iliolumbar ligament could determine the degree of subluxation.

The morphological relationship between the transverse process of L5 and the iliolumbar ligament has not been described and there have been few reports concerning the clinical role of the iliolumbar ligament, probably because of the difficulty in determining its mechanical strength and measuring its size in vivo. The purpose of this study was to determine whether the iliolumbar ligaments prevent anterior displacement of the fifth lumbar vertebra in the presence of defects of the pars interarticularis.
en were compared separately using the unpaired Student \( t \)-test, there was no statistical difference between the spondylolysis and spondylolisthesis groups (men, \( p = 0.24 \); women, \( p = 0.13 \)). The percentage of slip was measured on a lateral radiograph using the methods of Taillard\(^{11}\) and Wiltse and Winter;\(^{12}\) it ranged from 6% to 29% (mean, 23.4) in the men and from 10% to 33% (mean, 23.1) in the women. Spina bifida occulta was present in two men and one woman with spondylolysis, and in one man with spondylolisthesis.

Anteroposterior (AP) radiographs were taken in line with the superior surface of the L5 vertebra (Fig. 2). The distance between the x-ray tube and the film was constant at 1 metre. The length of the transverse process of L5 from the lateral margin of the pedicle to the tip, and its width, taken as the perpendicular bisector of the length line (Fig. 3), were measured on these films. We also measured the distance from the tip of the transverse process to the intercrestal line and compared these between the spondylolysis and spondylolisthesis groups using the unpaired Student \( t \)-test. Men and women were evaluated separately. A \( p \) value of less than 0.05 was considered statistically significant.

Anatomical study. We dissected 71 cadavers and took AP and lateral radiographs of the lumbosacral spine. Of these, eight with lumbosacral transitional vertebrae, four with ossification of the iliolumbar ligament, and three with spondylolisthesis of L5 were excluded. Of the remaining 56 cadavers, 28 were male and 28 were female. The mean age at death was 72.1 years (39 to 102).

The length and width of the transverse processes of L5 were measured on films taken in the same manner as in the clinical study. We defined the length of the anterior and posterior bands of the iliolumbar ligament as the distance from the tip of the transverse process of L5 to the point of insertion on the ilium. If this was oblique, we took the median between the longest and shortest lines. We also measured the craniocaudal width and AP thickness of the anterior and posterior bands of the iliolumbar ligament at its narrowest portion, as an indication of its strength. The cross-sectional area of the anterior and posterior bands of the ligament were calculated by multiplying the width by the thickness.

The length and width of the transverse process of L5, and the length and width of the anterior and posterior bands of the iliolumbar ligament were grouped according to gender and compared using the unpaired Student \( t \)-test. A \( p \) value of less than 0.05 was considered to be statistically significant. The results were compared using the simple regression test between the length of the transverse process of L5 and the length of the anterior and posterior bands of the iliolumbar ligament, between the width of the transverse process and the width of the anterior and posterior bands of the ligament, and between the width of the transverse process and the cross-sectional area of the anterior and posterior bands of the iliolumbar ligament. Male and female specimens were evaluated separately.

Results

Clinical study. The length and width of the transverse processes are shown in Table I. There was no statistical difference between the spondylolysis and spondylolisthesis groups when considering the length (men, \( p = 0.061 \); women, \( p = 0.34 \)). However, the processes were significantly wider in the patients with spondylolysis than in those with spondylolisthesis (men, \( p = 0.00016 \); women, \( p = 0.00034 \)).

There was no significant correlation between the width of the transverse process and the percentage slip (men, \( r = 0.17 \), \( p = 0.48 \); women, \( r = 0.41 \), \( p = 0.071 \)). The dis-
tance from the tip of the transverse process to the inter-
crestal line was significantly greater in the women in the 
spondylolysis group than in those in the spondylolisthesis 
group (p = 0.015), but there was no significant difference 
between the two groups in the men (p = 0.66).

Anatomical study. The length and width of the transverse 
processes in the anatomical specimens and the lengths, 
widths and approximate cross-sectional areas of the anterior 
and posterior bands of the iliolumbar ligament are 
shown in Table II. Although statistically not significant 
(p = 0.095), the transverse processes were wider in the 
males than in the females (Table II). The anterior and 
posterior bands of the iliolumbar ligament were statistically 
longer in the females than in the males (anterior band, 
p = 0.045; posterior band, p = 0.015). The widths of the 
anterior and posterior bands of the iliolumbar ligament did 
not differ between the males and females (anterior band, 
p = 0.40; posterior band, p = 0.87).

A summary of the simple regression test is given in 
Table III. It showed that there was no correlation in either 
males or females between the length of the transverse 
process and the length of the anterior and posterior bands of 
the iliolumbar ligament, or between its width and the 
width and cross-sectional area of the anterior band of the ili-
lumbar ligament. There was a positive correlation between 
the width of the transverse process and the width of the 
posterior band of the iliolumbar ligament in both males and 
females (male, r = 0.29, p = 0.03; female, r = 0.46, 
p = 0.0004), indicating that wide transverse processes have 
wide posterior bands of this ligament. In addition, a pos-
itive correlation was confirmed between the width of the 
transverse process and the approximate cross-sectional area 
of the posterior band of the ligament in both males and 
females (male, r = 0.33, p = 0.01; female, r = 0.32, 
p = 0.02).

Discussion

The iliolumbar ligament has been variously described.\textsuperscript{1,3-5} 
Luk et al\textsuperscript{3} distinguished two separate bands, whereas 
Shell-shear and Macintosh\textsuperscript{1} classified the ligament into five parts. 
Although their superior, inferior, and vertical components 
were much thinner and weaker than the anterior and poster-
ior bands, they were not present in all of the specimens in 
our study. We evaluated the anterior and posterior bands of 
the ligament taking into consideration the biomechanical 
strength. We found the three-dimensional relationship 
between the ilium and the iliolumbar ligaments to be very 
complicated. For example, the point of insertion on the 
iliac crest varied among the specimens. Therefore, even if the 
intercrestal line was high and the fifth lumbar vertebra was 
deeply seated, the iliolumbar ligament would have a differ-

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**Table I.** Mean (± SD) length (mm) and width (mm) of the transverse process of L5 in the 23 patients with bilateral spondylolysis and the 20 with bilateral spondylolytic spondylolisthesis

<table>
<thead>
<tr>
<th>Number of transverse processes</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spondylolysis</td>
<td>26</td>
<td>25.4 ± 3.2</td>
</tr>
<tr>
<td>Spondylolytic spondylolisthesis</td>
<td>20</td>
<td>23.5 ± 3.3</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spondylolysis</td>
<td>20</td>
<td>21.3 ± 2.7</td>
</tr>
<tr>
<td>Spondylolytic spondylolisthesis</td>
<td>20</td>
<td>22.1 ± 2.9</td>
</tr>
</tbody>
</table>

* statistically different between the spondylolysis and spondylolisthesis groups (men, p = 0.00016; women p = 0.00034)

**Table II.** Mean (± SD) length (mm) and width (mm) and cross-sectional area (mm\(^2\)) of the transverse process of L5 and the iliolumbar ligaments in the 56 male and female cadavers

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transverse process of L5</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>28.1 ± 4.7</td>
<td>28.7 ± 4.5</td>
</tr>
<tr>
<td>Width</td>
<td>19.9 ± 3.4</td>
<td>18.8 ± 3.3</td>
</tr>
<tr>
<td><strong>Anterior band of iliolumbar ligament</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>25.0 ± 7.1*</td>
<td>27.5 ± 6.1*</td>
</tr>
<tr>
<td>Width</td>
<td>5.5 ± 1.9</td>
<td>5.8 ± 2.2</td>
</tr>
<tr>
<td><strong>Posterior band of iliolumbar ligament</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>12.2 ± 5.0*</td>
<td>14.5 ± 4.9*</td>
</tr>
<tr>
<td>Width</td>
<td>8.0 ± 3.5</td>
<td>7.9 ± 2.8</td>
</tr>
<tr>
<td><strong>Cross-sectional area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior band</td>
<td>14.8 ± 6.9</td>
<td>17.2 ± 10.5</td>
</tr>
<tr>
<td>Posterior band</td>
<td>23.9 ± 13.9</td>
<td>26.9 ± 12.4</td>
</tr>
</tbody>
</table>

* statistically different between male and female specimens (anterior band, p = 0.045; posterior band, p = 0.015)

**Table III.** Summary of simple regression test

<table>
<thead>
<tr>
<th>Parameters*</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r value</td>
<td>p value</td>
</tr>
<tr>
<td>Length of TP – Length of A band</td>
<td>0.04</td>
<td>0.75</td>
</tr>
<tr>
<td>Length of TP – Length of P band</td>
<td>0.03</td>
<td>0.82</td>
</tr>
<tr>
<td>Width of TP – Width of A band</td>
<td>0.02</td>
<td>0.89</td>
</tr>
<tr>
<td>Width of TP – Width of P band†</td>
<td>0.29</td>
<td>0.03</td>
</tr>
<tr>
<td>Width of TP – CSA of A band</td>
<td>0.14</td>
<td>0.32</td>
</tr>
<tr>
<td>Width of TP – CSA of P band†</td>
<td>0.33</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* TP, transverse process; A band, anterior band of iliolumbar ligament; P band, posterior band of iliolumbar ligament; CSA, cross-sectional area
† positive correlation was confirmed in both male and female specimens
ent stabilising effect. We were unable to determine the biomechanical relationship between the height of the inter-crestal line and the iliolumbar ligaments.

Various clinical and radiological studies have identified prognostic factors regulating the progression from spondylolysis to spondylolisthesis. Farfan, Osteria and Lamy found that in spondylolisthesis at the L5-S1 level, slippage most commonly occurred when the transverse processes of L5 were short, giving less stability to the vertebra because of the longer iliolumbar ligament. Saraste et al. stated that the lengths of the transverse processes and the iliolumbar ligaments could not be used to predict the development of vertebral slippage. Ohmori et al. found that the craniocaudal width of the L5 transverse processes was significantly greater in 13 patients with no slip than in two other groups who showed progression of the slip. They postulated that the relative width of the transverse processes of L5 may be related to the functional strength of the iliolumbar ligament.

In our anatomical study, three of the female specimens showed a spondylolisthesis at L5; they were excluded from the review. The lengths of the anterior and posterior bands of the iliolumbar ligaments were longer in these specimens than in the 28 females entered into the study. The widths of the anterior and posterior bands of the iliolumbar ligaments were also thinner than in the 28 females. It is difficult, however, to determine whether the long and thin bands of the iliolumbar ligaments were originally of this shape before L5 spondylolisthesis occurred or whether it developed as a result of this condition. To ascertain whether the iliolumbar ligaments prevent anterior displacement of the fifth lumbar vertebra with pars defects, ideally we need measurements of the exact size of the ligaments in patients with spondylolysis and a prospective long-term follow-up study of such patients.

It is difficult to visualise the iliolumbar ligament in vivo by any imaging techniques because of the complexity and variability of the musculotendinous, fascial and ligamentous structures present in the area. Basadonna, Gasparini and Rucco analysed the anatomical characteristics of the insertion of the ligament in man using MRI. The problem remains of how to determine the biomechanical strength of the iliolumbar ligament and measure accurately its size in vivo. Therefore, we combined the clinical and anatomical study.

Ishida et al. reviewed the radiographs of 325 patients with defects of the pars of L5 and noted that the incidence of spondylolisthesis increased with age from 17% in the second decade to 51% in the sixth, but their study was retrospective and lacked follow-up. On the basis of a prospective long-term follow-up study, Fredrickson et al. reported that slippage occurred during the first and second decades, with the largest change taking place during the early teenage years, with no further slip after the age of 18 years. Hensinger found that the incidence of spondylolysis and spondylolisthesis increased until the age of 20 years and then remained constant. Wilte and Jackson reported that spondylolisthesis occurs before the age of 18 years and increases only very slightly above this age. It has thus been established that it is extremely rare for further movement to occur beyond the age of 20 years unless there has been surgical intervention. Overall, although there are exceptions regarding the development of vertebral slip in L5 spondylolisthesis after the age of 20 years, we believe it to be highly improbable that vertebral slip in L5 spondylolisthesis would occur after the age of 40 years. Hence, all our clinical subjects were older than 40 years.

Ohmori et al. made radiological measurements of L5 in the AP projection and recorded the length and width of the transverse processes as percentages of the interpedicular distance; they did not evaluate males and females separately. The tilt of L5 is, however, variable in the AP view in patients with spondylolysis at this level and even more so in patients with spondyloytic spondylolisthesis. The width of the transverse processes is not reliably measured if the tilt of L5 is variable. MacGibbon and Farfan reported that gender did influence the length of the transverse process of L5 which was significantly longer in females. Konari and Machida measured the length and width of these structures in 45 Japanese cadavers and found that they were wider in males than females. These observations agree with the findings in our anatomical study. Furthermore, we observed that the lengths of the anterior and posterior bands of the iliolumbar ligament were statistically greater in females than in males.

Ikata et al. described lesions of the endplates on either side of the lumbosacral disc associated with spondylolysis in young adults. They noted a high risk of slippage between the osseous and cartilaginous endplates, resulting in spondylolisthesis. Saraste et al. found that all spondyloytic patients, without spondylolisthesis, had a normal disc height at the time of diagnosis but that height was lost with the progression of spondylolisthesis. Saraste reported that disc degeneration was an important factor in the progress of slippage. Hensinger observed that the disc space between the fifth lumbar and first sacral vertebrae had narrowed by late adolescence or early adulthood. We believe that if a patient with defects in the pars has strong iliolumbar ligaments, the lumbosacral junction may be stable and slippage between the osseous and cartilaginous endplates or degeneration of the disc may be avoided.

Luk et al. stated that the direction of the posterior band of the iliolumbar ligament suggested that it may serve to prevent anterior slippage of the fifth lumbar vertebra. In our previous biomechanical study of the iliolumbar ligament in L5 spondylolysis, we noted that flexion and axial rotation are controlled mainly by the posterior band of the ligament. Therefore, we think that if a subject with pars defects has powerful posterior bands of the iliolumbar ligaments, they may prevent anterior slippage of the fifth lumbar vertebra by their direct restraining force.

We observed that the width of the transverse processes of
L5 was significantly greater in spondylolysis than in spondyloolisthesis in both men and women. Our anatomical study suggests that if a subject with defects in the pars has wide transverse processes, the lumbosacral junction may be stabilised by the wide posterior bands of the iliolumbar ligaments and the fifth lumbar vertebra stabilised by their direct restraining force, avoiding its anterior displacement. Clinically, there may be other factors which influence the development of vertebral slip in L5 spondylolysis, but the iliolumbar ligament is of considerable importance.

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References