Which Portion in a Facet is Specifically Affected by Articular Cartilage Degeneration with Aging in the Human Lumbar Zygaphophysial Joint?

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Summary: Using 10 osteoligamentous vertebral columns obtained from elderly donated cadavers, we describe in detail degenerative changes of the articular cartilage in lumbar zygaphophysial joints to show which portion in a facet is specifically affected. Degenerative changes, including extended cartilage defects, occurred in multiple facets of every specimen. The results demonstrated 5 basic morphologies of degeneration, i.e., 1) marginal dominance in the articular surface, 2) lower segment dominance except for the lowest (L5/S) facet, 3) advancement in the inferior articular process, 4) cranial and caudal dominance rather than the dorsal dominance in the articular surface and 5) progress in a mirror-image manner. These rules seemed to be consistent with differences in size, shape and kinesiological aspects of the facet between segments and between portions in a facet.

Although degenerative changes of the articular cartilage (DCs) in the human lumbar zygaphysial joint are very commonly found in routine clinical work (Fujiwara et al., 1999), anatomical observations on them are surprisingly few in number, especially for investigation of DC localization in a facet. Swanepoel et al. (1995) reported that, using 29 cadavers (ages, 17–78 years), the DCs were evident in the superior joint surface, marginal portions and dorsal side of the facet. Notably, they also reported that there was no significant correlation between age and DCs. Gries et al. (2000), using 29 cadavers (ages, 15–40 years), histologically described dorsal dominance in DCs in the lower lumbar facet. Data on localization of DCs in a facet are helpful for a discussion connected to the detailed morphometrical results of the joint surface and capsule such as that recently provided by Sato et al. (2002). However, the few previous reports seem to be too general to use for such a discussion. Consequently, the aim of this study is to examine the DCs in human lumbar zygaphophysial joints to describe in detail which portion in a facet is specifically affected.

Materials and Methods

We obtained 10 osteoligamentous specimens (5 males and 5 females) of the lumbar vertebral column (20 surfaces in L1/2–L5/S per body) from the annual dissection practices in Sapporo Medical University and Health Sciences University of Hokkaido. The ages of cadavers ranged from 62–95 years (mean, 78.8 years). Because of complete fusion of the facet with severe degeneration and because of damage during dissection, 28 of the 200 articular surfaces were not available for observa-
Complete fusion of the facet with severe degeneration was found in L4/5 (3 sides of 2 cadavers) and L3/4 (1 side). Numbers of facets examined are shown in Table 1. In short, we examined 172 articular surfaces (85 left and 87 right surfaces; 86 superior and 86 inferior surfaces) or 860 sectors (425 sectors in the left side and 435 sectors in the right side; 430 sectors in each of the superior and inferior articular processes). The DCs were depicted according to the classification of Grogan et al. (1997), i.e., normal cartilage (grade 1), fibrillation (grade 2, Fig. 1A), and cartilage defects (grades 3 and 4, Fig. 1B). However, in most of the present results, we simply divided the DCs (grades 2–4) into “fibrillation” and “cartilage defect” categories. To differentiate regional specificity of DCs, the superior and inferior joint surfaces were divided into 5 sectors for depiction, i.e., the dorsal, ventral, cranial, caudal and central sectors (Fig. 2).

### Results

All 10 specimens had DCs in some or most articular surfaces (the superior and inferior surfaces of the bilateral 10 facets) in the lumbar vertebral column. Cartilage defects were found in all 10 cadavers. They existed in 98 of the 172 articular surfaces examined (57.0%) although the size or number of affected sectors varied individually (from 1 to all 5 sectors). The smallest number of affected articular surfaces with cartilage defects was 5 in specimen No. S18 (this specimen will also be referred to below). Surprisingly, non-affected surfaces were limited to 2 in number (the unilateral L1/2 in a single cadaver), whereas in the most advanced case (1 cadaver), cartilage defects were found in every articular surface. The cartilage defects tended to occur in the lower segments (Fig. 2), but the lower 2 facets, except for L5/S (i.e., L3/4 and L4/5), were most frequently affected with cartilage defects, including complete fusion (L3/4, 14 of the 20 sides or 70.0%; L4/5, 17 of the 20 sides or 85.0%).

Cartilage defects were observed in 210 of the 860 sectors examined. Which of the superior and inferior articular processes was more frequently affected? In the 430 superior articular processes, 92 sectors displayed cartilage defects (21.4%), whereas in the inferior processes with another 430 sectors, we found them in 118 sectors (27.4%). This slight dominance in the inferior process was particularly evident in 2 cadavers, i.e., 15.0% (superior) vs. 37.8% (inferior) in specimen No. T10 and 6.0% vs. 30.0% in specimen No. S18. However, when the incidence of fibrillation was compared between the superior and inferior processes, this early lesion occurred more frequently in the superior process (206 of 430 sectors, 47.9%) than in the inferior one (41.9% of another 430 sectors). Likewise, in the 2 above-mentioned specimens, the fibrillation also showed superior process dominance, i.e., 67.5% (superior) vs. 48.9% (inferior) in specimen No. T10 and 52.0% vs. 32.0% in specimen No. S18. Thus, the superior process tended to be affected frequently, whereas the DCs advanced more severely in the inferior process. In addition, there was a slight difference in localization of DCs in the articular surface between the superior and inferior processes (see below).

Of the 860 sectors examined, we could depict data about 390 pairs in the complementary superior and inferior articular surfaces. In the majority of the 390 paired sectors (230/390 or 59.0%), the grade of DCs, including normal cartilage or grade 1, was the same in the 2 complementary surfaces. Thus, DCs tended to occur in a mirror-image manner. However, in another 160 pairs of sectors, the superior (inferior) surface was advanced in 77 (83). Which of the complementary surfaces was advanced varied between segments as well as between individuals, e.g., in specimen No. S18, the superior (inferior) surface was advanced in 10 (18) of the 28 sectors showing non-mirror image lesions. However, in those 160 paired non-mirror-image lesions, the difference in the DC grade between the complementary surfaces was usually limited to 1 grade such as between grades 2 and 3. In only 24 pairs of sectors (6 of the 10 cadaver), was there a 2-grade-difference such as between grades 1 and 3. Nevertheless, non-mirror-image lesions tended to be associated grade 4, severe cartilage defects (21 of the 24 pairs).

Of 5 sectors of one facet surface, most cartilage defects were found in the cranial, caudal and dorsal

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<th>Table 1. Numbers of facets examined</th>
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<tr>
<td>L1 inferior articular surface</td>
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*14 of all 20 articular surfaces in 10 specimens. Totally, 172 of all 200 surfaces (or 860 of the 1000 sectors) were examined.
sectors (65, 59 and 58 sectors, respectively). DCs occurred much less frequently in the central sector than in the 4 marginal sectors with statistical significance (p < 0.01 by Student’s T test) in every segmental level. In the 4 marginal sectors, the ventral sector was affected less frequently than the cranial and dorsal sectors (p < 0.01) and the caudal sector (p < 0.05). Thus, we often observed a regional specificity or localization of DCs in a facet, which could be summarized in the order “central sector < ventral sector < dorsal sector < caudal sector < cranial sector” in frequency and/or grade (Figs. 1 and 2). However, a slight difference was found in this order of incidence between the superior and inferior articular process, i.e., “< the dorsal sector < caudal sector < cranial sector” in the superior process, whereas in the inferior process, it was “< the caudal sector < dorsal sector < cranial sector.”

Although cartilage defects were observed in 98 of the 172 articular surfaces (see above), they sometimes (29 of 98; 29.6%) occurred solitarily in the surface, i.e., only in the cranial (11 surfaces), dorsal (10), caudal (6) or ventral (2) sector. No solitary cartilage defect was restricted to the central sector. Even solitary fibrillation restricted to the central sector was found only in 2 articular surfaces.
In contrast, in the majority, multiple sectors in one surface had cartilage defects. A combination “the dorsal and cranial sectors” was most frequent for the affected sectors (37 of the 98 surfaces; 37.8%) and a similar combination of “the dorsal, cranial and caudal sectors” was next most frequent (22 of the 98 surfaces; 22.4%), irrespective of whether any other sector was also affected.

Left/right difference or laterality in DCs was not evident, i.e., a 2-grade difference such as “grade 1 in the left side and grade 3 in the right side” was limited to 18 of the 860 sectors (2.1%). These 18 cases were distributed almost evenly in the 4 marginal sectors (3 cranial, 4 caudal, 6 dorsal and 5 ventral sectors). Intergender difference in DCs was not evident. Because most cadavers were 70–90 years of age, age-dependent differences could not be found. In addition, the inferior articular surface was slightly curved and convex, whereas the complementary superior surface was almost flat. Usually, the superior surface appeared to be larger than the inferior one.

**Discussion**

According to Takada (1973), in Japanese, the DCs in the lumbar zygapophysial joint begin at around 20 years of age and greatly advance in the forties and fifties. Thus, the DCs seemed to be advanced almost completely in the present population examined. Our results included 5 basic morphologies of the lumbar facet DCs, i.e., 1) marginal dominance, 2) lower segment dominance except for the L5/S facets, 3) advancement in the inferior articular process, 4) cranial and caudal dominance and 5) progress in a mirror-image manner.

Although the present descriptions were much more detailed than in previous reports, features 1 and 2 were consistent with Swanepoel et al. (1995). The lower segment dominance seemed to depend on range of rotation as well as the load increasing in the lower segment. In the lower segment, severe disk degeneration also seemed to be connected to the high incidence of DCs. The marginal dominance seems to be understandable because the ar-
ticular surface is not flat but curved. Thus, depending on the increasing load, the contact area in the facet also seems to increase, i.e., there should be, in varying degrees, a change in congruity from the marginal contact to the whole area contact as is well known in the elbow joint (Eckstein et al., 1995).

The third point of the basic morphologies, i.e., the advancement in the inferior articular process, appeared to be different from the conclusion of Swanepoel et al. (1995). However, their observations were concentrated on fibrillations and grade 2 of DCs. Actually, in the present study as well, fibrillation was found in the superior process more frequently than in the inferior one. Moreover, the population they examined was much younger than that in the present study. Thus, they seemed to conclude that there was superior articular process dominance (discussed also in the last paragraph).

The fourth feature, the cranial and caudal dominance, seemed to be a result of our minute description. Conversely, the previous study simply divided the facet surface into the dorsal and ventral portions. In the upper lumbar segments, the craniocaudal alignment of the facet seemed to provide the craniocaudal dominance of DCs. This high incidence in the craniocaudal sectors seemed to indicate an overall tendency because, in the lower segments, all marginal sectors including the craniocaudal ones were equally liable to be affected with DCs in the elderly.

The final point, the mirror-image progress, was not well investigated in previous studies except by Hirose et al. (1999) and Nakamura et al. (2001). In general, all DCs seemed to have been believed to occur in the mirror-image manner because in radiological observations of is hard to identify non-mirror lesion images. However, we found clear exceptions in 24 sectors, i.e., a 2-grade difference in the DCs between the complementary articular surfaces. These non-mirror lesions tended to be associated severe the grade 4 cartilage defect (21 of the 24 pairs).

The superior articular process had fibrillation more frequently than the inferior one. This result was consistent with Swanepoel et al. (1995). However, the advanced stage of DCs or cartilage defects showed inferior dominance (see above). Why does the DC advance in the inferior process rather than the superior one? Sato et al. (2002) reported that, in their recent morphometrical study, the superior articular surface was almost always larger than the complementary inferior surface. In general, a wide and curved surface can distribute a load to the entire surface depending on amount of the load, whereas a small flat surface tends to concentrate it on a point (Eckstein et al., 1995; Gries et al., 2000).

Thus, the inferior surface is likely to be affected more easily than the superior one. This discussion may be controversial considering the high incidence of fibrillations in the superior articular process. Moreover, a high incidence of subcapsular pockets in the caudal margin of the inferior articular process (Sato et al., 2002) is likely to accelerate impingement of the capsule in extension. They may prevent DCs of the superior articular surface but seems to cause caudal capsular damage and following DCs in the caudal sector of the inferior articular process. However, in the present examinations, the dorsal sector was more frequently affected with cartilage defects than the caudal sector in the inferior process. The superior articular process also seems to have a disadvantage, i.e., a kind of collision (the so-called “bottoming”) with the vertebral arch (Yang and King, 1984; El-Bohy et al., 1989) that seems to cause DCs in the superior process. Overall, the above-mentioned disadvantage in the inferior articular process seemed to overcome that in the superior process and result in advanced DCs.

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References


