Age-Related Progression of Degenerative Lumbar Kyphoscoliosis: A Retrospective Study

Yohei Ishihara[1)], Masutaro Morishita[1)], Koji Kanzaki[2)] and Tomoaki Toyone[3)]

1) Asao General Hospital Spine Center, Kawasaki, Japan
2) Department of Orthopedic Surgery, Showa University Fujigaoka Hospital, Yokohama, Japan
3) Department of Orthopaedic Surgery, School of Medicine, Showa University, Tokyo, Japan

Abstract:

Introduction: Degenerative lumbar kyphoscoliosis is a serious clinical condition that affects activities of daily living. This study aimed to investigate the age-related progression of nonoperative degenerative lumbar kyphoscoliosis, to clarify its final state in elderly people, and to identify factors associated with its progression.

Methods: This retrospective longitudinal study included 115 nonoperative cases (mean age at first consultation, 70.9 years; range, 50-89 years). All were followed up for >6 years. The analysis included changes between initial and latest measurements in the coronal parameters (Cobb angle, L4 tilt angle, intervertebral angle, lateral spondylolisthesis, and C7-central sacral vertical line) and sagittal parameters (thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, sacral slope, sagittal vertical axis, and vertebral wedging rate). Factors in scoliosis progression were investigated by analyzing the correlations between the initial parameter values and the increase in Cobb angle.

Results: Changes in the coronal parameters increased with age from 50s to 70s but decreased significantly in those aged 80s. Sagittal parameters increased by the age group, accelerating in those aged 80s, with the progression of vertebral wedging. In patients aged 50s-70s, the increase in Cobb angle correlated significantly with the initial Cobb angle, L4 tilt angle, and L4/L5 intervertebral angle. However, in the cases without initial scoliosis, the increase in Cobb angle correlated significantly only with the L4 tilt angle. There were no significant differences in any parameter according to the use of a trunk brace or medication for osteoporosis.

Conclusions: L4 tilt angle is an important factor in the progression of degenerative scoliosis. The progression of scoliosis gradually ends after the age of 80 years with the decreasing variation of L4 tilt angle, whereas kyphosis accelerates with aging, especially in those aged >80 years, with the progression of vertebral wedging.

Keywords:

degenerative lumbar kyphoscoliosis, scoliosis, kyphosis, age-related progression, L4 tilt angle

Spine Surg Relat Res 2020; 4(3): 229-236
dx.doi.org/10.22603/ssrr.2019-0113

Introduction

Japanese society is aging to an unprecedented level, with people living longer and the birth rate declining. According to the 2018 annual report of Japan's Cabinet Office, 27.7% of the population was aged over 65 years and 13.8% over 75 years, with these proportions increasing rapidly year by year[1)].

Degenerative lumbar scoliosis is defined as curvature of the spine with a Cobb angle > 10° in the coronal plane that is associated with aging, with progressive disc and facet degeneration, and with no previous history of scoliosis[2,3)]. Schwab et al. investigated 75 cases of patients aged >60 years (mean, 70.5 years) with no previous spine surgery and found the prevalence rate of scoliosis to be 68%[4)]. Another characteristic spinal deformity observed in elderly people is degenerative lumbar kyphosis, first described by Takemitsu et al. in 1988[5)]. This condition is defined by abnormal sagittal curvature, with kyphosis or a marked loss of lordosis in the lumbar spine caused by degenerative changes, such as atrophy of the lumbar extensor muscle. As a result of the aging society, these spinal deformities, collectively referred

Corresponding author: Yohei Ishihara, youyuka627@yahoo.co.jp
Received: November 27, 2019, Accepted: January 25, 2020, Advance Publication: March 19, 2020

Table 1. Demographic Data on Initial Consultation (N=115).

	N=115
Sex	
Male	31 cases
Female	84 cases
Age	
Mean age	70.9 age-old (50-89)
50s (50-59 years)	17 cases (male: 5, female: 12)
60s (60-69 years)	24 cases (male: 5, female: 19)
70s (70-79 years)	51 cases (male: 18, female: 33)
80s (80-89 years)	23 cases (male: 3, female: 20)
Initial scoliosis (Cobb angle>10°)	
scoliosis+	66 cases (male: 14, female: 52)
scoliosis -	49 cases (male: 17, female: 32)
Main clinical symptoms	
low back pain	57 cases
neurologic manifestation	24 cases
same level with low back pain and neurologic manifestation	22 cases
others, unknown	12 cases

to as degenerative lumbar kyphoscoliosis (DLKS) have recently become among the most common spinal disorders. This is a serious clinical condition that affects the patient's ability to perform activities of daily living because of symptoms, such as severe back and leg pain, trunk imbalance, and gastroesophageal reflux disease[6,7].

With the increasing numbers of patients suffering from DLKS, there have been various reports describing surgical procedures, including corrective fusion with multi-segmental posterior instrumentation, vertebral osteotomy, and lateral interbody fusion[8,9]. These reports described perioperative complications; conversely, untreated degenerative scoliosis can result in curve progression, with studies reporting various risk factors for this[10,11]. However, most of these studies analyzed cases that included both those with and without scoliosis at the time of the first measurement, and so the most important factors of curve progression may have not been fully elucidated yet. In addition, thus far as we are aware, there have been no detailed reports on longitudinal investigations of the natural courses of degenerative scoliosis and kyphosis, especially for patients aged over 80 years.

This study aimed to investigate the age-related progression of nonoperative DLKS in patients aged 50-89 years at first consultation, clarify its final state in elderly people, and identify risk factors for its progression in patients without scoliosis at the first consultation, who were followed up conservatively for at least 6 years.

Materials and Methods

This is a retrospective study approved by the Institutional Review Board of our hospital, and informed consent was obtained from all patients.

Patients

From 2007 to 2012, 1604 patients underwent whole-spine X-ray radiography in association with their first consultation at our hospital. Of these, the present study included only those aged >50 years at the first consultation, who had been followed up for at least 6 years, and who underwent subsequent whole-spine X-ray imaging at least 6 years after the first consultation in which the latest Cobb angle was over 10°. Patients were excluded if they had undergone surgical treatment or if their condition was accompanied by pathological vertebral collapse, including from a primary or metastatic tumor or from infection. Of the excluded cases, 866 underwent surgical treatments. These included corrective fusion for DLKS (n = 20), fusion for lumbar spondylolisthesis or lumbar canal stenosis (n = 115), fusion for vertebral collapse (n = 14), lumbar laminoplasty or laminectomy (n = 551), discectomy (n = 117), and others (n = 49). The final analysis included 115 nonoperative cases (31 men and 84 women) of patients with back pain or neurological symptoms that were not severe enough to require surgical treatment. The main clinical symptoms on initial consultation were low back pain (n = 57), neurologic manifestations (n = 24), same level with low back pain and neurological manifestations (n = 22), and others and unknown (n = 12). All were treated conservatively and followed up for at least 6 years (mean, 84.5 months; range, 72-120 months) with the occasional checking of X-ray images. The mean age at first consultation was 70.9 years (range, 50-89 years); 17 were aged 50s (50-59 years), 24 were 60s (60-69 years), 51 were 70s (70-79 years), and 23 were 80s (80-89 years) (Table 1).

Measures

The following measurements were made from front-lateral standing whole-spine radiographs (MUVERIC Web Viewer

Table 2. Changes in Coronal Parameters between the Initial and Latest Consultation (N=115).

		Initial consultation	Latest consultation	Change
Cobb angle (degrees)		12.3±8.3	18.1±10.9*	+5.9±5.4 ↑
L4 tilt (degrees)		6.3±4.8	10.0±5.4*	+3.7±2.9 ↑
Intervertebral angle (degrees)	L1/2	1.9±2.0	3.0±2.6	+1.2±1.4 ↑
	L2/3	3.0±2.6	4.2±3.3*	+1.2±1.8 ↑
	L3/4	2.6±2.4	3.9±3.3*	+1.3±1.6 ↑
	L4/5	4.0±2.8	6.0±3.7*	+2.0±2.3 ↑
	L5/S	1.0±1.4	2.0±2.3	+1.0±1.5 ↑
C7-CSVL (mm)		15.6±16.8	22.9±17.6*	+7.3±7.4 ↑
Lateral spondylolisthesis (mm)	L1	1.1±1.2	1.7±1.8	+0.6±0.9 ↑
	L2	1.6±1.5	2.6±2.1	+1.0±1.2 ↑
	L3	3.4±2.3	4.6±3.1*	+1.2±1.8 ↑
	L4	2.8±2.3	4.2±2.9*	+1.4±1.7 ↑
	L5	0.9±0.8	1.3±1.4	+0.4±0.5 ↑

CSVL, central sacral vertical line. * P<0.05

10.2, Rimpack Inc., Kanagawa, Japan): coronal parameters, including the Cobb angle, L4 tilt angle, intervertebral angle (L1/2-L5/S), lateral spondylolisthesis (L1-L5), and C7-central sacral vertical line; sagittal parameters, including thoracic kyphosis (Th1-Th12), lumbar lordosis (L1-S1), pelvic incidence, pelvic tilt, sacral slope, sagittal vertical axis, and vertebral wedging rate (L1-L5, calculated as the anterior height of the vertebra / the posterior height of the vertebra × 100%). In cases where vertebral height was not clearly identified by vertebral collapse or degeneration, we applied the average height (maximum height + minimum height × 1/2). These measurements were made from the initial and latest radiographs for each patient, and changes from initial to latest measurement (latest measurement value - initial measurement value) was calculated. The degree of osteophyte formation using Nathan's classification[12] was also evaluated in each age group from the initial radiographs (L1/L2-L4/L5, total: 460 segments). In addition, the patient's age at the first consultation, sex, the use or not of a trunk brace, and the use or not of medication for osteoporosis were recorded.

Statistical analysis

The measurement values are expressed as mean ± standard deviation. Comparisons between the initial and latest measurement values were evaluated by paired t-tests. Differences between the 10-year age groups were evaluated by one-way analysis of variance, and comparisons of parameters between the sexes, the use or not of a trunk brace, and the use or not of medication for osteoporosis were evaluated by Mann-Whitney U tests. Risk factors for the progression of degenerative scoliosis were investigated by evaluating Spearman's rank correlation coefficients for the correlations between the initial value of each parameter and the increase in Cobb angle between the initial and latest measurements. A P-value < 0.05 was considered statistically significant. The analyses were conducted using the JMP 13 software (SAS Institute Inc., Cary, NC, USA).

Results

The progression of kyphoscoliosis was observed between the initial and latest X-ray acquisitions, with significant differences in the measurements of almost all the parameters (Table 2, 3). Changes in the coronal parameters, such as the Cobb angle and L4 tilt, increased with age group from 50s to 70s but decreased significantly in the 80s group (Fig. 1). In the patients aged 50s-70s, but not those aged 80s, the increase in Cobb angle exhibited significant correlations with the initial Cobb angle (r = 0.32), L4 tilt angle (r = 0.35), and L4/L5 intervertebral angle (r = 0.31) (P < 0.05). In the 49 cases without scoliosis at the first consultation (i.e., with an initial Cobb angle <10°), the mean increase in Cobb angle was 5.0°, and this correlated significantly with only the initial L4 tilt angle (r = 0.43). In four cases, rapid and severe progression was observed over only a few years. Two of these patients were women aged over 80 years, and the progression was associated with lumbar vertebral collapse. The other two patients had large L4 tilt angles at the initial measurement (13.8° and 11.5°), and the progression of scoliosis was accompanied by a serious increase in the L4 tilt angle and lateral vertebral spondylolisthesis with coronal imbalance (Fig. 2, 3)[13].

Unlike the coronal parameters, the change in sagittal parameters increased with age, accelerating especially in those aged 80s with the progression of vertebral wedging (Fig. 4). There were 15 cases [70s (n = 8), 80s (n = 7)] in which we identified severe progression of vertebral wedging (average change in vertebral wedging was >20%), and significant changes were found in lumbar lordosis, pelvic tilt, sacral slope, and sagittal vertical axis.

Table 3. Changes in Sagittal Parameters between the Initial and Latest Consultations (N=115).

		Initial consultation	Latest consultation	Change
Thoracic kyphosis (degrees)		32.9±8.1	39.2±12.2	+6.3±10.5 ↑
Lumbar lordosis (degrees)		42.4±10.3	37.0±13.5*	−5.4±6.5 ↓
Pelvic tilt (degrees)		20.0±6.1	24.5±7.8*	+4.5±6.0 ↑
Sacral slope (degrees)		30.2±6.4	26.9±7.1*	−3.2±4.1 ↓
Pelvic incidence (degrees)		49.6±8.2	51.7±8.7	+2.2±2.1 ↑
Sagittal vertical axis (mm)		42.2±30.6	76.7±43.6*	+34.5±23.5 ↑
Wedging rate (%)	L1	87.9±10.2	78.2±13.1*	−9.7±10.1 ↓
	L2	89.3±8.5	79.7±11.7*	−9.6±8.4 ↓
	L3	92.7±8.0	82.3±11.6*	−10.4±11.0 ↓
	L4	93.6±8.3	85.7±11.0*	−9.8±10.6 ↓
	L5	99.7±7.6	92.1±8.6*	−7.6±5.6 ↓
	Average (L1-L5)	93.0±4.8	83.6±8.2*	−9.4±7.5 ↓

* P<0.05

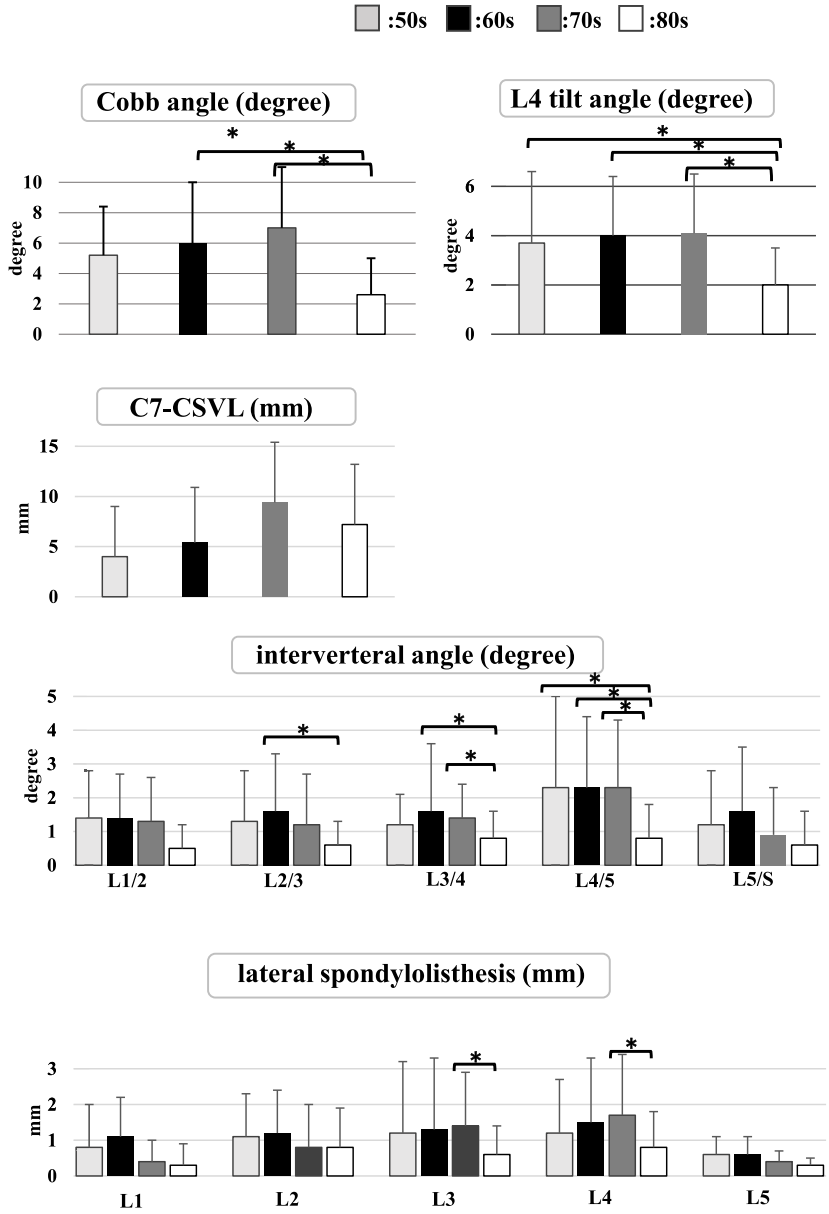

Figure 1. Changes in the coronal parameters by age group. *P<0.05

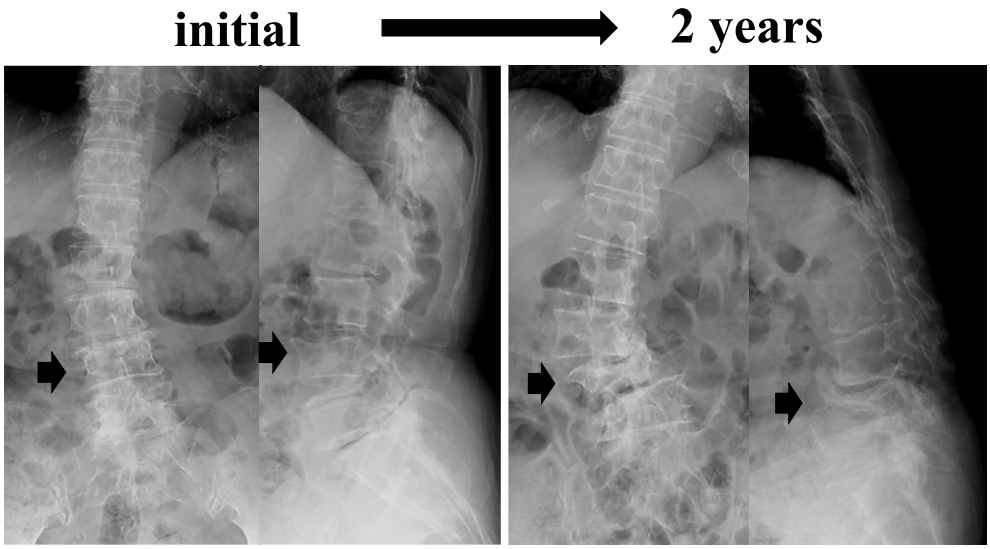

Figure 2. Rapid progression of kyphoscoliosis in an 83 age-old woman. The progressions observed over 2 years, accompanied by collapse of the L4 vertebra despite the use of a hard brace and parathyroid hormone medication.

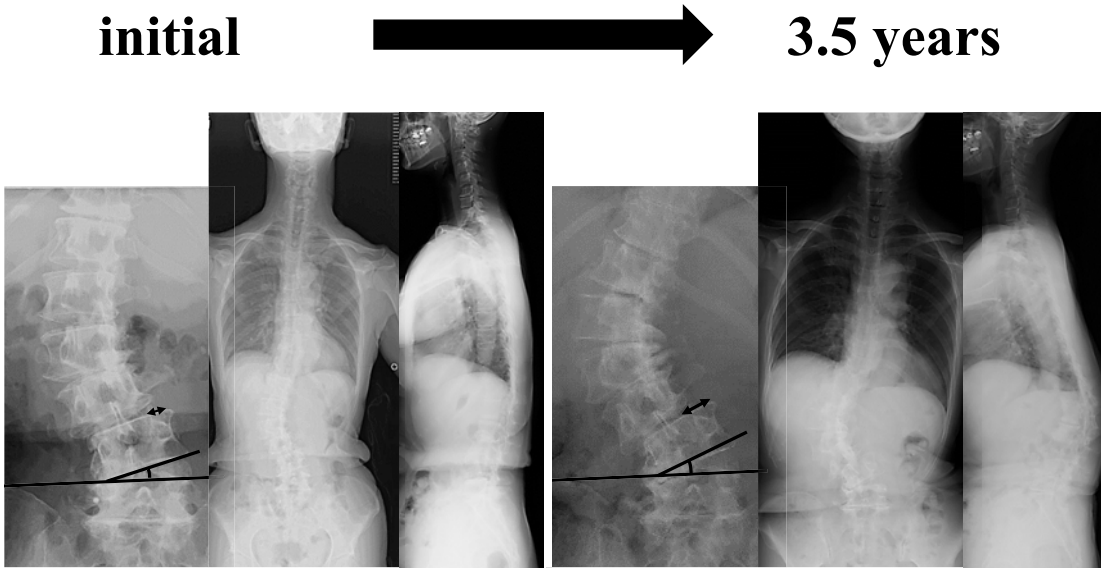

Figure 3. A 74 age-old woman with a large L4 tilt (13.8°). Serious progression of kyphoscoliosis was observed over a 3.5-year period, as shown by the increase in L4 tilt with the collapse of L5 cranial endplate and vertebrae lateral spondylolisthesis (double-headed arrow).

According to Nathan's classification, the degree of osteophyte formation proceeded significantly with age group ($P < 0.05$), classified as 50s (68 segments); lst degree: 64.7% (44 segments), 2nd: 27.9% (19 segments), 3rd: 7.4% (5 segments), 60s (96 segments); lst degree: 25.0% (24 segments), 2nd: 51.0% (49 segments), 3rd: 19.8% (19 segments), 4th: 4.2% (4 segments), 70s (204 segments); lst degree: 13.2% (27 segments), 2nd: 41.7% (85 segments), 3rd: 30.4% (62 segments), 4th: 14.7% (30 segments), 80s (92 segments): 1st degree: 1.0% (1 segment), 2nd: 23.9% (22 segments), 3rd: 39.1% (36 segments), 4th: 35.9% (33 segments).

There were no significant differences in the coronal parameters between the sexes. However, changes in lumbar lordosis, pelvic tilt, sagittal vertical axis, and vertebral wedging rate were significantly greater in the female patients.

Osteoporosis treatment was administered to 35 of the patients (30.4%), 9 with parathyroid hormone. Trunk braces were used by 25 patients (21.7%), the hard type by 6 and the soft type by 19. These treatments were started after a compression fracture or vertebral collapse was detected, and there was no significant difference in any of the measurement values between these patients and the others.

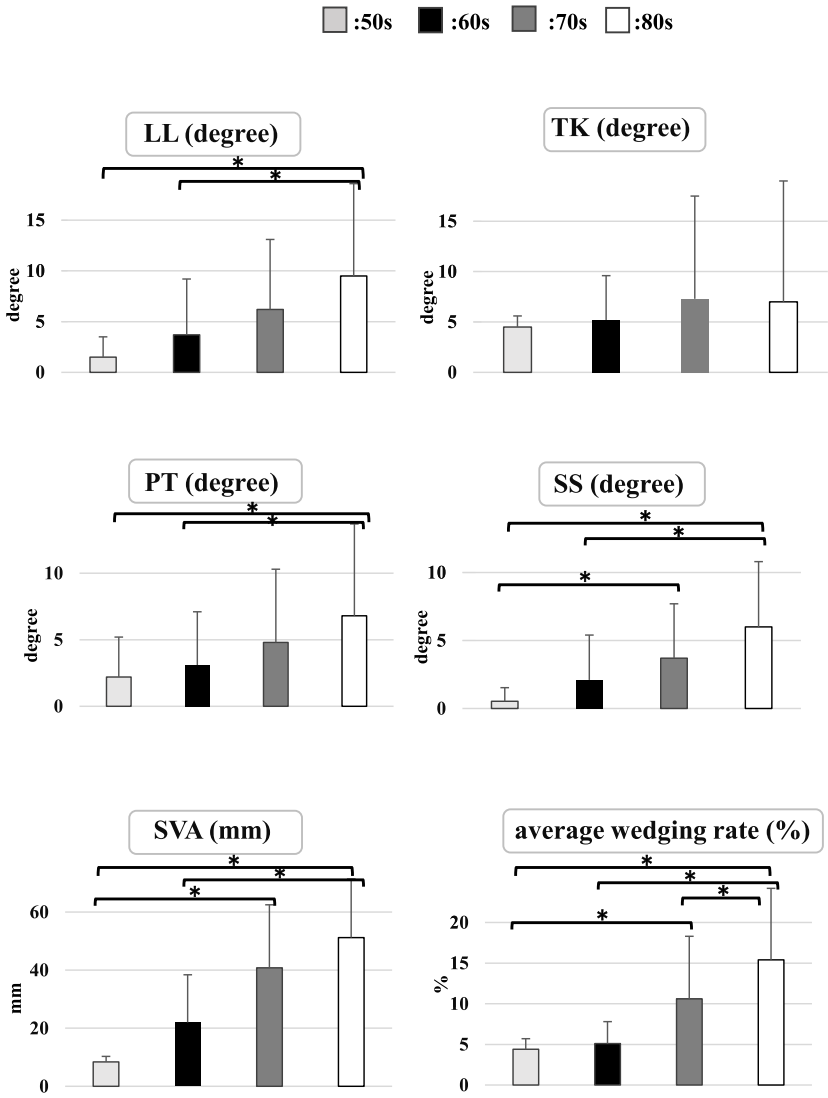

Figure 4. Changes in sagittal parameters by age group. *P<0.05

Discussion

The progression of degenerative scoliosis causes serious disability in daily life associated with a variety of clinical symptoms, and it shortens the healthy life expectancy of elderly people. Previously reported risk factors for the progression of scoliosis include sex, the presence of vertebral lateral spondylolisthesis, and a Cobb angle > 30°[10,11].

In our country, a large community-based cohort study was conducted from 1990 to 2008 prospectively in Wakayama Prefecture[14,15]. A total of 400 subjects (including 12 subjects that already have scoliosis on 1990) were selected, and the cumulative incidence of *de novo* scoliosis was 17.0% (33 out of 194 cases) on 2005 and 37.7% (57 out of 151 cases) on 2008. Additionally, this study identified L3 rotation and lateral spondylolisthesis as a risk factor for the occurrence of scoliosis. Compared with this prospective study, our study was conducted retrospectively for symptomatic patients that might differ the basic condition of subjects pathologically.

Toyone et al.[16] investigated cases that underwent posterior lumbar interbody fusion and were followed up over 10 years, reporting that the progression of degenerative scoliosis could be prevented by the reduction of the L3/L4 tilt angle to less than 5°. The results of the present study also suggested that the L4 tilt angle plays a significant role in the progression of scoliosis. In patients with a large L4 tilt angle, scoliosis progressed gradually, accompanied by vertebral lateral spondylolisthesis and trunk imbalance. Our results suggested that, if the L4 tilt angle is large, even the patients without scoliosis at the initial consultation (with an initial Cobb angle < 10°) might experience the future progression of scoliosis and should be observed over a long period, including periodical checks of radiographs.

The changes in the coronal parameters from initial to latest measurement increased gradually between those aged 50s and 70s, but the increase slowed down significantly for those aged 80s. Chin et al.[17] investigated 24 cases of scoliosis (mean, 68.2 years; range, 50-81 years), followed up for 1-14 years (mean: 4.85 years). They reported the rate of increase in Cobb angle to be 2.5°/year for the patients aged > 69 years and 1.5°/year for those aged <69 years. They therefore concluded that scoliosis progressed with aging. Jimbo

et al.[18] evaluated 42 cases of scoliosis (mean age, 58.4 years; range, 40-77 years) and reported that the progression of scoliosis was not observed in the patients aged >70 years. These previous studies mostly included patients aged 50-79, with few aged >80 years, which may have been insufficient to evaluate the final state of degenerative scoliosis in elderly people. The present study included 23 patients aged >80 years and revealed a significant decrease in the changes in parameter values in this older age group. This suggests that the progression of scoliosis may come to a gradual end in patients older than 80 years with the decreasing change in L4 tilt angle, perhaps because of degenerative changes to the spine, such as the formation of osteophytes indicated in our results and narrowing of the disc space, or because of hypoactivity in daily life associated with old age. However, two of the patients aged >80 years experienced a rapid progression of scoliosis with vertebral collapse. In the elderly people, it is necessary to check for morphologic changes in the vertebral body, including the osteoporotic compression fractures that cause the scoliosis.

In contrast to the coronal parameters, the results of the present study revealed that the change in sagittal parameters increased with age group, with the progression of vertebral wedging. No previous report has investigated the natural course of kyphosis longitudinally. However, some previous cross-sectional studies have reported that sagittal alignment gradually deteriorated with age[19,20]. Yeh et al.[20] analyzed the normative values of whole-body sagittal alignment by age in 392 asymptomatic volunteers, reporting a decrease in lumbar lordosis and increase in pelvic tilt in the elderly people, which is consistent with the results of the present study.

In addition to the wedging change in lumbar vertebrae with aging observed in our study, the lumbar trunk muscle is also an important factor in the progression of kyphosis. Takemitsu et al.[5] used isokinetic measurements for patients with spinal kyphosis and reported weakness and marked atrophy of the lumbar extensor muscles with increased fatty replacement. Kazzman et al.[21] reported that a spine-strengthening exercise with postural training for older adults reduced spinal hyperkyphosis and improved the patients' self-image, including increased satisfaction with their appearance. The term "locomotive syndrome" was proposed by the Japanese Orthopedic Association in 2007 as a condition of reduced mobility due to the impairment of locomotive organs; many reports have revealed the effectiveness of physical intervention for elderly people in preventing the locomotive syndrome and the decline in activities of daily living[22,23].

Shortening of the anterior element in lumbar vertebrae with wedging change causes morphological sagittal imbalance. The combination of this with weakness of the trunk muscles accelerates the progression of kyphotic deformity with aging, especially after the age of 80 years. With the aging society, it is likely that the number of elderly people who experience this will increase in the near future. In the present study, there was no significant difference between the patients who used osteoporotic medicine and those who did not, because in almost all cases, the treatment was started after the occurrence of a compression fracture. Preventive treatments for elderly people, including medication for osteoporosis before the occurrence of morphological vertebral changes and exercise of the trunk muscles, may be essential for the extension of healthy life expectancy.

This study had several limitations. In the present study, patients with clinical symptoms were retrospectively analyzed; however, the clinical evaluation as SF-36, Japanese Orthopedic Association scores was not performed. Investigation on the clinical data will be essential to understand the effects of clinical symptoms on coronal and sagittal alignments. It also included only patients aged over 50 years who were followed up for at least 6 years. Continuous observation, and extension of the studied population to younger patients, including cases of adolescent idiopathic scoliosis, might help with more specific clarification of the etiology and natural course of spinal kyphoscoliosis. This study investigated only nonoperative cases without serious symptoms that required operative treatment. In a future study, we intend to extend the investigation to operative cases. A comparison between operative and nonoperative cases could elucidate factors that exacerbate clinical symptoms, as well as the limitations of conservative treatment.

In conclusion, the results of this study revealed that L4 tilt angle was an important factor in the progression of degenerative scoliosis and that the progression of scoliosis comes to a gradual end along with the decreased change in L4 tilt angle in patients aged >80 years. Conversely, kyphosis accelerated with aging, especially in those aged >80 years, with the progression of vertebral wedging.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Yohei Ishihara wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

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