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Outcome in adolescent idiopathic scoliosis after brace treatment and surgery assessed by means of the Scoliosis Research Society Instrument 24

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Abstract A retrospectively designed long-term follow-up study of adolescent idiopathic scoliosis (AIS) patients who had completed treatment, of at least 2 years, by means of brace, surgery, or both brace and surgery. This study is to assess the outcome after treatment for AIS by means of the Scoliosis Research Society Outcome Instrument 24 (SRS 24). One hundred and eighteen AIS patients (99 females and 19 males), treated at the Aarhus University Hospital from January 1, 1987 to December 31, 1997, were investigated with at least 2 years follow-up at the time of receiving a posted self-administered questionnaire. Forty-four patients were treated with Boston brace (B) only, 41 patients had surgery (S), and 33 patients were treated both with brace and surgery (BS). The Cobb angles of the three treatment groups did not differ significantly after completed treatment. The outcome in terms of the total SRS 24 score was not significantly different among the three groups. B patients had a significantly better general (not treatment related) self-image and higher general activity level than the total group of surgically treated patients, while surgically treated patients scored significantly better in post-treatment self-image and satisfaction. Comparing B with BS we found a significantly higher general activity level in B patients, while the BS group had significantly higher satisfaction. There were no significant differences between BS and S patients in any of the domain scores. All treatment groups scored "fair or better" in all domain scores of the SRS 24 questionnaire, except in post-treatment function, where all groups scored worse than "fair". Improvement of appearance by means of surgical correction increases mean scores for post-treatment self-image and post-treatment satisfaction. Double-treatment by brace and surgery does not appear to jeopardize a good final outcome.

Keywords Scoliosis · Quality of life · Functional outcome · Brace · Surgery

Introduction

Indication for treatment of adolescent idiopathic scoliosis (AIS) patients by means of brace treatment is a Cobb angle of 25° and, for surgical treatment, a Cobb angle exceeding 40° in immature patients [1]. Montgomery and Willner [2] pointed out that brace treatment is often started when the curve magnitude is between 25° and 35°, which radically reduces the Cobb interval between the two treatment modalities, placing the indication boundaries for whether brace treatment is indicated or whether surgery should be performed in close proximity of each other. Brace treatment should be started in patients with more than 5° increase in curve magnitude per year, a

Cobb angle exceeding 25° [3, 4] and a substantial residual growth potential. Surgery is indicated when the Cobb angle exceeds 40° [5, 6] or when no acceptable correction of the curve is achieved by brace treatment and the curve progresses despite brace treatment [7].

Measurement of quality of life or treatment outcome by subjective data has become an important tool in evidence-based medicine [8–18]. The Scoliosis Research Society instrument for outcome assessment (SRS 24) was designed to measure outcome after surgery, particularly in adolescent idiopathic scoliosis (AIS) patients [19–21].

Recently published studies suggest that the magnitude of the curve and the degree of curve correction in surgically treated patients are weak predictors for outcome scores and patient satisfaction [21]. They may even show a negative correlation, even though the pain score might improve after corrective surgery. Previous studies have demonstrated that the lumbar curve is the most reliable predictor of self-image: A large pretreatment curve correlates to negative patient satisfaction and low total SRS outcome score [22]. However, the degree of curve correction does not appear to correlate significantly with the outcome [21, 23].

The aim of this study was to identify the impact of brace treatment and surgery on the overall treatment results among AIS patients as measured by the SRS 24 instrument. We attempted to compare the quality of life in relation to the treatment performed in order to point out possible differences in the outcome among AIS treatment groups.

Our first hypothesis was that brace-treated patients scored lower than surgically treated patients because of a long-lasting impact of brace treatment on the life quality and because brace treatment is noncorrective. Secondly, we expected patients treated with both brace and surgery to score particularly low in general self-image, post-treatment self-image, and post-treatment satisfaction due to the strenuousness of the dual treatment they had undergone.

Patients and methods

This survey is a long-term follow-up study of AIS patients that includes both retrospective and follow-up data. The study initially comprised 796 patients registered, respectively, as referred, active, and concluded cases in the central computer system of the intranetwork system for Aarhus County under the referral diagnosis of "scoliosis" at the department of orthopedic surgery, Aarhus University Hospital (AUH), from January 1, 1990 to December 31, 1999.

Primarily retrieved were patients with the referral diagnosis of scoliosis and age at referral 8–28 years; exclusion criteria could not be predefined. The second round of selection determined exclusion based on supplementary diagnoses which likewise were collected by means of the intranetwork database; these supplementary diagnoses were congenital-, neuromuscular-, functional-, and secondary scoliosis and other spinal diseases, syndromes, and other osteogenic diseases. Thus 456 cases were selected for further investigation.

The medical records were then retrieved. Exclusion criteria in the second selection round were the presence of other conditions which were not directly accessible via the data base search; these conditions included intervertebral disc disease, tumor, sequelae after previous radiotherapy for neoplastic disease, previous spondylitis, symptomatic spondylolisthesis > Stage 1, marblebone disease, spina bifida, myelomeningocele, interavertebral tumor, Marfan's syndrome, ankylosing spondylitis, Scheuermann's disease, Recklinghausen's disease, kyphosis, anisomelia with total correction of the spine after correction, curve magnitude < 10°, mental retardation, multiple handicaps, and less than the minimum follow-up of 2 years. Two hundred and ninety-eight patients met these first inclusion criteria.

Two hundred and ninety-eight patients received a self-administered questionnaire by mail. The information from the questionnaires was complemented with data from medical records and X-rays (accessible for 256 of the 298 patients). The primary author re-examined the radiographic images for Risser-sign, curve pattern according to the King-Moe classification, and Cobb angle. After two reminders, a total of 264 patients had returned a filled out questionnaire. Seven patients actively declined participation and 27 never replied. Thus, the total follow-up percentage was 88.6%.

From this pool of patients, we finally selected patients with a first outpatient clinic visit between January 1, 1987 and December 31, 1997, who had undergone bracing, surgery, or bracing and surgery, with at least 2 years of follow-up after completed brace treatment (after weaning and discontinuation of bracing) and/or surgery (last performed surgical intervention) at the time of receiving the questionnaire. Eighty-eight of the patients had been solely monitored and were not included in this study; 118 had active treatment and met the final inclusion criteria.

Patients treated with Boston brace only were assigned to group B, those who underwent surgical treatment after bracing constitute group BS, and those who had surgery alone were denoted as group S.

Method and questionnaire

We used the Scoliosis Research Society Instrument for Outcome Assessment 24 (SRS 24) [19–21]. We chose the SRS 24 questionnaire because it is specially designed for scoliosis patients, is recommended by the Scoliosis

Research Society, and has found worldwide acceptance. In this study, we used SRS 24 for brace-treated patients and surgically treated patients, knowing well that SRS 24 was originally developed for the surgically treated population.

The instrument comprises seven domains: pain (questions 1, 2, 3, 6, 8, 11, 18), general self-image (questions 5, 14, 15), function from back condition (questions 7, 12, 13), general level of activity (questions 4, 9, 10), post-treatment self-image (questions 19, 20, 21), post-treatment function (questions 16, 17), and satisfaction with the treatment (questions 22, 23, 24); each of these domains can be evaluated independently and/or by summarizing all questions in a total outcome score.

The SRS 24 was translated into Danish by means of standard procedures including reverse translation. The evaluation of SRS 24 by the patients was performed by means of an evaluation scheme comprising 12 questions concerning relevance, semantic problems, missing items, time required to fill out, and the possibility of contributing suggestions by means of free text. There was overall very good acceptance and satisfaction with the instrument, also among young patients under the age of 14.

Two reminders were sent out at 3-week intervals. The patients who decided not to participate in the study were asked to actively decline by returning a blank form.

The scores were calculated by giving all 24 questions an answer value within a five-point scale. Eleven questions (3–8, 14, 20, 22–24) have five answer categories which are quantified by 1–5: 1 was the most negative response and 5 the most positive; seven questions (12, 13, 16–19, 21) have three answer categories quantified by 1, 3, and 5: decrease counts one point, no change or the same three points, and increase five points; three questions have two answer categories quantified by 1 and 5: no counts as one point and yes as five points; two questions (1, 2) have scales with a range from 1 to 9, rating the sensation of pain; 1 is no pain and 9 severe pain: 1 and 2 = 5 points, 3 and 4 = 4 points, 5 = 3 points, 6 and 7 = 2 points, and 8 and 9 = 1 point. One question (15) has a scale with a range from 1 to 9 rating the feeling of self-image; 1 is very low and 9 is extremely high self-image; 1 and 2 = 1 point, 3 and 4 = 2 points, 5 = 3 points, 6 and 7 = 4 points, and 8 and 9 = 5 points. The domain scores were calculated by the sum of points and the norm score is calculated by dividing by the number of questions in the specific domain. The total SRS 24 score was calculated by means of the total sum score and normalized by dividing with the total number of questions (24).

Statistics

We organized the data by means of computer using the program EpiDATA 2.b (EpiDATA-cooperation, 2001–2004) and transferred the data for statistical analysis by SPSS 11.0 (Statistical Package for Social Sciences, SPSS incl., Chicago, IL, USA). Mean and standard deviation were calculated for each parameter.

Patients who did not completely fill out the questionnaire were excluded in both the respective domain score and the total score. Outcome scores and Cobb angles were checked by QQ-plots and found to be normally distributed. Independent samples *t* test (two-sided) was used for assessment of statistical significance, which was considered at a P value of ≤ 0.05. Furthermore, we used one-way ANOVA test and multiple comparisons with a post hoc test by Bonferroni to compare the three treatment groups with each other. Statistical analyses were performed for the discrete domain scores, the total SRS 24 score, and the Cobb angle at different junctures. Correlation analyses were performed by simple Pearson Correlations test.

The Department for Data Security (Danish: Datatilsynet) permitted the data collection and data storage (J.no.2002-41-2221), and the local Medical Ethics Committee (Den Videnskabsetiske Komité for Aarhus Amt) authorized the study (J.no.2002-2.0/40).

Results

Gender and treatment groups

The 118 patients comprised 19 males (16.1%) and 99 females (83.9%). Forty-four (37.9%) had brace treatment, 41 (34.7%) had surgery alone, and 33 (28%) underwent brace treatment prior to surgery. The pooled group of patients had a mean age of 21.7 ± 3.5 years at the time of filling out the questionnaire. Brace-treated patients were 22.1 ± 3.9 years old; their age at brace start was 14.7 ± 2.7 years; mean brace time 2.1 ± 1.3 years (age 16.6 ± 1.0 years) until weaning, and 2.4 years (age 17.6 ± 3.5 years) until completion of brace treatment, age at last outpatient clinic visit 19.1 ± 2.8 years. Surgically treated patients were 22.2 ± 4.2 years when filling out the questionnaire; age at operation 16.7 ± 3.7 years, age at last outpatient clinic visit 19.8 ± 3.8 years. Patients who underwent brace treatment followed by surgery were 22.9 ± 4.5 years when filling out the questionnaire, they were 14.3 ± 1.8 years at the start of brace treatment, the time interval between brace start and surgery was 3.1 ± 3.7 years, age at operation 17.3 ± 4.4 years, and age at last outpatient clinic visit was 20.3 ± 4.3 years. The last outpatient clinic visit quoted is the last examination before the patient participated in this study.

Curve type and curve magnitude

The deformities were classified according to the King-Moe classification (KMC) as shown in Table 1. The

Table 1 Cobb angles in relation to treatment groups, King-Moe classification (KMC), and treatment groups and KMC

Treatment groups	KMC	*N*	Percent	Cobb at first outpatient clinic visit		Cobb before brace treatment		Cobb preoperatively		Cobb at last follow-up	
Braced		44	37.3	33.6	± 10.2	33.2	± 6.6			33.2	± 11.5
Surgically treated		41	34.7	49.5	± 15.9			57.1	± 14.3	33.7	± 12.3
Braced and surgically treated		33	28.0	48.5	± 15.1	44.9	± 10.5	54.9	± 11.4	34.3	± 13.7
Braced	Type I	18	40.9	33.8	± 10.7	34.0	± 7.5			31.7	± 7.5
	Type II	6	13.6	31.8	± 13.5	37.3	± 6.1			30.7	± 13.9
	Type III	8	18.2	33.0	± 7.1	31.0	± 5.4			34.4	± 13.4
	Type IV	11	25.0	35.7	± 10.3	31.9	± 6.3			36.5	± 14.3
	Type V	1	2.3	22.0						25.0	
Surgically treated	Type I	5	12.2	63.6	± 9.1			67.6	± 7.1	37.0	± 7.5
	Type II	5	12.2	51.2	± 7.6			53.6	± 5.5	36.8	± 10.4
	Type III	14	34.1	46.6	± 10.0			52.6	± 9.8	33.3	± 8.1
	Type IV	15	36.6	47.5	± 21.8			58.2	± 20.4	30.0	± 16.9
	Type V	2	4.9	44.0	± 12.7			61.0	± 1.4	47.0	± 7.1
Braced and surgically treated	Type I	2	6.1	61.0	± 1.4	62.0	± 3.6	59.0	± 4.2	38.0	± 14.1
	Type II	9	27.3	44.0	± 10.6	40.5	± 7.3	52.8	± 8.6	29.9	± 9.1
	Type III	5	15.2	57.0	± 15.8	48.3	± 10.4	60.0	± 11.8	31.2	± 16.8
	Type IV	14	42.4	44.4	± 12.5	47.2	± 10.6	54.6	± 12.4	36.0	± 14.3
	Type V	3	9.1	58.7	± 31.3	33.5	± 9.2	52.0	± 19.1	42.0	± 20.4

distribution of curve magnitude corresponded closely to KMC types II, III, and IV, meaning that the most commonly occurring major curves were located in the thoracic region. Comparing the KMC curve types with each other, no significantly different curve magnitudes were found.

Comparing the Cobb angles of the different treatment groups (Table 1) we found that the brace-treated group had significantly smaller Cobb angles than the surgery and the brace and surgery group at the first outpatient clinic visit, but all three groups ended up with Cobb angles nonsignificantly different from each other at the final outpatient clinic visit. Furthermore, the brace group had significantly smaller curve magnitude before the start of brace treatment than the double-treated group. The two surgically treated groups did not differ significantly in Cobb angle size preoperatively.

Stabilization of the curves before and after treatment was achieved in those patients who only underwent brace treatment; the difference in curve sizes is shown in Table 1. Postoperatively, the double-treated patients did not achieve a better curve correction in comparison to solely surgically treated patients.

Surgical procedures performed

The instrumentations used in the surgically treated patients were a posterior Cotrel-Dubousset double rod system in 66 cases, synergy in two cases, and Harrington single rod system in three. Two had surgery with an anterior Kaneda Scoliosis System (KASS). The length of instrumentation described by number of vertebra was mean 9.4 ± 1.8 (range 5–13): number of free vertebra below the fusion mass was mean 3.9 ± 1.3 (range 2–7), highest instrumented vertebra Th2 and lowest instrumented vertebra L3.

Surgical complications

There were seven (10.8%) surgery-related complications which did not require surgical intervention: one excessive bleeding intraoperatively without postoperative complications; one paralysis of the right lower extremity with complete remission; one case of strength impairment over the hip after screw misplacement, which was corrected intraoperatively, resulting in a minor residual paresis; one click sound from the instrumentation; two long-lasting pain complaints without evidence of infection; and one continuing imbalance postoperatively. Long-term reoperation rate was 21.6% (16 patients). The indications for reoperation are listed in Table 2. Four (5.4%) of these patients had a second reoperation, three because of implant removal, and one because of instrumentation extension.

SRS 24 scores

Before we compared the outcome scores between treatment groups, we tested for internal correlation of the domain scores by correlating all other domain scores and the total SRS 24 score with the domain "satisfaction" (Table 3). The Pearson correlation test showed an overall significant ($P \leq 0.01$) correlation between all

Table 2 Scoliosis surgery which required long-term operative revision

Indication for reoperation	Reason in detail	*N*	Percent
First reoperation			
Deep infection	Abscess	3	4.2
	Fistulation	2	2.8
	Scintigraphic "hot spots"	1	1.4
Bursa	No bacterial infection verified	2	2.8
Implant failure	Hook loosening	4	5.6
	Implant breakage	1	1.4
Implant-related pain		3	4.2
Total		16	21.6
Second reoperation			
Extension of the fusion levels		1	1.4
Implant removal		3	3.2
Total		4	5.6

domain scales; the coefficient (r) was positive in all cases, the strongest correlation was found between pain and satisfaction ($r = 0.58$), post-treatment self-image ($r = 0.45$), and general self-image ($r = 0.36$).

Comparing the outcome scores of treatment groups by independent samples t test (Table 4 and Fig. 1) we found that the treatment groups had similar total SRS 24 scores, no significant differences were found; all groups scored 3.8 and higher.

The brace group had a significantly higher general self-image than the surgically treated patients (B 4.22 ± 0.74 vs. S 3.76 ± 0.81, $P < 0.05$), but a significantly lower post-treatment self-image (B 2.99 ± 0.76 vs. S 3.37 ± 0.74, $P < 0.05$). The solely brace-treated patients had a significantly higher general activity level than both operatively treated patient groups S and BS (B 4.40 ± 0.76 vs. S 3.80 ± 1.20, $P \leq 0.05$, vs. BS 3.88 ± 1.28, $P < 0.05$), but a significantly better post-treatment function only in comparison to the double-treated group (B 2.82 ± 0.95 vs. BS 2.24 ± 1.03, $P < 0.05$). Both surgically treated groups, S and BS, were significantly more satisfied with the treatment than B (B 3.32 ± 0.74 vs. S 3.78 ± 0.93, $P \leq 0.05$, vs. BS 3.94 ± 0.91, $P \leq 0.05$).

Additionally, we compared the scores from the brace group with the pooled group of surgically treated patients (S_{total}) (Table 5). We could not discern any significant differences in the total scores. Neither could we find any significant differences in the domain scores: pain, function from back-related condition, and post-treatment function. B had a significantly higher general self-image (B 4.22 ± 0.74 vs. S_{total} 3.89 ± 0.81, $P < 0.05$), and a higher general level of activity (B 4.40 ± 0.76 vs. S_{total} 3.84 ± 1.23, $P < 0.05$). S_{total} had a significantly higher post-treatment self-image (S_{total} 3.30 ± 0.74 vs. B 2.99 ± 0.76, $P < 0.05$) and a higher level of satisfaction (S_{total} 3.85 ± 0.92 vs. B 3.32 ± 0.74, $P < 0.05$). The patients with surgical complications had a significantly lower level of satisfaction; all other domain scores were unaffected by this factor and were similar to the scores of patients without complications.

Correlation of outcome scores and Cobb angles at various points in time

The correlation of the outcome scores was then tested in a correlation analysis (Table 6). When we looked at the outcome scores in correlation to the Cobb angle before and after treatment, we found a significant positive correlation among pain and curve magnitude at the first outpatient clinic visit and prebrace treatment Cobb angle. A positive correlation was found among the curve magnitude at the first outpatient clinic visit and prebrace treatment Cobb angle and post-treatment self-image. This means that pain increases and self-image suffers with increasing Cobb angle at the first outpatient clinic visit and increasing Cobb angle before start of the brace treatment. We found a significant positive correlation between prebrace-treatment curve magnitude and post-treatment self-image, as well as between prebrace-treatment curve magnitude and satisfaction and total SRS 24 score. The prebrace-treatment Cobb angle correlated positively with the total SRS 24 score. No significant correlation was found among any of the SRS 24 domain scores and the Cobb angle before surgery and at last outpatient clinic visit.

Table 3 Simple Pearson correlation coefficients between satisfaction and the other SRS 24 domains and total SRS 24 score

SRS 24 domains	*N*	*r*	*P*
Pain	97	0.58	0.000*
General self-image	93	0.36	0.000*
Function from back condition	96	0.35	0.000*
General level of activity	95	0.32	0.001*
Post-treatment self-image	95	0.47	0.000*
Post-treatment function	95	0.33	0.000*
Total SRS 24 score	87	0.67	0.000*

*$P < 0.05$

Table 4 SRS 24 outcome scores at least 2 years after completed treatment of AIS patients treated with brace or surgery, or brace and surgery

SRS 24 domains	Treatment groups	N	Mean	SD	P	
Pain	Braced	35	3.94	±0.77	B/S	0.491
	Surgically treated	35	4.08	±0.94	B/B + S	0.289
	Braced and surgically treated	27	4.14	±0.70	S/B + S	0.779
	Total	97	4.05	±0.82		
General self-image	Braced	43	4.22	±0.74	B/S	0.010*
	Surgically treated	37	3.76	±0.81	B/B + S	0.357
	Braced and surgically treated	32	4.05	±0.79	S/B + S	0.132
	Total	112	4.02	±0.80		
Function from back condition	Braced	44	4.02	±0.62	B/S	0.903
	Surgically treated	41	4.01	±0.47	B/B + S	0.162
	Braced and surgically treated	32	3.81	±0.67	S/B + S	0.167
	Total	117	3.96	±0.59		
General level of activity	Brace	43	4.40	±0.76	B/S	0.011*
	Surgery	39	3.80	±1.20	B/B + S	0.045*
	Braced and surgically treated	33	3.88	±1.28	S/B + S	0.798
	Total	115	4.05	±1.11		
Post-treatment self-image	Braced	38	2.99	±0.76	B/S	0.030*
	Surgically treated	41	3.37	±0.74	B/B + S	0.236
	Braced and surgically treated	30	3.21	±0.74	S/B+S	0.387
	Total	109	3.19	±0.76		
Post-treatment function	Braced	38	2.82	±0.95	B/S	0.550
	Surgically treated	41	2.66	±1.35	B/B + S	0.018*
	Braced and surgically treated	33	2.24	±1.03	S/B+S	0.149
	Total	112	2.59	±1.15		
Satisfaction	Braced	38	3.32	±0.74	B/S	0.021*
	Surgically treated	40	3.78	±0.93	B/B + S	0.002*
	Braced and surgically treated	33	3.94	±0.91	S/B+S	0.451
	Total	111	3.67	±0.89		
Total SRS 24 score	Braced	31	3.85	±0.45	B/S	0.653
	Surgically treated	30	3.79	±0.65	B/B + S	0.802
	Braced and surgically treated	26	3.88	±0.52	S/B + S	0.544
	Total	87	3.84	±0.54		

*$P < 0.05$

Discussion

We conducted this study in order to detect possible differences in the subjective outcome of AIS patients after completed brace-, surgery-, and double-treatment, and to relate the subjective outcome data with objective findings from radiographs and medical records. Actively treated patients ended up with equal total SRS 24 outcome scores as well as similar Cobb angles. Thus, the different treatment modalities were not reflected in total scores. The overall impression was that these patients thrived; the mean total SRS 24 score of 3.84 corresponds from fair to good regardless of the treatment performed.

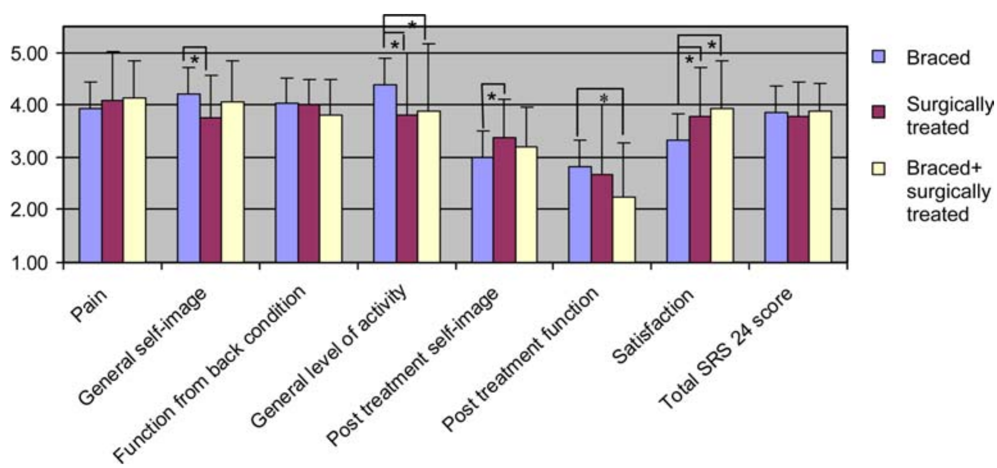

Fig. 1 SRS 24 outcome scores (mean domain scores and SD) at least 2 years after completed brace treatment, surgical-, and brace- and surgical treatment for AIS. Significant differences were shown between B versus S in general self-image, general level of activity, post-treatment self-image, and satisfaction; and between B versus BS in general level of activity and satisfaction. *$P < 0.05$

Table 5 SRS 24 outcome scores at least 2 years after completed treatment of AIS patients: comparing solely brace-treated patients and the pooled group of solely surgically treated patients and patients who had both brace- and surgical treatment

	Treatment groups	*N*	Mean	SD	*P*
Pain	Only brace	35	3.94	0.77	
	All surgery	62	4.11	0.84	0.330
General self-image	Only brace	43	4.22	0.74	
	All surgery	69	3.89	0.81	0.036*
Function of back condition	Only brace	44	4.02	0.62	
	All surgery	73	3.92	0.57	0.373
General level of activity	Only brace	43	4.40	0.76	
	All surgery	72	3.84	1.23	0.003*
Post-treatment self-image	Only brace	38	2.99	0.76	
	All surgery	71	3.30	0.74	0.042*
Post-treatment function	Only brace	38	2.82	0.95	
	All surgery	74	2.47	1.23	0.107
Satisfaction	Only brace	38	3.32	0.74	
	All surgery	73	3.85	0.92	0.003*
Total SRS 24 score	Only brace	31	3.85	0.45	
	All surgery	56	3.83	0.59	0.872

N number of patients who replied to all questions
$*P<0.05$

Table 6 Simple Pearson correlation coefficients between the Cobb angles and SRS 24 outcome subscales and total score

SRS 24 subscales	Cobb angle at first out-patient clinic visit			Cobb before brace treatment			Cobb of main curve preoperatively			Cobb at last follow-up		
	N	*r*	*P*	*N*	*r*	*P*	*N*	*r*	*P*	*N*	*r*	*P*
Pain	96	0.22	0.032*	56	0.27	0.044*	62	0.19	0.130	92	0.04	0.706
General self-image	111	−0.14	0.130	61	0.08	0.533	68	−0.02	0.849	106	−0.15	0.124
Function from back condition	116	0.01	0.905	64	0.14	0.266	72	0.06	0.598	111	0.00	0.970
General level of activity	114	−0.11	0.261	64	0.04	0.764	71	0.06	0.616	109	−0.06	0.522
Post-treatment self-image	108	0.21	0.029*	61	0.35	0.006*	70	0.14	0.256	104	0.08	0.441
Post-treatment function	111	−0.08	0.420	62	0.05	0.678	73	0.13	0.277	107	−0.13	0.196
Satisfaction	110	0.01	0.235	61	0.38	0.003*	72	0.08	0.508	106	−0.05	0.638
Total SRS 24 score	86	0.12	0.259	48	0.30	0.042*	56	0.14	0.304	82	−0.02	0.838

N number patients who answered all question; *r* Pearson coefficient
$*P<0.05$

Looking at the domain scores, we found scores higher than three in six of the seven domain scores. Post-treatment function was the only domain score where all three groups scored lower than three, equating to "worse" or "fair."

The question of whether or not brace treatment compromised the outcome at least 2 years after completed treatment in comparison to surgical treatment has to be answered negatively. We found that brace-treated patients scored highest (best) in most of the domains, which is an endorsement of the conservative treatment strategy often criticized for causing more psychological harm to the teenager than providing benefit. The braced groups seemed to suffer from a significantly lower post-treatment self-image than the surgery group, but the question is whether these results are attributable to the deformity itself or to the potential psychological harm of brace treatment. The scores differ within the range of 2.99–3.21, hence all the patients included in the study score fairly well. In addition, the double-treated group was the group that scored highest or second highest in most of the domain scores and highest in satisfaction, which is another indication that brace treatment does not have any significant long-lasting negative impact on life quality. The survey shows that brace treatment has a detrimental effect on post-treatment self-image in both brace-treated groups. The question is whether or not the measured difference in self-image is crucial and whether or not it is caused by brace treatment.

Furthermore, the double-treated patients and the solely surgically treated patients' domain scores did not differ significantly. The conclusion is that the tendencies shown by our study did not identify the brace treatment as an extraordinary burden with long-lasting effects on life quality. The apparent benefit of double-treatment—bracing followed by surgery—could possibly be explained by the fact that these patients with difficult curves experience the attempt to avoid surgery by brace treatment as a positive effort. Thus, the ensuing decision to convert treatment from bracing to corrective surgery may have been perceived by the patients differently from what we had expected.

The surgery group scored highest in post-treatment self-image, which confirms that the more or less immediate correction of their severe deformity makes a positive difference in terms of their post-treatment self-image. The significantly higher score of the S and the SB groups in post-treatment self-image and satisfaction is without doubt related to the correction of the spinal deformity and an obvious change in their appearance by reduction of the magnitude of the humped back [11, 15]. It was, therefore, surprising that we could not show any correlation between Cobb angle correction and post-treatment Cobb angle with any of the domain scores, but these results confirm the findings of other studies [21, 22] which could not determine any correlation between curve correction or curve size after surgery either.

In contrast to the lack of correlation among the domain scores and the post-treatment Cobb angles and Cobb angle improvement after treatment, we could determine a positive correlation among prebrace treatment Cobb angle and pain, post-treatment self-image and satisfaction and total SRS score. Why an increase in Cobb angle before brace initiation should have a positive effect on these three domain scores and the total score is difficult to discern, but one explanation could be that self-image and satisfaction are dependent on expectations to the treatment outcome. Patients with large curve magnitudes before start of treatment will probably be easier to please with any attempt of stabilizing or correcting the curve, whereas those patients who initially present relatively small Cobb angles and experience curve progression, or at least no absolute curve correction despite brace treatment, will feel disappointment, evaluate the treatment more negatively, and experience a lower post-treatment self-image.

Comparing our patients' outcome data with the post-treatment data from the study performed by Merola et al. [21], we find that all three treatment groups had significantly more pain and lower post-treatment self-image, reduced post-treatment function, and were less satisfied with the treatment result. In Merola's study, the outcome scores were significantly higher (better) than the ones in our study, which might reflect the fact that our patient population is on an average 7 years older; another explanation might be that Merola's study included both a pre- and post-treatment questionnaire and thus the patients' responses and the results of the study might be positively biased.

Comparing the SRS 24 domain scores from the present study with those of the study performed by Haher et al. [20] we found a stronger correlation coefficient between treatment and the domain scores, and a higher P value between treatment and satisfaction in terms of postoperative function, function from back condition, and general activity level.

Comparing the findings of the present study with those of other studies employing normal matched control groups, other studies do not find significant differences between the control groups and treated patients, especially in relation to brace-treated patients and controls [14, 17, 24–26]. They do not find self-image to be adversely influenced by brace treatment in comparison to a normal control group. In this study, we did not find distinct differences in the domain scores among the treatment groups. But even if there had been significant differences, we have to bear in mind that what is statistically significantly different in mean scores need not be clinically relevant.

Surprisingly, there were no significant differences in the domain and total SRS 24 score between the two surgically treated groups. Double treatment thus does not exert any measurable long-term impact. We expected a lower score, at least concerning satisfaction, in the double-treated group, but the experience of brace treatment did not have an unfavorable impact on the postoperative outcome scores in this patient series.

The SRS 24 instrument, since 1999, has been further developed and validated, resulting in the SRS 22 [27–29]. This instrument is more comprehensive, with a stronger internal consistency among the five new domains, which have incorporated elements of the SF 36. The SRS 22 is more sensitive to measures that change over time and it will, because of this advantage, be the preferred outcome instrument in future. Our study showed good discriminative abilities of the SRS 24 in distinguishing among the brace-treated, solely surgically treated, and brace- and surgically treated patients. It did not discriminate between the two surgically treated groups.

The SRS 22 has shown very good discriminative validity within most of the domain scores in the comparison of patients awaiting surgical treatment and patients who are in the process of being treated conservatively [30]. It is not able to discriminate between controls and conservatively treated patients, which means that SRS 22 is unable to measure the impact of the stigmatizing factor inflicted on the patient by the scoliosis diagnosis per se as much as it is able to discriminate between those who are in conservative treatment and those about to be surgically treated. Differences measured by a quality-of-life instrument must be clinically relevant and not merely a theoretical entity. It is difficult to believe that there are no measurable differences between controls and brace-treated patients at the time of brace treatment, but it is possible that any differences between these groups would be harmonized several years after completed treatment.

The reason why the SRS 24 did not distinguish between the two surgically treated groups in our study might be explained by the exclusively retrospective study design. Or, it might not be sensitive enough, or differences in treatment-related self-perception among braced patients who are subsequently surgically treated and solely surgically treated patients are eradicated several years after completed treatment. Another reason might be that the number of evaluated patients was relatively small and did not suffice to reveal true differences significantly.

In the evaluation of the data it is important to keep in mind that even though the data show some outcome differences among the treatment groups, the differences shown are not solely reliant on different treatment modalities but also on differences among the groups' severity of deformity.

Conclusion

These findings suggest that treatment of AIS with brace should be considered appropriate treatment, which does not leave the patients with a long-term decrease in life quality. By the same token, double-treatment does not appear to impair life quality either. Thus, there is no valid reason for avoiding or delaying brace treatment. Surgical treatment after failed bracing still gives good results despite the fact that post-treatment function will be compromised. The adolescent child is able to cope with the strain of brace treatment without negative effects on their quality of life as young adults, as demonstrated, by means of the SRS 24.

Future prospective studies should be conducted in order to explore quality of life from treatment start until adulthood in comparison to age- and sex-matched controls and furthermore, to determine to what extent significant differences in mean scores represent clinically measurable and relevant differences among treatment groups and controls.

The overall conclusions of this study indicate that AIS patients thrive after completed treatment; that different treatment modalities do not clearly differ with respect to total SRS 24 outcome scores; that brace treatment does not permanently impair quality of life, whether applied alone or before surgery; and that combined treatment does not need to be regarded as a double burden with long-lasting negative effects on quality of life in AIS patients.

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