



Concomitant low-grade isthmic L5-spondylolisthesis does not affect the course of adolescent idiopathic scoliosis

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Abstract

Background Scoliosis with spondylolisthesis was described in 4.4–48%. No information on clinical impact or outcome is available.

Purpose To determine the prevalence of this pathology and to investigate its affect on the course of adolescent idiopathic scoliosis (AIS).

Methods A retrospective comparative study using patients' records, radiographs, the national inpatient registry, and Patient-rated outcome measures (PROM): Oswestry disability index (ODI), modif.SRS-24 questionnaire, WHO-Quality of life index (WHOQoL), Numerical rating scale (NRS) for pain. Clinical follow-up time was 4.4 (4.3) years, and follow-up rate was 95%. PROM follow-up time 26.4 (2.8) years χ^2 statistics and t-tests were applied. Significance threshold was set at $P < 0.05$.

Results Out of 1531 consecutive Caucasian AIS patients, aged 13.9 (1.8) years, primary curve 29.2 (11.5) drs., 120 (7.8%) had low-grade isthmic L5-slip of mean 15.0 (8.3)% (Study group = S). The distribution of the curve types in the study group was comparable to the remaining 1411 patients with AIS only. In comparison with a pair-matched control group (C) at admission, back pain interfering with activities of daily living had 4.2% of the study group and 1.7% of the control group, at clinical follow-up 2.6/4.2% resp. (n.s.). Between groups S/C, there was no significant difference concerning scoliosis treatment: observation 38.3/45.8%, bracing 48.3/46.6%, surgery 10.8/10.2%. Results of treatment were equal in both groups. Long-term outcomes (ODI, SRS-24, WHOQoL, NRS-back/leg pain) were comparable.

Conclusions The prevalence of low-grade isthmic L5-spondylolisthesis in AIS patients was 7.8%. The presence of low-grade isthmic spondylolisthesis did not influence the curve type of AIS nor did it affect the course or long-term outcome.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.

Key points

- Adolescent idiopathic scoliosis
- Isthmic spondylolisthesis
- Long-term follow up
- Patient-rated outcome measures

Comparison of the results of the patient-rated outcome measures between the Study group and the Controls

	Study group [Score(SD,range)]	Control group [Score(SD,range)]	P
Oswestry index	5.6(7.8;0-36)	6.2(9.3;0-46)	0.724
NRS¹			
Back pain ²	2.6(2.5)	2.1(2.2)	0.401
Leg pain ²	1.3(2.1)	1.4(2.2)	0.865
SRS-24 (Questions 1-15)³	93.9(11.6)	91.9(10.6)	0.844
WHOQoL⁴			
Physical health	81.0	78.5	0.440
Psychological	75.2	71.5	0.242
Social relationships	76.3	75.0	0.742
Environment	81.9	78.7	0.190

¹ Numerical Rating Scale (1 = No pain, 10 = Maximum pain)
² Pain during the last 30 days
³ Percentage of the maximum of 75 points; the higher, the better
⁴ Scale 0 to 100, 0 = worst, 100 = best

Take Home Messages

- Out of 1531 AIS patients, 7.8 % had concomitant low-grade L5 isthmic spondylolisthesis.
- In comparison to a pair-matched control group, there was no difference in the distribution of scoliotic curve types indicating that the presence of a low-grade spondylolisthesis does not influence the development of the scoliosis.
- No statistically significant differences could be found between the two groups concerning patient outcome.
- The recommendation by Goldstein et al. to treat each of the two pathologies separately according to generally accepted rules is supported by the data.

Keywords Adolescent idiopathic scoliosis · Isthmic spondylolisthesis · Patient-rated outcome measures · Long-term follow-up

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Extended author information available on the last page of the article

Introduction

The occurrence of scoliosis and spondylolisthesis in the same patient is not rare. In the literature, percentages from 4.4 to 48 have been reported. The published data, however, are impossible to comprehend. The majority of authors looked at smaller selected groups of adult symptomatic patients arriving to their institution primarily for assessment and/or treatment of spondylolisthesis. Scoliosis percentages derived from predominantly symptomatic patients with spondylolisthesis do not tell how common this finding is in general. Besides, the patient populations presented are of different ages, some study groups are mixtures of high- and low-grade slips, and inconsistent Cobb angle thresholds are applied to define scoliosis.

We could find only one paper reporting on AIS and spondylolisthesis. Fisk et al. [4] analysed the radiographs of 500 young patients with adolescent idiopathic scoliosis (AIS). They found a spondylolisthesis in 4.4%. To the best of our knowledge, the possible influence of a low-grade lumbar vertebral slip on the course of a coexistent adolescent idiopathic scoliosis has not been studied.

The purpose of this study is:

- to establish the prevalence of low-grade spondylolisthesis in an AIS population of considerable size,
- to investigate if there is any relation between the presence of low-grade isthmic L5-spondylolisthesis and the curve type of scoliosis, and
- to study whether the presence of a low-grade isthmic L5-spondylolisthesis has an influence on the radiologic and clinical course of a concomitant adolescent idiopathic scoliosis and its outcome.

In addition, an attempt is made to elucidate the individual features of patients with poor treatment result.

Patients and methods

This is a retrospective analysis from a single institution based on hospital records, patients' radiographs, the National Inpatient Registry (NIR) of the country, and patient-reported outcome questionnaires (PROM). All radiographic measurements were performed by a single experienced spinal radiologist. Ethical approval was obtained from the local authorities.

At the outpatient clinics of the authors' institution during the years 1987–1999, 1531 consecutive young patients were diagnosed having AIS based on history, clinical examination and standing p.a. and lateral thoracolumbar

spine radiographs. Lateral radiographs were checked for the presence of lumbar spondylolisthesis.

All patients having AIS and a low-grade (<50%) L5 isthmic spondylolisthesis were included in the study group.

For comparison with the study group, a pair-matched control group was created out of the remaining patients with AIS only, based on the conditions listed in Table 1. During the matching process, patient data like history, symptoms, mode of treatment, and outcome were hidden.

Primary clinical and radiographic follow-up

These data were collected during the original period of patient treatment and/or observation according to the hospital's routine. From patients' records, the following items were checked for both groups:

- Back pain at admission and at follow-up grouped as follows:
 - *No pain*
 - *Insignificant pain*, not interfering with activities of daily living (ADL), no doctors' visit, no pain medication
 - *Significant pain*, restricting ADL, repeated doctors' visits, pain medication.
- Mode of treatment (*observation/bracing/surgery*)
- Course of treatment and complications

Structured questionnaires were not yet in use at the institution during that time period.

The development of the scoliotic curves and the vertebral slips were verified from baseline and final follow-up radiographs. Patients did not have final follow-up radiographs if they were free of symptoms, had minor curves and/or slips at baseline and the risk for progression was found to be negligible.

Long-term follow-up

The National Inpatient Registry was searched up for the years 1987–2017 to identify patients who may have had surgery at other hospitals of the country.

Table 1 Matching criteria for the control group in relation to the study group

Gender
Age at admission (± 3 months)
Magnitude of the primary curve (± 3 drs.)
Apex level of the primary curve (± 1 level)

To obtain patient-reported long-term outcomes (PROM), the following questionnaires were mailed to the patients of both groups, including one postal reminder to non-responders about two months later: Oswestry Disability Index (ODI) [3], the WHO-Quality of Life questionnaire (WHOQoL) [24], the Numerical Rating Scale (NRS) [8] for back pain and for leg pain, and a shortened version of the SRS-24 [7] using only questions No. 1–15. The SRS questionnaire was originally created to compare pre- and post-operative data, i.e. to measure the effect of surgery. The reason for us to apply only questions 1–15 was that our patient population was mixed. In both groups, there were patients who were only observed, i.e. they were not treated at all. Others were treated by bracing what usually does not very much affect cosmetics, and only some patients underwent surgery. Questions No. 16–24 of the SRS-24, however, aim at the effect of treatment what was not equally relevant for the whole population. Thus, we decided to use only questions No. 1–15 in order to get a comparable picture of the condition of the whole patient population at follow-up. The score is presented as the percentage of the possible maximum of 75 points for questions 1–15. A non-response analysis was performed to check for selection bias.

Statistics

Frequencies, proportions, means, ranges, and standard deviations (SD) were presented as descriptive statistics. Pearson's Chi-squared test was applied in the categorical data between study and control group. *t* test was used in continuous variables such as age at admission, age at questionnaire time, follow-up time, radiological variables, and patient-related outcome (ODI, SRS-24, WHOQoL, NRS) between study group and control group. Significance was set at 0.05 (two-tailed). All statistical analyses were performed using SPSS® (Version 25.0, IBM, SPSS, Inc., Chicago, Illinois, USA).

Results

The data sources, lengths and rates of follow-up are listed in Table 2.

At admission, the mean age of the 1531 AIS patients was 13.9 (1.8) years, 86.9% were female. All patients were Caucasians. The mean Cobb angle of the primary scoliotic curve was 29.2 (11.5) drs. The curve type was thoracic in 62.1%, thoracolumbar in 25.0%, and lumbar in 12.9%. Of them, 151 were registered to have isthmic L5-spondylolisthesis. After a double check of radiographs and clinical records, 31 patients were excluded. The reasons for exclusion are listed in Table 3. High-grade slips were excluded because they have a high rate of secondary ("sciatic") curves [9, 16, 18, 22, 25].

Table 2 Overview of data sources, mean follow-up times and follow-up rates

	Data source	Mean follow-up time (years)	Follow-up rate (%)
Primary outpatient clinics baseline and follow-up			
Clinical	Pat. records	4.4	95
Radiographic	Radiographs ^a	4.4	88.3 ^b /94.1 ^c
Surgery	Pat. records and NIR ^d 1987–2017 ^e	25.4	100
PROM ^f	Questionnaires	26.4	34.5

^aSymptom-free patients with mild curves did not have final follow-up radiographs

^bStudy group

^cControl group

^dNational inpatient registry

^eData for 2018 not available yet in spring 2019

^fPatient-rated outcome measures

Table 3 Reasons for the exclusion of 31 patients from the study group

Reason for exclusion	<i>n</i>
Primary curve < 10 drs.	14
High-grade slip (≥ 50%)	7
No vertebral slip	6
Spondylolysis/olisthesis at L4	2
Neurologic disease	1
Patient accidentally registered twice	1
Total	31

Of the 1531 consecutive patients with AIS, 120 had a low-grade isthmic L5-slip resulting in a prevalence of 7.8%. These 120 patients form the study group.

Their mean slip was 15.0 (8.3)%, measured as the percentage of the length of the olisthetic vertebral body according to Laurent and Einola [11]. The mean age of the patients was 13.8 (1.7) years, 83.3% were female, and the mean Cobb angle of their main curve was 29.8 (10.3) drs.

The pair-matched control group was formed out of the remaining 1411 patients. For two patients, no matching pair fulfilling the given criteria could be generated. One was a 10.2-year-old girl with an 11-degree curve, the apex being at L2 and an L5-slip of 6%. The other patient was a boy of 11.6 years who had a curve of 36 drs with the apex at T 10 and also a slip of 6%. This left us with a control group of 118 patients.

Table 4 shows the baseline data of the study group and the control group demonstrating that they are comparable.

Table 4 Comparison of the baseline data between the study group and the control group

	Study group <i>n</i> = 120	Control group <i>n</i> = 118	<i>p</i>
Age at admission [years (SD)]	13.8 (1.7)	13.9 (1.6)	0.771
Female gender (%)	83.3	83.9	0.906
Primary curve [drs. (SD)]	29.8 (10.3)	29.2 (10.6)	0.679

Fig. 1 Presentation of the apex levels of the primary curves in the study group, and the remaining 1411 patients with AIS only

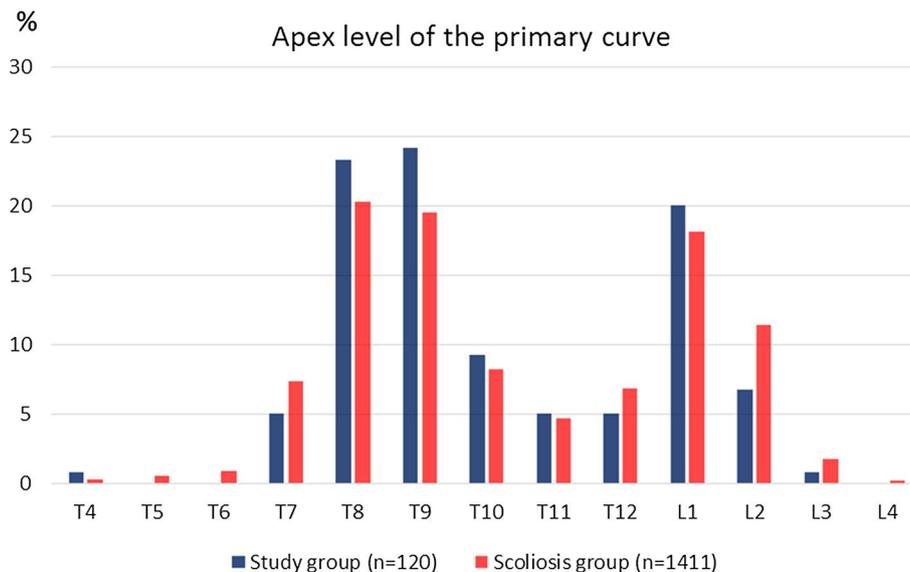


Table 5 Comparison of the distribution of curve types in the study group and the scoliosis group

Curve type	Study group <i>n</i> = 120 [<i>n</i> (%)]	Scoliosis group <i>n</i> = 1411 [<i>n</i> (%)]	<i>p</i> ^a
Thoracic	81 (67.5)	876 (62.1)	0.206
Thoracolumbar	30 (25.0)	352 (24.9)	
Lumbar	9 (7.7)	183 (13.0)	

^a*p* value is distributed between curve type and two groups (study group and scoliosis group)

Curve type of scoliosis

The apex levels of the primary curves are equally distributed in the study group and the control group (Fig. 1), respectively; there is no statistically significant difference in the distribution of the curve types (thoracic, thoracolumbar, and lumbar) (Table 5). The presence of the spondylolisthesis did not seem to influence the development of the curve type of scoliosis.

Treatment of scoliosis

The mode of treatment for the patients in both groups is presented in Table 6. In comparison between the groups, there were no statistical significant differences. The distribution

Table 6 Mode of scoliosis treatment in the study group and the control group

Treatment	Study group <i>n</i> = 120 [<i>n</i> (%)]	Control group <i>n</i> = 118 [<i>n</i> (%)]	<i>p</i>
Observation	46 ^a (38.3)	54 ^a (45.8)	0.458
Bracing for scoliosis	50 ^b (48.3)	51 ^b (46.6)	0.878
Curve type of brace patients			
Thoracic	33 (66.0)	34 (66.7)	
Thoracolumbar	13 (26.0)	13 (25.5)	
Lumbar	4 (8.0)	4 (7.8)	
Fusion for scoliosis	13 ^c (10.8)	13 (10.2)	
Curves fused			
Thoracic	10 ^c	11	
Thoracolumbar	2	1	
Thoracic + th-lumbar	1	1	

^aOne non-compliant brace patient included in both groups

^bIn both groups, additional four patients progressed and had scoliosis surgery

^cTwo patients had fusion for both, scoliosis and spondylolisthesis

of curve types in patients who underwent bracing as well as in those who underwent surgery for scoliosis was also comparable between the groups.

The development of the Cobb angle of the main scoliotic curves in the braced patients from admission to follow-up

Table 7 Radiographic results of scoliosis brace treatment in 109 patients comparing study group and control group

	<i>n</i>	Mean age [years (SD)]	Mean Cobb angle		Surgery despite bracing [<i>n</i> (%)]
			Admission [drs. (SD)]	Follow-up ^a [drs. (SD)]	
Study group	54 ^b	13.2 (1.6)	30.0 (6.5)	29.6 (9.6)	4 (7.4)
Control group	55 ^b	13.3 (1.7)	31.0 (6.2)	31.7 (9.0)	4 (7.3)
<i>p</i>		0.718	0.448	0.251	0.980

^aFor the eight patients who underwent scoliosis surgery because of curve progression the last Cobb angle before surgery was used

^bFour patients who progressed to surgery included

Table 8 Surgical technique and reoperations in 26 patients who underwent instrumentation and fusion for scoliosis

	Study group (<i>n</i> = 13)	Control group (<i>n</i> = 13)
<i>Technique</i>		
Posterior		
Selective thoracic	10	11
Double curve	1	–
Anterior		
Th-lumbar or lumbar	2	1
Combined (ant. + post.)		
Double curve	1	–
<i>Reoperation</i>		
Implant removal		
Late infection	–	2
Pain	–	1

is shown in Table 7. The effect of bracing was equally satisfactory in both groups. Of the 100 patients who were only observed, no one did have scoliosis surgery later as proven by the National Inpatient Register. The curve of one of the two patients who did not comply with bracing (see Table 6) progressed to 50°. She refused surgery. The curve of the other non-complier did not progress significantly.

Scoliosis surgery was performed in 26 patients, 13 in each group. Surgical technique and reoperations are listed in Table 8. The two late infections occurred in patients with CD instrumentation. No other complications were encountered in scoliosis surgery. The primary outcome of scoliosis surgery after mean follow-up of 4.4 years is presented in Table 9. There was no significant difference between the groups, neither in curve correction or in back pain at follow-up.

Surgery for spondylolisthesis

The indication for surgery in low-grade L5 spondylolisthesis was persisting pain interfering with daily life after a three to 6 months period of non-operative treatment (interruption

Table 9 Radiographic and clinical outcome of 26 patients who underwent scoliosis surgery

	Study group (<i>n</i> = 13)	Control group (<i>n</i> = 13)	<i>p</i>
Mean Cobb angle (drs.)			
Preoperative	50.1 (6.4)	49.5 (4.8)	0.783
Follow-up	23.8 (6.0)	26.7 (11.7)	0.431
Back pain at follow-up (<i>n</i>)			
No	9	8	
Insignificant ^a	3	4	
Significant ^b	1 ^c	1 ^d	

^aNot interfering with ADL, no doctor’s visit, no pain medication

^bInterfering with ADL, repeated doctor’s visits, pain medication

^cPatient had surgery for scoliosis and spondylolisthesis

^dPatient had leg pain only

Table 10 Percentage of L5 slip of spondylolisthesis patients treated by fusion in comparison with slip in patients who did not need surgery for spondylolisthesis

Fusion for spondylolisthesis	<i>n</i> (%)	Mean slip [% (SD)]	<i>p</i>
Yes	13 (10.8)	24.7 (10.0)	0.002
No	107 (89.2)	13.9 (7.3)	

or modification of sports activities, strengthening exercises of abdominal and back muscles). In 13 out of 120 (10.8%) patients of the study group, surgery for spondylolisthesis was performed at a mean age of 13.5 (1.2) years. Ten patients had surgery at the authors’ institution and three later in elsewhere hospitals as documented by the National Inpatient Registry. On average, the patients who had surgery for spondylolisthesis showed significantly higher percentages of L5 slips pre-operatively compared to those who did not need a lumbosacral fusion operation (Table 10). In ten patients, successful uninstrumented posterolateral fusion L5–S1 was performed using autogenic iliac crest graft. The remaining three patients had significant tilt of L4 being the caudal end-vertebra of a lumbar or thoracolumbar curve. Therefore, an instrumented posterolateral fusion L4–S1 with

L4-tilt correction using pedicle screws was performed. No attempt was made to reduce the L5 slip. After the operation, Boston brace treatment was continued until the end of growth. All three curves stabilized, none of the three patients has had scoliosis surgery later. One of them had painful sacral screw breakage. Pain resolved after implant removal. There were no other complications related to surgery for spondylolisthesis.

Back pain

At admission, 73.9% in the study group and 77.1% in the control group reported not to have had back pain at all. Significant pain was reported by 4.2 and 1.7% at admission and by 2.6 and 2.7% at follow-up (Table 11). The differences between the groups are not significant statistically.

Problem cases

The data of the patients with poor outcome were analysed in detail to find out if there are certain common characteristics which would allow predicting the problems. Overall, there were six patients, who had significant back pain at last clinical follow-up visit, three in each group.

One girl with a symptomatic L5 slip of 36% and a thoracic curve of 39° underwent successful L5/S1 posterolateral fusion at the age of 14.5 years. The thoracic curve progressed to 48 drs. and at age 17 years posterior correction and fusion from T4 to T11 was performed. There were no

Table 11 Back pain at admission and at clinical follow-up in the study group (mean follow-up 4.7 years) and in the control group (mean follow-up 4.0 years)

Back pain	Study group [n (%)]	Control group [n (%)]	<i>p</i> *
At admission	(<i>n</i> = 119 ^a)	(<i>n</i> = 118)	
No	88 (73.9)	91 (77.1)	0.509
Insignificant ^b	26 (21.8)	25 (21.2)	
Significant ^c	5 (4.2)	2 (1.7)	
At follow-up	(<i>n</i> = 114 ^d)	(<i>n</i> = 113 ^d)	
No	82 (71.9)	88 (77.0)	0.250
Insignificant	29 (25.4)	20 (17.7)	
Significant	3 ^e (2.6)	3 ^f (2.7)	

^aPain data of one patient missing

^bNot interfering with ADL, no doctor's visit, no pain medication

^cInterfering with ADL, repeated doctor's visits, pain medication

^dFive primarily pain-free patients in both groups with minor slips and/or curves at admission did not attend follow-up visit

^eOne patient had back pain and leg pain

^fOne patient had leg pain only

**p* values are distributed between study group and control group and pain scale at admission and at follow-up

complications, neither intra- nor post-operative. At age 25, she had combined L4/5 fusion with autogenic bone graft and translamina L4/5 screws for adjacent segment degeneration. After every surgery, she was free of pain for several years (Figs. 2, 3, 4, 5, 6, 7, 8, 9).

Another girl, aged 12.6 years with a mildly symptomatic L5 slip of 9% and a right thoracic curve of 28 drs. had brace treatment for the scoliosis. The L5 slip progressed from 9 to 17%, and the patient had severe low-back pain at follow-up. She refused fusion for the spondylolisthesis.

The third patient of the study group with significant pain, a male of 15.8 years, had an L5 slip of 33% and a 28/26 drs. double curve, leg length inequality and sacral tilt. He did not want to have any treatment.



Fig. 2 Thoracic curve at admission



Fig. 3 Isthmic L5 slip at admission

A 16.7-year-old girl presented with a 36° thoracolumbar curve at the end of growth. Non-operative treatment for the pain was proposed. According to the answers to the PROM questionnaires, after 23.2 years of follow-up she is in good condition now.

The second patient, a girl of 10.3 years, had a thoracic double curve of 36/29° without back pain at admission. Despite of bracing, the curves progressed 55/50°. Rotation of both curves was minimal. The cosmetic appearance was excellent and no surgery was proposed.

The third patient in the control group an 11.8-year-old girl with a thoracic/lumbar double curve of 61/59° underwent combined instrumentation and fusion (anterior VDS + posterior CD). The curves improved to 28/28°. Twenty-two years after surgery, she started getting disturbing back pain with radiating pain to the left leg. The reason for the pain could not be identified. ODI was 20 at her last outpatient clinic visit.



Fig. 4 Two years after uninstrumented posterolateral fusion L5/S1

The case descriptions show that no common denominator predicting poor outcome was found.

Patient-reported outcome measures (PROM)

ODI, NRS for back pain and leg pain, WHOQoL questionnaire, and a modified version of SRS-24 questionnaires were mailed to 192/238 patients, 100/120 patients of the study group and 92/118 of the control group, 82.8% were female. The remaining patients could not be traced. We received back 82 filled questionnaires, 45/120 (37.5%) of the study group and 37/118 (31.4%) of the control group. The mean follow-up time was 26.4 (2.8) years. Females responded more often than males, 45.9% versus 27.2%. Of those 82 patients who answered the questionnaires, 56% had undergone brace treatment for scoliosis.

The long-term outcome as rated by the patients who responded to the questionnaires was equally satisfactory in the patients with AIS and concomitant spondylolisthesis compared to those with AIS only (Table 12).

Non-response analysis

The comparison of the baseline characteristics between responders and non-responders is presented in Table 13. No statistically significant differences could be found, indicating that the responders are representative for the whole patient population reducing the obvious risk of



Fig. 5 Significant thoracic curve progression within 2 years

selection bias. The answering activity of the patients of the study group was well-comparable with that of the control group. Both groups were also equally represented concerning the mode of treatment (Table 14).

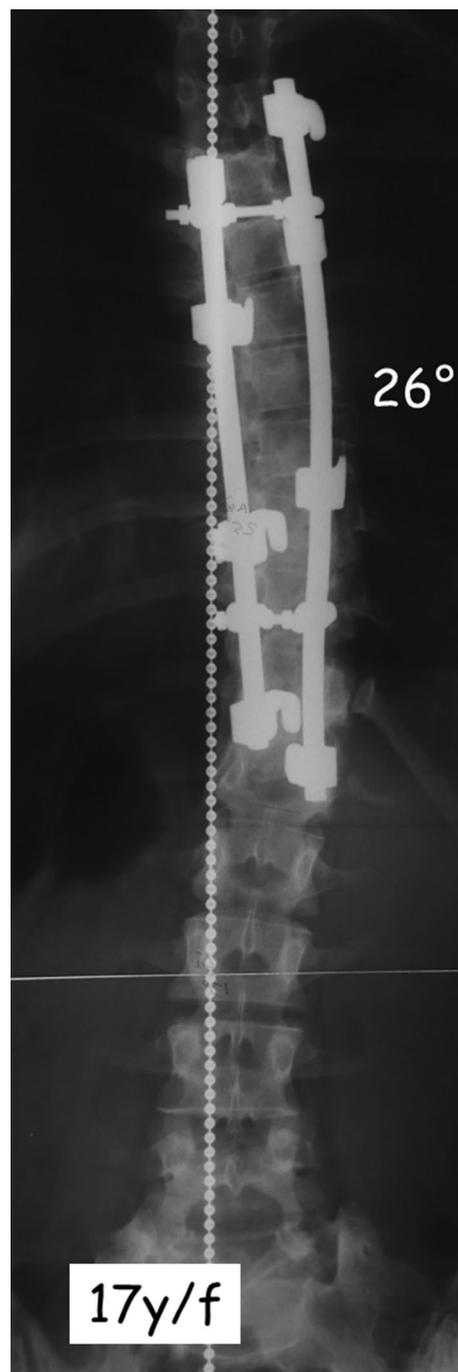


Fig. 6 Posterior instrumentation and fusion T4/T11

Discussion

Among 1531 consecutive young Caucasian patients with adolescent idiopathic scoliosis, 120 were found to have low-grade L5-spondylolisthesis. This makes a prevalence of 7.8% corresponding to the prevalence of isthmic spondylolisthesis in the Caucasian population. This figure is, however, quite far from most percentages for this double



Fig. 7 Lumbar MR Image. Black disc L4/5



Fig. 8 Discography L4/L5. Internal disc disruption

pathology published in the literature. The reason lies in the different approach to the problem by most authors. To define how common scoliosis is, the authors looked primarily at populations of symptomatic adult or adolescent patients

with spondylolisthesis [14, 23] or at selected patients who had undergone surgery for a slip [1, 2, 10–12, 21]. Several authors used 5° Cobb angle as threshold for scoliosis and looked only at the lumbar spine and/or did not describe at all how radiographs were taken, supine or standing. In addition, the type of scoliosis is usually not specified. Those figures cannot be compared to our findings.

We found only one publication searching a series of AIS patients for the prevalence of spondylolisthesis. Fisk et al. [4] saw among 500 young patients with AIS a lytic slip in 4.4% and a spondylolysis without a slip in 1.8% on oblique and lateral radiographs of the lumbar spine. If one excludes high-grade slips ($\geq 50\%$), for comparison with our figures, 3.6% of low-grades remain. We did not see spondylolysis without a slip in our patients. This is probably because we had all standing lateral pictures on which it is very difficult to detect a pure spondylolysis without a slip, especially if the lysis is unilateral. In their paper, the exact imaging position of the patient is not mentioned. Possibly, the lateral radiographs were taken supine. If so, on standing lateral films at least some of the patients with a lysis would have turned out to have also a mild slip. No data on magnitude of scoliotic curves, curve types, patients' symptoms, and mode of treatment or outcome are provided in the paper.

Libson et al. [13] compared 936 asymptomatic and 807 symptomatic male soldiers, aged 18–30 years. They took supine a.-p., lateral, and oblique radiographs of the lumbar spine. Due to that, their results represent only lumbar curves, a fact not pointed out in their paper. Their threshold for scoliosis was a Cobb angle of $\geq 5^\circ$. But in their abstract, they name curves from 0° to 9° as “mild” which is obviously a contradiction. The type of scoliosis was not mentioned. Out of 841 asymptomatic individuals without a lysis, 56 (6.7%) had a scoliosis of 5° – 20° , 51 of them being “mild” (5–9 drs.) and five “moderate” (10–20 drs.) Among 21 soldiers with an asymptomatic slip, five (23.8%) had a scoliosis. Under 44 individuals with a symptomatic spondylolisthesis, 19 (43.3%) had a “scoliosis”. This high percentage, derive from a small subgroup of symptomatic patients defining scoliosis from 5° upward on supine lumbar radiographs, is often cited in the literature. This cannot be compared at all with our findings.

Glorieux and Roederer [5], in their paper, discussed the mechanism of a secondary scoliosis due to asymmetric slipping in patients with unilateral or bilateral spondylolysis. In their opinion, this could happen in L5, or in L4 if L5 is sacralized. They named it “listhetic” scoliosis. Lumbar a.-p. and oblique radiographs of some adult patients are presented. Bony structures are asymmetric and/or rotated, some having also degenerative changes. Surprisingly, the authors did not show any true lateral radiograph showing a forward slip, nor did they mention the grades of vertebral slips; i.e. there is no proof that all their patients did really

Fig. 9 a, b Two years after instrumented combined fusion L4/5 (Surgery: Dr.Timo Laine)

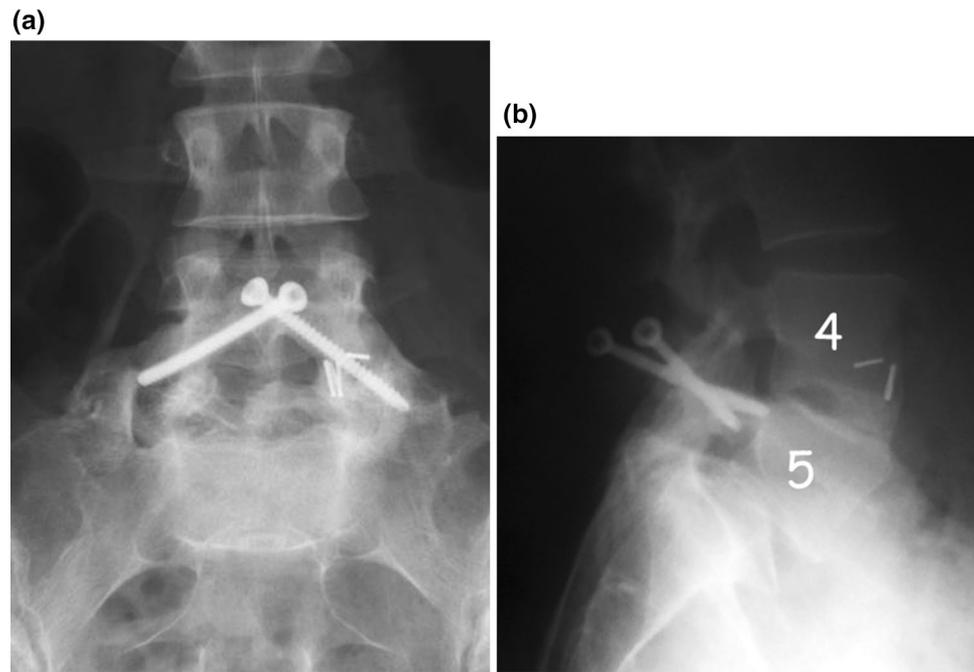


Table 12 Comparison of the results of the patient-rated outcome measures between the study group and the control group

	Study group (<i>n</i> = 45) [Score (SD; range)]	Control group (<i>n</i> = 37) [Score (SD; range)]	<i>p</i>
Oswestry index	5.6 (7.8; 0–36)	6.2 (9.3; 0–46)	0.724
NRS ^a			
Back pain ^b	2.6 (2.5)	2.1 (2.2)	0.401
Leg pain ^b	1.3 (2.1)	1.4 (2.2)	0.865
SRS-24 (questions 1–15) ^c	93.9 (11.6)	91.9 (10.6)	0.844
WHOQol ^d			
Physical health	81.0	78.5	0.440
Psychological	75.2	71.5	0.242
Social relationships	76.3	75.0	0.742
Environment	81.9	78.7	0.190

^aNumerical rating scale (1 = no pain, 10 = maximum pain)

^bPain during the last 30 days

^cPercentage of the maximum of 75 points; the higher, the better

^dScale 0–100, 0 = worst, 100 = best

have spondylolisthesis. This is incomprehensible. No prevalence percentages were given.

Bosworth et al. [2] analysed radiographic and clinical findings of 115 patients who had undergone surgery for isthmic spondylolisthesis. Their mean age at onset of symptoms was 30.4 (3–65) years, the mean slip measured 19 (0–95)%. In more than three quarters of the patients, the slip was less than 25%. A “total slip” was seen in 19%. Twenty-six of 115 patients (22.6%) had “some degree of scoliosis”. Due to this high frequency, they assumed a causal relation between the slip and the scoliosis. Apex levels or type of curves are not

mentioned. Most likely, only lumbar radiographs were taken. Under “Clinical findings” the authors did not allude to scoliosis at all. In the light of our data, a causal relation between isthmic spondylolisthesis and AIS seems not very likely.

During the time period studied in this paper, basic treatment decisions at our institution followed the recommendation of Goldstein et al. [6] to treat spondylolisthesis and AIS occurring in the same patient separately according to generally accepted rules. As to the best of our knowledge, this recommendation has never been substantiated by any clinical study. Our results seem to support this approach

Table 13 Comparison of baseline data between responders and non-responders to the outcome questionnaires

	Responders	Non-responders	<i>p</i>
Study group (<i>n</i> = 120) [<i>n</i> (%)]	45 (37.5)	75 (62.5)	
Age at admission [years (SD)]	13.5 (1.7)	14.0 (1.6)	0.081
Female gender (%)	88.9	80.0	0.206
Clinical follow-up [years (SD)]	4.9 (3.5)	4.6 (5.1)	0.683
Primary curve [drs. (SD)]	31.6 (11.3)	28.8 (11.2)	0.187
L5-Slip [% (SD)]	13.4 (7.4)	16.0 (8.7)	
Control group (<i>n</i> = 118) [<i>n</i> (%)]	37 (31.4)	81 (68.6)	
Age at admission [years (SD)]	13.7 (1.7)	14.0 (1.5)	0.469
Female gender (%)	89.2	81.5	0.291
Clinical follow-up [years (SD)]	4.7 (4.7)	3.7 (3.6)	0.239
Primary curve (drs. SD)	30.0 (9.4)	28.9 (11.1)	0.613
L5-Slip (%)	n.a.	n.a.	

Under “Non-responders” rank, those patients who did not return the questionnaire as well as those who could not be reached

Table 14 Distribution of the 82 patients who returned the PROM questionnaires concerning mode of treatment

Mode of treatment	Study group [<i>n</i> (%)]	Control group [<i>n</i> (%)]
None	12/46 (26.1)	14/54 (25.9)
Bracing for scoliosis	26/50 (52.0)	20/51 (39.2)
Fusion for scoliosis	7 ^a /13 (53.8)	2/13 (15.4)
Fusion for spondylolisthesis	1 ^a /13 (1.2)	n.a. ^b

^aOne patient had fusion for both, scoliosis and spondylolisthesis

^bNot applicable

very strongly. The indications for AIS management (observation, bracing, surgery) did not change at our institution over the years under analysis. So, it is no surprise that the numbers of patients who were chosen for the different modes of treatment are very similar in comparison between the matched groups. But it is remarkable that also results of treatment and patient outcomes are fully comparable in the long term. This means that generally the concomitant low-grade spondylolisthesis does not jeopardize the future of an AIS patient, neither in view of the deformity nor with respect to pain symptoms.

For brace treatment of AIS, an individually fitted Boston type TLSO was used. In scoliosis surgery, thoracic curves were instrumented and fused posteriorly, thoracolumbar and lumbar curves from the anterior approach.

Only the type of instrumentation changed over the years with the technical development.

Routine procedure for symptomatic spondylolisthesis was uninstrumented L5–S1 postero-lateral fusion in situ using autogenic iliac crest graft. Three patients with a symptomatic L5 slip and a lumbar curve needing brace treatment had a significant tilt of L4 in the frontal plane. To avoid a wedged disc adjacent to the L5–S1 fusion, we applied a technique recommended by Goldstein et al. [6] who proposed to fuse the lumbosacral area with L4 in a corrected position. It did work in our three patients. The curves stabilized and none of them needed scoliosis surgery later. But we are unable to say whether the satisfactory results were a merit of the surgical technique, the bracing or the combination of both. Therefore, no far reaching conclusions should be made. The fact that only 10.8% of the 120 patients with low-grade isthmic spondylolisthesis needed fusion surgery during a period of over 25 years proves once again the benign nature of low-grade isthmic spondylolisthesis. Interestingly, the amount of slip in those patients who needed surgery was significantly bigger than in the patients who were not operated (24.7 vs. 13.9%). One could speculate that in this age group the further progressed slip may cause symptoms due to increased segmental instability caused by disc damage [19, 20]. A possible correlation between the occurrence of back pain and sports activities could not be investigated. There was no consistent information on that in the files.

In both groups, the occurrence of back pain did not differ from figures provided from the literature for healthy teenagers without spinal deformities [15, 17]. The presence of a low-grade L5 slip did not significantly increase the risk for getting pain symptoms, neither at baseline nor at follow-up.

Patient-reported outcomes measured by commonly used and validated methods were equally satisfactory in both groups. Although there was no group of healthy controls, one can state that the vast majority of patients is able to live a normal life. The presence of a spondylolisthesis did not interfere with the course or the prognosis of AIS.

Being a retrospective study is obviously seen as a weakness. However, it may be also an advantage. Due to its homogeneity and size and the fact that the data comes from one institution, the study reflects “real life”. All treatment decisions were made by the same surgeons during their daily work life based on agreed principles not knowing that the data will be used sometimes in a study on the problem we investigated here. This excludes the real danger that patient selection and/or treatment decisions could be influenced unconsciously by the surgeon knowing that an incoming patient may be a candidate for an ongoing prospective study. Another weakness of the study is that no structured patient questionnaires were used at baseline. This kind of questionnaires was not in clinical routine use at the time. AIS patients may complain about pain in the thoracic region

but also in the lower back. Symptomatic patients with spondylolisthesis do usually have pain in the low back. As the localization of the pain, if there was any, was not specified in all of the patient records, we were not able to analyse this more in detail and had to use the general term back pain. On the other hand, this is not so much of importance in view of the study questions.

The low response rate to the patient-rated outcome questionnaires is a serious drawback. It lessens the value of the long-term data considerably. The reasons for the poor response are manifold: increasing mobility of the population makes it more and more difficult to trace people due to tightened personal data protection rules. The patients are now around 40 years old, thus living a very busy period of their lives. As we are dealing with a mostly benign medical problem, the majority does not have significant back problems at the time. This surely lowers their interest in filling forms, especially if one considers the mean follow-up interval of 26.4 years. This drawback, however, is attenuated by the non-response analysis showing that responders and non-responders were quite similar concerning their basic characteristics at admission, i.e. non-response was random. This lessens the risk of selection bias. In addition, we could draw true long-term data from the National Inpatient Registry on surgeries performed after the end of observation and treatment at our institution.

The most important strength of this study is the homogeneity and the size of the unselected basic patient population originating from one single institution which served a population of about five million people. In a way, it reflects the clinical occurrence of AIS in teenagers in the area during the given period of time. The treatment principles at our institution were unchanged during that time span, and all treatment decisions were supervised by two experienced orthopaedic spine surgeons who were in full agreement with each other concerning those principles. All radiographs were measured by one experienced dedicated spinal radiologist. A pair-matched control group is used. And the primary clinical and radiological follow-up time for the patients of the study group and the control group is over four years on average with a follow-up rate of more than 90%. In contrast to the valuable paper by Fisk et al. [4], we analysed scoliotic curve types and provide clinical outcome data. As far as we could find, there is no earlier study of this extent and versatility available.

Conclusions

The prevalence of low-grade L5 isthmic spondylolisthesis in teenagers with AIS is comparable with the prevalence of this pathology in individuals without AIS in this age group. The concomitant presence of the L5 slip does not influence the

course or the outcome of AIS. Each of the two pathologies can be treated separately according to the generally accepted specific rules.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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