Degenerative lumbar spondylolisthesis is a representative lumbar degenerative disease characterized by anterior slippage of an upper vertebra onto a lower one. This slippage results from segmental sagittal instability due to morphological abnormality of posterior components in the lumbar spine, dysfunction of the disc, and other causes such as hormogenic factors and general laxity. The slippage disc level is likely to be accompanied by spinal canal stenosis, which produces sciatica and neurogenic claudication, in which surgical intervention is sometimes necessary. Kirkaldy-Willis and Farfan divided the process of degenerative lumbar diseases into 3 phases: 1) temporary

DEGENERATIVE lumbar spondylolisthesis is a representative lumbar degenerative disease characterized by anterior slippage of an upper vertebra onto a lower one. This slippage results from segmental sagittal instability due to morphological abnormality of posterior components in the lumbar spine, dysfunction of the disc, and other causes such as hormogenic factors and general laxity. The slippage disc level is likely to be accompanied by spinal canal stenosis, which produces sciatica and neurogenic claudication, in which surgical intervention is sometimes necessary. Kirkaldy-Willis and Farfan divided the process of degenerative lumbar diseases into 3 phases: 1) temporary
dysfunction, 2) unstable phase, and 3) stabilization. Therefore, degenerative lumbar spondylolisthesis is also restabilized with further degeneration. However, in surgical intervention, some cases are treated using a laminectomy procedure only because of noninstability at the affected levels, whereas other cases require a laminectomy with fusion due to instability at the involved segments, which is usually assessed by functional radiographic findings. Thus, there are 2 different natural courses in patients with degenerative lumbar spondylolisthesis at the time of operation. It is important clinically to analyze which factors determine whether the involved disc levels are restabilized or remain unstable at the time of operation, but to our knowledge, this has not been studied in detail.

Recent studies have indicated that T2-weighted axial MR imaging detected more facet effusion in degenerative spondylolisthesis than in lumbar canal stenosis without spondylolisthesis, and that the grade of facet effusion was positively correlated with the amount of sagittal radiographic instability in degenerative lumbar disease. These results suggest the possibility that facet effusion, which is a result of degeneration in the synovial joints, might be associated with the instability of the involved segments at the time of operation in patients with lumbar degenerative spondylolisthesis.

On the other hand, other factors might affect instability at the time of operation. Increased disc degeneration, disc and facet spur formation, and ossification of longitudinal ligaments might advance restabilization, whereas highly sagittal orientation in the facet joints, representing abnormality of posterior components in the lumbar spine, is one of the causes of spondylolisthesis and might inhibit restabilization. Physical loading such as BMI also affects the skeletal features of degenerative changes, because obesity is frequently associated with osteophytosis in both sexes, and BMI might be associated with restabilization. In addition, this pathological condition occurs most often in patients over 50 years of age at the L4–5 disc level, and is found more frequently in women. Therefore, age, sex difference, and difference at the disc level might also influence the instability of the involved segment at the time of operation.

Using multifactorial analysis, we have attempted to assess which factors from those noted above determine whether the involved disc levels are restabilized or remain unstable at the time of operation in patients with degenerative lumbar spondylolisthesis.

**Methods**

**Study Population**

The candidates for participation in this study were consecutive patients who had received a laminectomy with or without fusion at our hospital between 2003 and 2007 for progressed degenerative spondylolisthesis (slip percentage > 10% in the lateral flexion position) with spinal canal stenosis. These patients had symptoms of persistent sciatica or claudication with or without low-back pain. Patients who had undergone a previous operation, as well as those with vertebral fractures, rheumatoid arthritis, or degenerative scoliosis (defined as > 10° for the entire curve) were excluded from this study. Also excluded were cases with multiple levels of vertebral slippage and slippage at the L5–S1 disc level. The Committee on the Ethics of Human Research at our hospital approved the study protocol, and informed consent for the examination was obtained from all patients.

**Study Variables**

Radiographic unstable motion in the sagittal plane was defined according to the criteria of excessive segmental motion, in which translatory displacement was > 4 mm (translatory hypermobility) or rotatory displacement was > 10° (rotatory hypermobility). The translatory and rotatory displacements were calculated as the difference of slippage length and angle in flexion-extension lateral radiographs obtained in the left decubitus position. The slip percentage was calculated as a percentage of the slippage length of the affected upper vertebra to the total length of the upper face on the affected lower vertebra. The slippage length was measured using the methods described by White and Panjabi.

The following 9 parameters were investigated retrospectively as the candidate factors to determine whether the affected segments were restabilized or not at the time of operation: age, sex, BMI, disc level, grade of disc degeneration, grade of disc spur formation, facet effusion size, length of facet spur formation, and angle between facets. Age and BMI were investigated at the time of operation. The grade of disc degeneration and disc spur formation was evaluated using semiquantitative assessment of disc degeneration and spur formation. For semiquantitative assessment of disc degeneration, the grading scale of Pearce (Grades 1–5, cited by Eyre et al.) was used in MR imaging. For the semiquantitative assessment of spur formation, the grading scale of Nathan (Grades 0–4) was used for anteroposterior plain radiographs. Facet effusion was evaluated by the method used by Chaput et al., in which facet effusion was defined as a high intensity signal area, closely matched to CSF on axial T2-weighted MR images (MRT-2003/P2, 1.5 T, Toshiba) at the slice line of the affected disc level. The measurement was recorded perpendicularly to the joint line, and the largest value was recorded as the effusion size (Fig. 1A). The length of facet spur formation was defined as the transverse length of the medial spur from the superior facet joints, which was measured from the base of the pedicle to the tip of the spur on CT (TSX-021B/4A, Toshiba) at the slice of the upper level of the pedicle in the affected lower vertebrae (Fig. 1B). This parameter was expressed as the average of the right and left values. The angle between the facets was measured as the angle between the right and left lines drawn from the intersection between the facet joints on CT images at the slice of the affected disc level (Fig. 1C). Radiographs and CT scans were obtained within 1 week before the operation. Magnetic resonance imaging was obtained within 3 months before the operation.

All radiographs, CT scans, and MR images were captured digitally and viewed using image analysis software on a Synapse viewer (Fuji). Measurements were obtained using the digital measuring tools included with the
software. All measurements were performed by a single surgeon blinded to patient data. To permit calculation of the intraclass correlation coefficients, the measurements were repeated on the same 50 patients 1 month later, and Pearson regression coefficients or kappa coefficients were calculated.

**Statistical Analysis**

The differences in sex and disc level between the unstable and stable groups were assessed using the chi-square test. The differences in the grade of candidate factors other than sex and disc level between the unstable and stable groups were assessed using the Mann-Whitney U-test.

The correlations between translatory or rotatory displacement and factors other than sex and disc level were assessed by multiple regression analysis. Multivariate logistic regression analysis for all the candidate factors was performed to assess independent factors for the presence of unstable motion at the time of operation. Multiple regression analysis and logistic regression analysis were also performed in the following 3 groups: female patients only (132 total); all patients (male and female) in which the involved segment was the L4–5 disc level only (165 total); and female patients in which the involved segment was the L4–5 disc level only (110 total). In the male patients only and the patients in whom the involved segment was the L3–4 disc level only, these analyses were not performed because of the small number of patients. In the multiple regression and logistic regression analyses, a forward stepwise selection procedure was used with probability of F ≤ 0.05 for entry and ≥ 1.0 for exit, and ORs were calculated using a CI of 95%. Probability values < 0.05 were considered significant. Analysis was performed using SPSS version 14.0 (SPSS Inc.).

**Results**

A total of 195 patients were included in this study. There were 63 males (32%) and 132 females (68%), with an average age of 66.8 years (range 37–88 years) at the time of operation. In 30 patients the involved segment was at the L3–4 disc level, and in 165 it was at the L4–5 disc level (Table 1).

The average translatory and rotatory displacements were 2.3 mm (range 0–7.1 mm) and 6.8° (range 0–20°), respectively. There were 52 unstable cases, including 23 with translatory hypermobility and 43 with rotatory hypermobility, and 143 stable cases.

The intraclass correlation coefficients calculated using the initial and repeated measurements of facet effusion size, length of facet spur formation, angle between facets, and translatory and rotatory displacement were 0.88, 0.85, 0.83, 0.71, and 0.75, respectively. The κ coefficients of disc degeneration and disc spur formation were 0.89 and 0.78, respectively.

**Sex Differences and Presence of Unstable Motion**

The proportion of male to female patients was 21/31 for the unstable group and 42/101 for the stable group. There was no significant correlation between sex differences and the presence of unstable motion (Table 1). At the L3–4 or L4–5 disc level only, there was also no significant association between sex differences and the presence of unstable motion.

**Disc Levels and Presence of Unstable Motion**

The proportion of patients in which the involved segment was the L3–4 to L4–5 disc level was 5/47 for the unstable group and 25/118 for the stable group. There was no significant correlation between disc level and the presence of unstable motion (Table 1). In males or females...
Smaller facet effusion associated with restabilization

The average facet effusion size was 1.3 and 0.8 mm for the unstable group and stable groups, respectively. Seventeen percent of patients in the unstable group had no measurable facet effusion, compared with 48% patients in the stable group. The unstable group had significantly greater facet effusion \( (p < 0.001) \) than the stable group (Table 1). On the other hand, most of the affected disc levels appeared to have moderate disc degeneration and mild disc spur formation in both the unstable and stable groups. The average disc degeneration grade for the unstable group was 3.5, with 98% of patients having Grade 3 or 4. In the stable group, 93% of patients had Grade 3 or 4 disc degeneration, for an average of 3.5 for the group. The average grade of disc spur formation for the unstable group was 1.1, with 87% having Grade 1, while the average grade of disc spur formation for the stable group was 1.1, with 83% having Grade 1. There were no cases indicating ossification of the anterior or posterior longitudinal ligaments at the affected disc levels. There were no significant differences between the 2 groups in the grade of disc degeneration or disc spur formation (Table 1). For the unstable and stable groups, the average age was 66.0 and 67.1 years, the average BMI was 23.0 and 23.8, the average length of facet spur formation was 5.4 and 5.5 mm, and the average angle between facets was 63.0° and 58.8°, respectively. There were no significant differences between the 2 groups in any of these 4 variables (Table 1).

### Translatory Displacement and Candidate Factors

Multiple regression analysis for all the factors except sex and disc level indicated that translatory displacement was significantly positively correlated with facet effusion size \( (p < 0.001) \), and no correlations were found between translatory displacement and other related factors (Table 2). These trends appeared in the female \( (p < 0.001) \), the L4–5 \( (p < 0.001) \), and the female/L4–5 \( (p = 0.002) \) groups (Table 3).

### Rotatory Displacement and Candidate Factors

Multiple regression analysis for all the candidate factors except sex and disc level indicated that rotatory displacement was significantly positively correlated with facet effusion size \( (p < 0.001) \), and no correlations were found between rotatory displacement and other related factors (Table 2). These trends appeared in the female \( (p < 0.001) \), the L4–5 \( (p < 0.001) \), and the female/L4–5 \( (p = 0.002) \) groups (Table 3).

### Translatory Displacement and Candidate Factors

#### Table 1: Summary of patient demographic data according to group*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unstable Group</th>
<th>Stable Group</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (yrs)</td>
<td>66.0 ± 10.8</td>
<td>67.1 ± 10.2</td>
<td>66.8 ± 10.4</td>
</tr>
<tr>
<td>sex (M/F)</td>
<td>21/31</td>
<td>42/101</td>
<td>63/132</td>
</tr>
<tr>
<td>BMI</td>
<td>23.0 ± 3.3</td>
<td>23.8 ± 3.3</td>
<td>23.6 ± 3.3</td>
</tr>
<tr>
<td>grade of disc degeneration</td>
<td>3.5 ± 0.5</td>
<td>3.5 ± 0.6</td>
<td>3.5 ± 0.6</td>
</tr>
<tr>
<td>grade of disc spur formation</td>
<td>1.1 ± 0.4</td>
<td>1.1 ± 0.4</td>
<td>1.1 ± 0.4</td>
</tr>
<tr>
<td>facet effusion size (mm)</td>
<td>1.3 ± 0.9†</td>
<td>0.8 ± 0.9</td>
<td>0.9 ± 1.0</td>
</tr>
<tr>
<td>length of facet spur formation (mm)</td>
<td>5.4 ± 2.1</td>
<td>5.5 ± 1.6</td>
<td>5.5 ± 1.8</td>
</tr>
<tr>
<td>angle between facets (°)</td>
<td>63.0 ± 17.7</td>
<td>58.8 ± 20.7</td>
<td>59.9 ± 20.0</td>
</tr>
</tbody>
</table>

* All data given as mean ± SD.
† \( p < 0.001 \) versus stable group.

#### Table 2: Association between translatory displacements and candidate factors according to multiple regression analysis*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standardized Regression Coefficient</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>0.013</td>
<td>NS</td>
</tr>
<tr>
<td>BMI</td>
<td>−0.025</td>
<td>NS</td>
</tr>
<tr>
<td>grade of disc degeneration</td>
<td>−0.051</td>
<td>NS</td>
</tr>
<tr>
<td>grade of disc spur formation</td>
<td>0.000</td>
<td>NS</td>
</tr>
<tr>
<td>facet effusion size</td>
<td>0.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>length of facet spur formation</td>
<td>−0.071</td>
<td>NS</td>
</tr>
<tr>
<td>angle between facets</td>
<td>0.066</td>
<td>NS</td>
</tr>
</tbody>
</table>

* NS = not significant.

#### Table 3: Related factors that significantly correlated with translatory or rotatory displacements according to multiple regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall p Value</th>
<th>Female Patients Only p Value</th>
<th>L4–5 Group* p Value</th>
<th>Female/L4–5 Group† p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>correlation w/ translatory displacements</td>
<td>facet effusion &lt;0.001</td>
<td>facet effusion &lt;0.001</td>
<td>facet effusion &lt;0.001</td>
<td>facet effusion 0.002</td>
</tr>
<tr>
<td>correlation w/ rotatory displacements</td>
<td>facet effusion &lt;0.001</td>
<td>facet effusion 0.003</td>
<td>facet effusion 0.001</td>
<td>facet effusion 0.007</td>
</tr>
<tr>
<td>age</td>
<td>−0.042</td>
<td>age</td>
<td>−0.034</td>
<td>disc degeneration −0.034</td>
</tr>
<tr>
<td>disc degeneration</td>
<td>−0.033</td>
<td></td>
<td></td>
<td>disc degeneration −0.043</td>
</tr>
</tbody>
</table>

* All patients (male and female) in which the involved segment was the L4–5 disc level only.
† Female patients in which the involved segment was the L4–5 disc level only.
displacement was significantly positively correlated with facet effusion size \( (p < 0.001) \), and significantly negatively correlated with age \( (p = -0.042) \) and grade of disc degeneration \( (p = -0.033) \). There were no correlations between rotatory displacement and other related factors (Table 4).

In the female-only group, multiple regression analysis showed that rotatory displacement was positively correlated with facet effusion size \( (p = 0.003) \) and negatively correlated with age \( (p = -0.034) \). In the L4–5 and female/L4–5 groups, the multiple regression analysis demonstrated that rotatory displacement correlated with facet effusion size positively \( (p = 0.001 \) and \( 0.007 \), respectively \) and with the grade of disc degeneration negatively \( (p = -0.034 \) and \( -0.043 \), respectively \); Table 3).

**Independent Factor for the Presence of Unstable Motion at the Time of Operation**

Multivariate logistic regression analysis for all the candidate factors demonstrated that increased facet effusion size \( (OR \ 1.656, 95\% \ CI \ 1.182–2.321) \) was the only independent factor for the presence of unstable motion at the time of operation. Logistic regression analysis for related factors other than disc level indicated that this trend also appeared in the L4–5 groups \( (OR \ 1.739, 95\% \ CI \ 1.209–2.503) \). Logistic regression analysis for related factors other than sex demonstrated that increased facet effusion size \( (OR \ 1.779, 95\% \ CI \ 1.157–2.734) \) and increased angle between facets \( (OR \ 1.022, 95\% \ CI \ 1.000–1.045) \) were related factors for the presence of unstable motion in the female-only group, but logistic regression analysis for related factors other than sex and disc level showed that only increased facet effusion size \( (OR \ 1.710, 95\% \ CI \ 1.101–2.655) \) was a related factor for unstable motion in the female/L4–5 group (Table 5).

**Positive and Negative Predictive Value of Facet Effusion for Presence of Unstable Motion**

If the cutoff value of facet effusion size was assumed to be 1.0 or 1.5 mm based on the results in the previous paper, \(^3\) the PPV, meaning the ratio of patients manifesting the presence of both radiographic unstable motion and facet effusion to those manifesting the presence of facet effusion only, was 36 and 42%, respectively; the NPV, meaning the ratio of patients manifesting the absence of both radiographic unstable motion and facet effusion to those manifesting the absence of facet effusion only, was 81 and 79%, respectively. These results suggest that facet effusion size had a high NPV but low PPV for determining unstable motion at the time of operation (Table 6).

To analyze the reason for the low PPV, all candidate factors were compared between the stable and unstable groups in patients with larger or smaller facet effusion size. If the cutoff value of the facet effusion size was assumed to be 1.0 mm, there were no significant differences between the 2 groups in all the related factors in patients with larger facet effusions, while the unstable group had significantly greater facet effusion than the stable group \( (p = 0.006) \), and there were no significant differences between the 2 groups in other related factors, including the length of facet spur formation (Table 7).

**Table 4: Association between rotatory displacements and candidate factors according to multiple regression analysis**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standardized Regression Coefficient</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>-0.14</td>
<td>0.042</td>
</tr>
<tr>
<td>BMI</td>
<td>-0.054</td>
<td>NS</td>
</tr>
<tr>
<td>grade of disc degeneration</td>
<td>-0.15</td>
<td>0.033</td>
</tr>
<tr>
<td>grade of disc spur formation</td>
<td>-0.03</td>
<td>NS</td>
</tr>
<tr>
<td>facet effusion size</td>
<td>0.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>length of facet spur formation</td>
<td>-0.057</td>
<td>NS</td>
</tr>
<tr>
<td>angle between facets</td>
<td>0.056</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Discussion**

In this study, the unstable group had significantly greater facet effusion \( (p < 0.001) \) than the stable group. Multiple regression analysis demonstrated that translatory displacement correlated with facet effusion size positively, and that rotatory displacement correlated with facet effusion size positively and with age and grade of disc degeneration negatively. In addition, logistic regression analysis showed that increased facet effusion size was the only independent factor for the presence of unstable motion at the time of operation. These results suggest that the grade of facet effusion might have a strong association with radiographic unstable motion of the involved segments at the time of operation in patients with degenerative spondylolisthesis, which is consistent with the results of a recent previous study. \(^9\)

It is well accepted that segmental instability increases with moderate disc and facet degeneration, while restabilization occurs with advanced disc and facet degeneration. \(^12\) Fujiwara et al. \(^5\) also showed that segmental motion increased with increased severity of disc degeneration up to Grade 4 (Eyre et al.), but decreased when disc degeneration advanced to Grade 5 in both sexes, and that motion in all directions increased with Grade 3 (Grogan et al.) cartilage degeneration and decreased with Grade 4 cartilage degeneration in males in a biomechanical study using cadavers. In our study, most patients in both the unstable and stable groups had moderate disc degeneration (Grade 3 or 4) and mild spur formation. This finding implied that both groups might have the potential to increase segmental instability in reference to disc degeneration and disc spur formation, which presumably applied only to the operated cases in this study. A previous study demonstrated that most patients with advanced disc degeneration tended not to receive an operation. \(^13\) Because...
there were no significant differences in disc degeneration and disc spur formation between the unstable and stable groups, the role of facet degeneration might be more important in determining segmental instability at the time of operation.

Facet effusion results from degenerative arthritis in the facet joints. However, a previous paper demonstrated that facet effusion was greater in patients with moderate or less osteoarthritis than in patients with severe osteoarthritis. Accordingly, the existence of facet effusion implies an approximately moderate degeneration in the facet joints. Because segmental instability increased with moderate facet degeneration, presumably accompanied by loosening of capsules and ligaments in the facet joints, the existence of facet effusion might have the potential to increase segmental instability.

In the present study, most of the patients were over 50 years old, there were more than twice as many female patients as male, and the pathological conditions frequently occurred at the L4–5 disc level. The angles between the facets in the present patients were similar to the data of spondylolisthesis in a previous paper, which indicated a more sagittal orientation than that in patients with nonslippage degenerative lumbar disease. It was a natural result that the above findings were consistent with the characteristics indicated as the cause of spondylolisthesis. However, there were no significant associations between differences in sex, disc level, and presence of unstable motion. There were no significant differences between the unstable and stable groups in terms of age or angle between facets. The logistic regression analysis showed that age, sex, disc level, and angle between facets were not related factors for the presence of unstable motion. In addition, the results of multiple and logistic regression analysis in the L4–5, female-only, and female/L4–5 groups were similar to the results in all patients. These results suggest that the cause of spondylolisthesis might not be associated with the determination of whether the involved segments were restabilized or not.

In our study, the NPV of facet effusion was high, while the PPV was low. This finding suggests that if less facet effusion is observed, the affected disc level has a higher possibility to have already stabilized. However, if greater facet effusion is found, it might not always determine that the affected disc is unstable, meaning that greater facet effusion in itself might not be an indicator in clinically determining segmental instability in degenerative spondylolisthesis. One of the reasons for the low PPV might be the association of different related factors with stabilization of the affected discs in patients with greater facet effusion. In this study, the unstable group had significantly shorter facet spur formation than the stable group in the patients with greater facet effusion (facet effusion size \(\geq 1.5 \text{ mm}\); \(p = 0.042\)), but there was no significant difference in the length of facet spur formation between the 2 groups of patients with lesser facet effusion. This result demonstrated that facet spur formation might play an important role in stabilizing the affected segments in patients with greater facet effusion, which might reduce the PPV of facet effusion for the presence of unstable motion. Because the number of patients with smaller facet effusion was larger in this study, there might have been no significant difference between the 2 groups in the length of facet spur formation overall.

Compared with our results, previous recent studies noted a comparatively higher PPV of the grade of facet effusion for the presence of instability. To evaluate segmental motion, our study used the lateral decubitus functional position, whereas previous studies used the standing functional position, which included axial loading. Wood et al. demonstrated that the lateral decubitus position provided more radiographic translatory displacements than the standing position, presumably due to reduction of paraspinal and abdominal muscle power, but there was no significant difference between the 2 positions in the radiographic rotatory displacements. Therefore, the difference of positioning during the functional view (flexion-extension lateral radiographs) might have had a small effect on the low PPV in our results. On the other hand, the patients in our study were about 10 years older, on the average, than those in previous studies. This difference means that the patients in our study might have had a greater tendency to progression of facet spur formation with facet degeneration than did the patients in previous studies.

The criterion of excessive motion, or hypermobility, was used in this study to determine whether the affected segments were unstable or stable. Most surgeons define segmental instability as either 10° of angular motion or 4 mm of translation on controlled flexion-extension radiographs. However, instability should fundamentally be assessed as the radiographic abnormal motion concomitant with clinical symptoms. Although all the patients in our study had symptoms due to spinal canal stenosis with or
without abnormal motion, it was difficult to strictly distinguish the symptoms with abnormal motion from those without motion. Therefore, our study defined unstable motion based upon the radiographic excessive motion in the functional view.

There were some limitations in our study. This study had a small sample size. The patient population did not reflect the prevalence of degenerative spondylolisthesis in the general population, because the study participants were operated cases, as mentioned above. In addition, in this study we did not investigate the general laxity and muscle power of the participants, which might be related to instability, as such an assessment would have been difficult for older patients.

**Conclusions**

In Japanese patients with lumbar degenerative spondylolisthesis, facet effusion size was associated with the determination of whether the affected disc was stabilized or remained unstable at the time of operation. In particular, smaller facet effusion strongly suggested that the affected disc had been restabilized in these patients.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Smaller facet effusion associated with restabilization

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