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SPINAL FUSION IN SCOLIOSIS

A SURVEY OF 197 CASES

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INTRODUCTION AND BRIEF REVIEW OF THE LITERATURE

This paper presents the results of treatment of progressive structural scoliosis in the Orthopaedic Hospital of The Invalid Foundation in Helsinki from 1947 to 1962. The treatment is reviewed on the basis of 197 cases with spinal fusion of the scoliotic spine.

The treatment of structural scoliosis with spinal fusion may soon give way to new surgical methods. Thus A. LANGENSKIÖLD and MICHELSSON produced experimental progressive scoliosis in rabbits and pigs and found that a scoliotic spine can be made to grow straight with soft-tissue operations (21, 22, 23). ROAF, in 1962, presented late results of unilateral growth arrest of the spine in scoliosis, showing improvement in a considerable proportion (34, 35). GRUCA corrected the scoliotic deformity with springplasty (12), and in 1962 presented good results (13). BLOUNT, in 1962, reported results of treatment with the Milwaukee brace without operation in early paralytic scoliosis and in the treatment of minor idiopathic curvatures nearing maturity; results were gratifying (4, 5). In several cases the brace was worn for five years.

In recent years there has been a fall in the incidence of paralytic scoliosis because of the disappearance of anterior poliomyelitis, perhaps following the introduction of Salk vaccination. The need for spinal fusion will thus be reduced. In spite of this and of all new operative methods, the spinal fusion developed by HIBBS, either in its original form or as modified by others, will retain an important position. In some cases it will remain the best method available; in other instances it may be used as a supplementary procedure. Spinal fusion will keep the corrected spine straight.

There are several excellent papers on the treatment of scoliosis, some of which will be mentioned here because they have guided our choice of treatment. In 1924 HIBBS described his classic technique of spinal fusion (14). In 1931, together with RISSER and FERGUSON, he presented results obtained in 360 cases, also giving indications for fusion (15). These fundamental principles still hold. In 1952 COBB presented his modification of the spinal fusion (9), which has been our main tech-

nique since 1955. In 1954 JAMES classified idiopathic scoliosis into three groups by age at onset (17). In 1950 PONSETI and FRIEDMAN decisively clarified the understanding of the treatment of scoliosis by reporting on 117 cases treated with spinal fusion and by classifying the different curve patterns of idiopathic scoliosis which are important factors to reckon with in planning the treatment and for the prognosis (25, 26). BLOUNT and SCHMIDT made an important contribution by introducing the Milwaukee brace in 1954 (6). In 1958 they presented results of treatment with the Milwaukee brace in combination with spinal fusion (7, 8). In the same year, MOE published his excellent results obtained by spinal fusion. In his critical analysis of methods he stressed that a meticulous technique with wide exposure and careful decortication together with fusion of the articular facets is one of the most important conditions of success (24). In the same year, RISSER *et al.* presented their material of 347 cases corrected with the turnbuckle body cast and the localizer body cast (33). In 1962, ALVIK (1, 2), THOMASEN (37), and RISKA (27) reported on the treatment of scoliosis in Scandinavia, and at the same time BLOUNT demonstrated nonoperative treatment of some cases of scoliosis with the Milwaukee brace (4). GOLDSTEIN'S monograph of 1959 presented the treatment of scoliosis in detail and showed good results (11).

The present addition to the extensive literature on the subject (*cf.* also 10, 16, 36, 38) is made in the belief that any accumulation of clinical data on scoliosis is likely to yield new details. At the same time, the development of the treatment of scoliosis in our clinic will be reviewed and a description given of the method of correction and spinal fusion in use today. Some facts are common to all cases, and these will be discussed first.

MATERIAL AND METHODS OF TREATMENT

The treatment of structural scoliosis in this clinic was started by the late Professor FABIAN LANGENSKIÖLD and continued since 1956 by ANDERS LANGENSKIÖLD. It has followed the lines drawn by HIBBS (14, 15), RISSER (28, 29, 31, 32), COBB (9), and later by BLOUNT and SCHMIDT (6, 7).

Goals of Treatment

The aim of the treatment in idiopathic scoliosis has been to obtain some measure of correction, or at least to prevent further increase of the deformity in the growing child. The goal of treatment in paralytic scoliosis has been correction of the existing deformity, prevention of further deformation, and stabilization of a spine that has lost part of its normal muscular support.

Material

The data are based on analysis of 197 patients having curvatures classified according to PONSETI, FRIEDMAN (25, 26), and JAMES (17) as idiopathic, paralytic secondary to poliomyelitis, and miscellaneous (Table 1). Sixty-four patients out of 86 with idiopathic scoliosis had a

TABLE 1

CLASSIFICATION OF SCOLIOSIS

Scoliosis	No. of Cases	Infantile	Juvenile	Adolescent	Main Thoracic Curve	Thoracolumbar Curve	Combined Thoracic and Lumbar Curve	Main Lumbar Curve
Idiopathic	86	9	32	45	**64**	17	5	
Paralytic	99				26	66	6	1
Miscellaneous*	12				4	6	2	
Total	**197**				94	89	13	1

*Congenital anomaly 5 cases
Neurofibromatosis 3 cases
Scheuermann's disease 1 case
Chondrodystrophia 1 case
Post meningitidem 1 case
Post operationem of congenital heart disease 1 case

Degree of curvature before correction.

70 % of curvatures over 60°

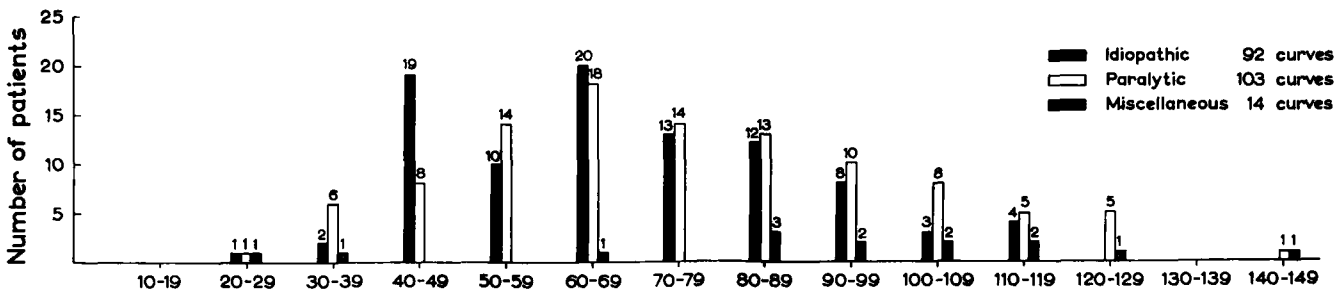


Chart 1.

main thoracic curve, and 66 out of 99 cases with paralytic scoliosis had a thoracolumbar curve. There were 13 cases with a combined thoracic and lumbar curve, and only one patient had a lumbar curve alone. The diagnoses of the miscellaneous cases are given in Table 1.

Two hundred and nine curves were corrected and treated with spinal fusion. Accordingly, 12 patients had 2 curves to be fused. Prior to correction, 70 per cent of the curvatures had an angle over 60° (Chart 1).

Correction of Scoliotic Deformity

The turnbuckle plaster cast of RISSER was used from 1947 to 1954 in 42 cases. During this period, the Milwaukee brace of BLOUNT and SCHMIDT was also employed for some patients; since 1954, it has been used as almost a routine measure, the total of cases now amounting to 155 (Table 2). In three cases the preoperative correction was made with

TABLE 2

TYPE OF CORRECTION

Correction	Idiopathic	Paralytic	Miscellaneous	Total
The turnbuckle cast of Risser	13	27	2	42
Milwaukee brace of Blount and Schmidt	73	72	10	**155**

the turnbuckle cast but after surgical intervention the treatment was continued with the Milwaukee brace.The turnbuckle body cast increases the angle of both secondary curves, which was one of the motives for our adoption of the Milwaukee brace. Because the results of correction with the Milwaukee brace have been good, no need has been felt to employ the localizer body cast.

Several patients were treated for more than one year with the Milwaukee brace before surgical intervention (Table 3a) depending on the age of the patient at the onset of the deformity, the age of the patient at the beginning of treatment, the degree of the deformity at first examination, and also the patient's general condition especially in cases with se-

TABLE 3 a

DURATION OF TREAMENT WITH MILWAUKEE BRACE BEFORE THE OPERATION

Time	No. of Cases
1 month	33
2 months	22
3 ,,	14
4 ,,	13
5 ,,	8
6 ,,	12
7 ,,	4
8 ,,	3
9 ,,	3
10 ,,	2
12—18 ,,	11
18—24 ,,	5
2— 3 years	2
3— 4 ,,	6
4— 5 ,,	7
5— 6 ,,	5
6— 7 ,,	3
7— 8 ,,	2
Total	155

vere paralysis after poliomyelitis. The tendency to progression was one of the most important factors to reckon with when deciding about commencement of the correction. In 33 patients the preoperative treatment with the Milwaukee brace lasted only one month (Table 3a), which sufficed to familiarize the patient with the brace. The treatment with the Milwaukee brace after spinal fusion was continued for 9 months in 45 patients, 10 months in 34, and 11 months in 22 patients. In 32 cases this treatment was continued for more than one year (Table 3b).

TABLE 3 b

DURATION OF TREATMENT WITH MILWAUKEE BRACE AFTER THE OPERATION

Time (months)	No. of Patients	Patients with Pseudarthroses
5—8	9	0
9	**45**	**10**
10	34	10
11	**22**	**5**
12	15	4
13	8	2
14	4	0
15	2	0
16	2	1
18	1	0
more than 19	15	8
Total	157	40

Patients with the turnbuckle body cast were operated on through a large posterior window in the plaster cast. The Milwaukee brace was removed before the operation and reapplied after the spinal fusion on the same day or in some cases on the day after the operation. In the patients treated with the turnbuckle cast, the correction was obtained prior to the operation; in the patients with the Milwaukee brace, correction continued during 10 days after the operation.

The results of correction with the Milwaukee brace were satisfactory (Tables 13—19), and when carefully fitted, the brace was well tolerated by the patient. Out of 45 patients treated with the Milwaukee brace during 9 months after the operation, 10 (22 per cent) had pseudarthroses in the fusion area, and out of 22 patients treated with the brace during 11 months, 5 (22 per cent) had pseudarthroses (Table 3b).

Sex and Age at Time of Surgical Intervention

The distribution of patients by age and sex is shown in Chart 2. The age of patients at the time of fusion varied from 8 to 29 years. Most of the patients (65 per cent) were operated on at an age of 12 to 15 years.

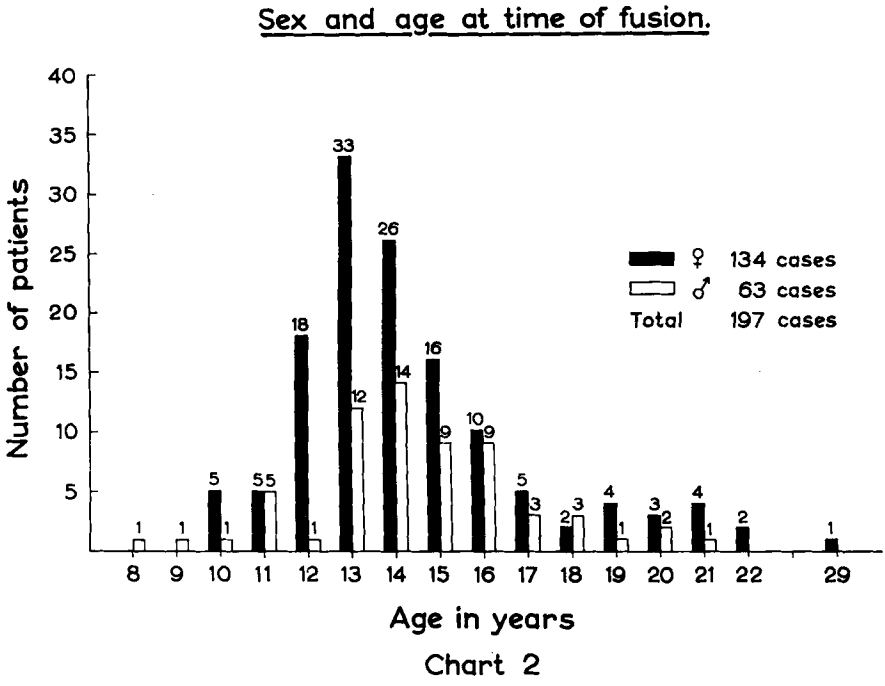


Chart 2

Risser in 1958 reported on the time of fusion of iliac apophyses by the age of patients stating that the vertebral growth is completed near the time when iliac apophyses are attached to the iliac crest (30). Like Risser we have noted that at least in idiopathic scoliosis the deformity no longer progressed when the growth of the spine was completed. The progression could, however, continue in patients with severe paralysis after poliomyelitis, which agrees with reports presented before (11, 24, 30). The development and fusion of iliac apophyses were examined and followed in most cases. The fusion took place earlier in girls than in boys (Table 4): in 47 girls it was completed at 16 years, and in 22 boys

TABLE 4

LATERAL FUSION OF ILIAC APOPHYSES CORRELATED WITH THE AGE OF PATIENTS

Age at Fusion of Apophyses	Girls	Boys	Total Patients		Patients with Pseudarthroses	
			No. of Cases	Average Age at Surgery	No. of Cases	Average Age at Surgery
Years	No. of Cases	No. of Cases		Years and Months		Years and Months
14	15	1	**16**	12.3	**2**	10.4
15	32	6	**38**	13.7	**10**	13.5
16	47	18	**65**	14.2	**19**	13.8
17	10	22	**32**	15.8	**10**	14.2
18	4	6	**10**	16.6	**4**	16.6
19	0	2	**2**	20.1	**2**	20.1
20	1	1	2	18.1	1	19.2
No apophyses	10	5	15	12.4	5	11.10
Unknown	15	2	17	18.3	4	16.9
Total	134	63	197		57	

at 17 years. Skeletal age was determined only in some cases, though today we recognise its importance in the planning of treatment.

A classification of the patients with postoperative pseudarthroses into age groups shows that the number of cases with pseudarthroses was greater in patients with a longer growth period of the spine or in patients with a late fusion of the iliac apophyses (Table 4). Correspondingly, there was major loss of correction in 9 cases and pseudarthrosis in 5 cases out of 19 operated on at a calendar age of 12, but major loss of correction in only 4 and pseudarthrosis in only 3 out of 19 patients operated on at a calendar age of 16 years. It therefore seems wise to postpone the time of surgical intervention. The development of iliac apophyses and vertebral growth must be closely watched, though the degree of the deformity and its progression are the most important factors in deciding the time for surgical intervention.

Operative Technique

Three general types of fusion were employed by about 20 different surgeons (Table 5). First, the original HIBBS method with fusion of articular facets was used in 23 cases until 1954—1955. One patient developed paraplegia on account of the operation, and destruction of articular facets was discontinued when the operation was done to 24 patients in 1955—1956. The clinical results were disappointing because of major loss of correction. Therefore, since 1955—1956, in the majority of cases the fusion was carried out by the COBB modification by adding substantial amounts of bone grafts into the fusion area. Until 1959, homogenous bone-bank bone was mostly used, altogether in 96 patients, but the number of cases with pseudarthroses was high. Therefore since 1959 most of the fusions have been done with autogenous bone grafts (40 patients), or with autogenous bone together with bank bone (14 patients). In 29 cases solely tibial bone and in 11 cases solely fresh ilium was used as grafting material (Table 5). In 22 out of 54 patients the autogenous bone was taken prior to the spinal fusion, banked, and used 2 weeks

TABLE 5

TYPE OF FUSION

Fusion	Idiopathic	Paralytic	Miscellaneous	Total
Hibbs-type fusion with articular-facets fusion	4	19		23
Without articular-facets fusion No bone added	8	15	1	24
Cobb-type fusion Bone-bank bone added	50	39	7	**96**
Cobb-type fusion Autogenous tibial bone added	13	12	4	29
Cobb-type fusion Autogenous ilium added	4	7		11
Cobb-type fusion Bone-bank bone and autogenous bone added	7	7		14

later for fusion. In 32 cases the autogenous bone was taken at the same operation and transplanted at once.

Out of 22 patients from whom the bone was taken two weeks before the spinal fusion, 3 (14 per cent) had pseudarthroses in the graft; out of 32 patients with fresh bone grafts transplanted at the same operation, 4 (13 per cent) had pseudarthroses. It seems better to transfer the bone afresh, though the operation takes more time. Only one anesthesia is needed for a spinal fusion in one stage.

In 117 patients the operation was done in one stage (Table 6), in 70 in two, and in 10 in 3 stages. Altogether, 287 operations were carried out on 197 patients.

The patients were kept in bed for 4 months after the operation.

TABLE 6

NUMBER OF OPERATIONS

Scoliosis	No. of Cases	No. of Operations			
		1	2	3	Total
Idiopathic	86	63	19	4	113
Paralytic	99	45	49	5	158
Miscellaneous	12	9	2	1	16
Total	197	117	70	10	287

Complications

There were 2 patients with paraplegia on account of the operation. One was a case of paralytic, the other of idiopathic scoliosis. In the second patient, the fusion area and the spinal cord were explored 60 days after the spinal fusion, but without any positive findings. There was one death of uraemia secondary to glomerulonephritis after thoracoplasty, which was the third operation for this patient. One patient died at home of congenital heart disease thirteen months after the operation. Another patient died, also at home, two years after the operation from infection of the respiratory tract, but she suffered from severe paralysis after poliomyelitis and had a high-degree scoliotic deformity. Thus there were 3 patients with serious complications on account of the operation.

RESULTS OF TREATMENT

A complete roentgenographic survey of the scoliotic spine was carried out, including anteroposterior roentgenograms made with the patient **supine,** standing, and bending to the right and to the left. Later, oblique roentgenograms were taken to evaluate the stability of the fused area. During the whole period, the COBB method of measurement of the scoliotic deformity was used (Table 7). According to this method, the scoliotic angulation is the angle formed by the intersection of lines drawn perpendicular to the superior surface of the top vertebra and the inferior surface of the lowest vertebra of the curve.

TABLE 7

MEASUREMENT OF SCOLIOTIC DEFORMITY
COBB'S METHOD

A **Precorrection curvature:** maximum curvature with the patient **standing.**

B **Corrected curvature:** minimum curvature after correction with the patient **supine.**

C **Final curvature:** measurement at the last follow-up examination with the patient **standing.**

Correction	(degrees)	$= A - B$
	(per cent)	$= \frac{A - B}{A} \times 100$
Loss of correction	(degrees)	$= C - B$
	(per cent)	$= \frac{C - B}{A - B} \times 100$
Net correction	(degrees)	$= A - C$
	(per cent)	$= \frac{A - C}{A} \times 100$
Progression	(degrees)	$= C - A$
	(per cent)	$= \frac{C - A}{A} \times 100$

The majority of the patients were followed up postoperatively for more than three years (Table 8). The mean duration of the follow-up period was over 4 years, and for 57 patients over 6 years. The data were obtained by the author's personal evaluation at the follow-up examination of patients treated in this hospital.

A partial correction of the scoliotic deformity can be achieved with the turnbuckle plaster cast, with the localizer body cast, or with the Milwaukee brace. Today, correction of a scoliotic deformity to an acceptable state is no longer a problem except in imbalanced patients with a great deformity. The greatest difficulty is to maintain the correction. If this can be done, a good result will be achieved. MOE in 1958 stressed the importance of a good operative technique (24), but even then the correction can be lost. The existence of pseudarthroses in

TABLE 8

TIME FROM OPERATION TO LAST FOLLOW-UP EXAMINATION

Time	No. of Cases
3—12 months	2*
12—18 ,,	26
18—24 ,,	25
2— 3 years	30
3— 4 ,,	21
4— 5 ,,	17
5— 6 ,,	19
6— 7 ,,	24
7— 8 ,,	12
8— 9 ,,	5
9—10 ,,	10
10—11 ,,	3
11—12 ,,	3
Total	197

* One death and one paraplegia

the grafts of the fused spine must be regarded as one of the main reasons for the loss of correction and for the progression of the scoliotic deformity after spinal fusion. Therefore it is worth while to try to diagnose these pseudarthroses at an early stage.

Incidence of Pseudarthroses

It is not always easy to find a pseudarthrosis in the fusion area of the spine. Roentgenograms made with the patient bending to both sides are imperative together with oblique exposures. In several cases in our clinic, tomography has been used. Patients with pseudarthroses have pain in the back mainly in the fusion area, and all of them complain of back fatigue after strain especially in the evening. Pseudarthrosis leads to movement in the fusion area, and a crack can be heard when the patient is bent sidewards. *If there is a real pseudarthrosis, most or all of the correction achieved will be lost.*

No major difference existed in the rate of pseudarthroses between patients with idiopathic scoliosis (24 cases out 86 patients; 28 per cent) and those with paralytic scoliosis (32 cases out of 99 patients; 32 per cent). Altogether there were 57 patients with pseudarthroses causing symptoms in 197 operated cases, which makes 29 per cent (Table 9). More pseudarthroses were found roentgenologically (in 81 patients; 45 per cent), but only 57 of them manifested all the clinical symptoms of a real pseudarthrosis. Of patients treated with spinal fusion without addition of supplementary bone to the fusion area, 40 per cent developed pseudarthroses; in patients with bank bone as supplementary graft, pseudarthroses occurred in 32

TABLE 9

INCIDENCE OF PSEUDARTHROSIS

Scoliosis	Cases	Pseudarthroses		Became Solid	Still Persisting
		No.	Per cent		
Idiopathic	86	24	28	14	10
Paralytic	99	32	32	20	12
Miscellaneous	12	1			1
Total	197	57	**29**	34	23

per cent (Table 10). Only 5 (13 per cent) of the patients treated with fusion with the addition of autogenous bone had pseudarthroses; when autogenous bone was used together with bank bone, pseudarthroses were found in 2 cases (14 per cent). Accordingly, autogenous bone must be regarded as superior to bone-bank bone as a grafting material, a principle known for some years (3, 24).

In 30 patients the pseudarthroses became solid with prolonged use of the Milwaukee brace (Table 9). Only in four cases were the pseudarthroses surgically treated.

TABLE 10

INCIDENCE OF PSEUDARTHROSIS IDIOPATHIC, PARALYTIC AND MISCELLANEOUS SCOLIOSIS

Type of Bone Added	Cases	Pseudarthroses	
		No.	Per cent
No bone added	47	19	40
Bone-bank bone	**96**	**31**	**32**
Autogenous bone	**40**	**5**	**13**
Bone-bank bone and autogenous bone	14	2	14
Total	197	**57**	**29**

Causes of Loss of Correction in 68 Patients

There was a major loss of correction in 68 patients (Table 11). In 46 patients a pseudarthrosis in the fusion area was responsible. In 12 out

TABLE 11

CAUSES OF MAJOR LOSS OF CORRECTION IN 68 CASES

	No. of Cases	Pseudarthroses	Fusion Area not of Adequate Length	Loss of Correction in Spite of Solid Fusion of Adequate Length
Idiopathic	30	21	6	3
Paralytic	35	25	5	5
Miscellaneous	3		1	2
Total	68	46	12	10

of 68 patients with a major loss of correction after the operation, the fusion area was of inadequate length, and in 10 cases no clear reason could be established. Unrelenting bending force acting upon the fused spine could perhaps cause such a loss of correction. In 37 out of the 68 patients with a major loss of correction, bank bone had been added to the fusion area, and in 20 patients no bone had been added at all (Table 11).

Good Results in 63 Patients

The result of treatment was classified as good if the loss of correction was less than about 15 degrees and if the net correction was about 20 per cent. No pseudarthroses were found in the fusion area, and the cosmetic result corresponded to the correction achieved.

A good result was obtained in a total of 63 out of 197 patients (Table 12), comprising 19 (48 per cent) out of the 40 patients treated with autogenous bone as supplementary graft. A good result was gained only in 25 cases (26 per cent) out of the 96 patients fused with the addition of bank bone. These 63 patients had an average net correction of 23 per cent, which corresponds to the good cosmetic results.

TABLE 12

SIXTY-THREE CASES WITH GOOD RESULT OF TREATMENT CORRELATED WITH THE TYPE OF BONE ADDED

Type of Bone Added	No. of Cases	Average Net Correction	
		Degrees	Per cent
No bone added	10 out of 47	21	22
Bone-bank bone added	25 out of 96	15	22
Autogenous bone added	19 out of 40	16	24
Autogenous bone and bone-bank bone added	9 out of 14	16	24
Total	63 out of 197	**16**	**23**

Idiopathic Scoliosis

The results of treatment with spinal fusion are given in Tables 13—15. In the last years the fusions have been done mostly with supplementary autogenous bone, or autogenous bone together with bank bone. In these two groups of patients (17 and 7 patients), the average net correction was between 10 and 26 per cent, and only in 2 patients did a pseudarthrosis occur in the graft. Sixteen out of 50 patients grafted with supplementary bone-bank bone had pseudarthroses, the average net correction being between 7 and 10 per cent. These results leave a great deal to be desired, especially when compared with statistics presented before (7, 11, 24), but it must here be repeated that the operations were performed by 20 different surgeons. Patients treated privately had better results, but are not considered separately in this study. The average maximum correction of the scoliotic deformity was good (Tables 13—15), but the loss of correction too great, even though the corrected curvature was measured from a roentgenogram made with the patient supine, and the final curvature at the last follow-up examination with the patient

TABLE 13

IDIOPATHIC SCOLIOSIS
PRECORRECTION CURVATURE UNDER 50°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion									
Without articular-facets fusion. No bone added	1955	1	26	65	17	65	9	22	0
Cobb-type fusion Bone-bank bone added	1955-1961	10	19	45	15	89	4	7	3
Cobb-type fusion Autogenous bone added	1960-1961	4	20	42	8	40	12	26	0
Cobb-type fusion Bone-bank bone and autogenous bone added	1959-1960	2	21	48	16	76	5	11	1
Total		17							4

TABLE 14

IDIOPATHIC SCOLIOSIS
PRECORRECTION CURVATURE BETWEEN 50-80°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion	1954	1	12	22	12	100	0	0	1
Without articular-facets fusion. No bone added	1953-1955	5	25	43	23	91	2	3	3
Cobb-type fusion Bone-bank bone added	1955-1961	24	26	40	19	70	7	**10**	**8**
Cobb-type fusion Autogenous bone added	1955-1961	8	24	37	15	65	9	**11**	**0**
Cobb-type fusion Bone-bank bone and autogenous bone added	1959-1961	4	31	47	15	49	16	**26**	**0**
Total		42							12

TABLE 15

IDIOPATHIC SCOLIOSIS
PRECORRECTION CURVATURE OVER 80°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion	1952-1954	3	6	7	6	100	0	0	1
Without articular-facets fusion. No bone added	1953	2	17	20	14	76	3	5	1
Cobb-type fusion Bone-bank bone added	1954-1961	16	28	31	19	67	9	10	**5**
Cobb-type fusion Autogenous bone added	1955-1961	5	27	29	17	66	10	10	**0**
Cobb-type fusion Bone-bank bone and autogenous bone added	1955	1	54	61	54	100	0	0	1
Total		27							8

standing. The development of pseudarthroses and the consequent loss were probably often caused by an operative technique with poor exposure and poor decortication, or arose as a result of grafting with bank bone. Regarding the degree of the deformity, the pseudarthrosis rate was almost the same in all three groups of patients (precorrection curve under 50°, between 50° and 80°, and over 80°): in the first group it was 24 per cent, in the second 29 per cent, and in the third 29 per cent (Tables 13—15).

Paralytic Scoliosis

The results are given in Tables 16—18. Percentually, the average maximum correction was almost the same in all three groups of patients with precorrection curves under 50°, between 50 or 80°, and over 80°. The average loss of correction was great in all three groups, being greatest in patients with precorrection curves under 50°. The greatest average net corrections were gained in patients with precorrection curvatures over 80° treated with the original Hibbs-type fusion (Table 18). The average net corrections were 9, 13 and 10 per cent in patients treated with supplementary autogenous bone, but only 3, 12 and 6

TABLE 16

PARALYTIC SCOLIOSIS
PRECORRECTION CURVATURE UNDER 50°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion	1952-1953	3	13	27	12	99	1	2	3
Without articular-facets fusion. No bone added	1953	1	18	47	18	100	0	0	1
Cobb-type fusion Bone-bank bone added	1955-1960	8	15	40	14	93	1	3	2
Cobb-type fusion Autogenous bone added	1955-1961	3	18	47	14	84	4	9	1
Cobb-type fusion Autogenous bone and bone-bank bone added									
Total		15							7

TABLE 17

PARALYTIC SCOLIOSIS
PRECORRECTION CURVATURE BETWEEN 50-80°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion	1951-1953	6	22	36	21	97	1	2	3
Without articular-facets fusion. No bone added	1953-1956	7	18	31	14	80	4	6	3
Cobb-type fusion Bone-bank bone added	1955-1961	17	28	42	20	70	8	12	8
Cobb-type fusion Autogenous bone added	1955-1961	10	27	39	19	70	8	13	3
Cobb-type fusion Autogenous bone and bone-bank bone added	1960-1961	5	27	39	15	58	12	17	0
Total		45							17

TABLE 18

PARALYTIC SCOLIOSIS
PRECORRECTION CURVATURE OVER 80°
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion	1951-1955	10	44	42	25	58	19	18	1
Without articular-facets fusion. No bone added	1951-1955	7	35	36	27	66	8	9	2
Cobb-type fusion Bone-bank bone added	1955-1961	14	33	32	26	77	7	6	4
Cobb-type fusion Autogenous bone added	1960-1961	6	32	32	23	75	10	10	1
Cobb-type fusion Autogenous bone and bone-bank bone added	1955-1958	2	28	29	20	74	8	8	0
Total		39							8

per cent in patients treated with bank bone (Tables 16—18). Only 5 patients out of 26 grafted with autogenous bone or with autogenous as well as bank bone had pseudarthroses. On the other hand, 14 patients out of 39 treated with supplementary bank bone had pseudarthroses. According to this, good results should be obtained with the original Hibbs-type fusion using autogenous bone as grafting material, which corresponds to the technique described by Moe (24). Seven patients (47 per cent) out of 15 with precorrection curvatures under 50° had pseudarthroses. When the precorrection curvature was between 50° and 80°, pseudarthroses occurred in 17 out of 45 (38 per cent); and when the precorrection curvature exceeded 80°, the pseudarthrosis rate fell to 8 out of 39 (21 per cent). The patients with precorrection curvatures over 80° were older when operated. Results thus improve when the time of surgical intervention approaches the time when vertebral growth is nearing completion (see above).

Miscellaneous Cases

The results are given in Table 19. The correction of the scoliotic deformity in 11 patients was good. The loss of correction averaging

TABLE 19

MISCELLANEOUS CASES OF SCOLIOSIS
CORRECTION OBTAINED FOLLOWING SURGERY

Type of Fusion and of Bone Added	Time of Operation	No. of Cases	Average Maximum Correction		Average Loss of Correction		Average Net Correction		No. of Pseudarthroses
			Degrees	Per cent	Degrees	Per cent	Degrees	Per cent	
Hibbs-type fusion with articular-facets fusion									
Without articular-facets fusion. No bane added	1955	1	10	9	1	10	9	8	0
Cobb-type fusion Bone-bank bone added	1955-1961	7	31	36	24	80	7	**10**	**1**
Cobb-type fusion Autogenous bone added	1959-1961	4	29	34	19	47	10	**15**	**0**
Cobb-type fusion Autogenous bone and bone-bank bone added									
Total		12							1

80 per cent in the 7 patients treated with supplementary bank bone is an unfortunate demonstration of the inferiority of this grafting material to autogenous bone. None of the 4 patients treated with autogenous bone had pseudarthroses, and the average net correction amounted to 15 per cent. One patient had a pseudarthrosis in the graft. In this case the fusion was done with supplementary bank bone.

Cosmetic Results

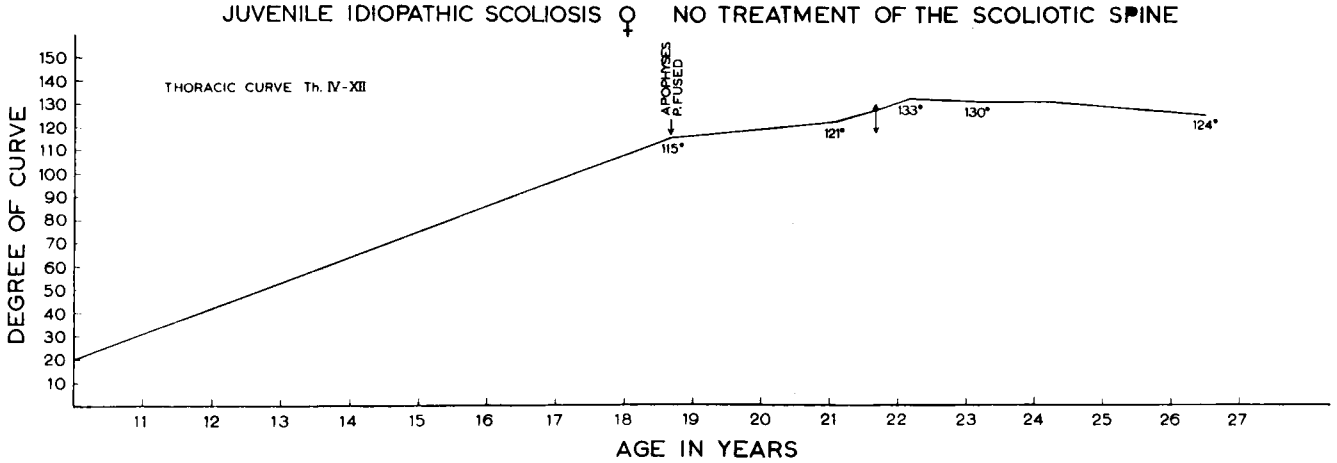
In judging the end results of treatment, the cosmetic result is as important as roentgenographic evidence of a corrected curvature. Compensation can be regained and the patient's appearance improved without roentgenographic evidence of correction, but in general a good cosmetic result indicates an improvement also demonstrable roentgenographically. On the other hand, a good correction of the deformity can give a poor cosmetic result with a column difficult to keep in balance. Therefore the surgeon's evaluation of the cosmetic result as well as the opinions of the patient and of the parents are important. To facilitate analysis of the development of the deformity, almost all patients were routinely photographed before, during and after treatment. The 63 patients with a net correction of 23 per cent had a good cosmetic result (Table 12). Most patients with a major loss of correction following spinal fusion of inadequate length showed a poor cosmetic result, some of them being still out of balance after treatment (Table 11). In 23 patients with pseudarthroses causing loss of correction or even a progression of the deformity, the cosmetic result was poor (*c.f.* Table 11).

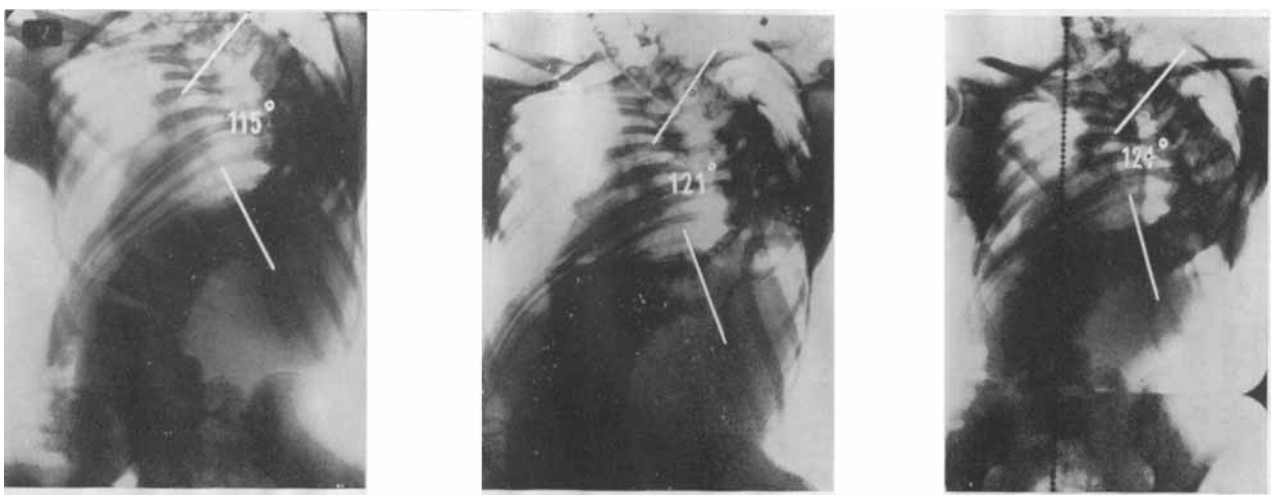
Degree of Deformity During Treatment

Graphic illustration facilitates evaluation of the total constellation of factors connected with the treatment and the development of the deformity. It should be noted that only the corrected curvature was measured from a roentgenogram made with the patient supine; all the others were determined with the patient standing. The graphic presentation accounts for the following data: the degree of the angle of the scoliotic deformity at the time of examination, the age of the patient, the time of commencement of treatment with the Milwaukee brace, the time when the brace was taken off, the time of surgical intervention, the type of bone added, the period

of recumbency after the operation, the time of fusion of iliac apophyses, and the follow-up period with the time of last examination. The photographs and roentgenograms below the graphs illustrate the patient's condition before and after treatment. Together with 9 cases treated with spinal fusion, three untreated cases are presented graphically, two having juvenile and one infantile idiopathic scoliosis. These three unoperated patients may serve as points of reference in the advising of surgical treatment, *e.g.* spinal fusion, in progressive structural scoliosis. At an early date they will develop complications and cardiopulmonary trouble (*cf.* 20), which of course must be avoided. The graphs may also throw light on the progress of the scoliosis and on the patient's prognosis, which are difficult to estimate at an early stage. Comparison of the results of surgery with the condition of these three untreated patients suggests that there is reason enough to continue with spinal fusion until a better and/or simpler method of treatment has been developed.

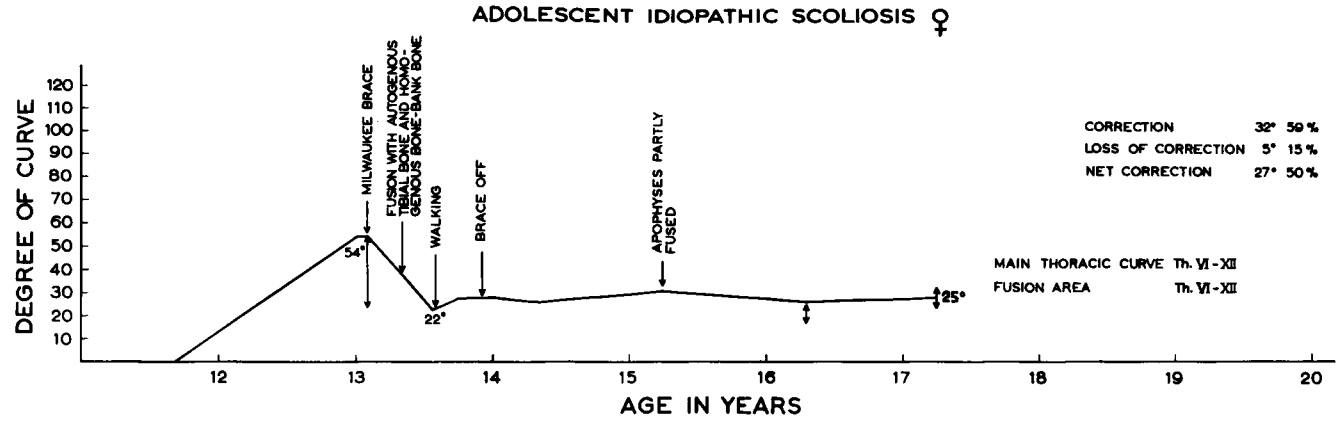
Patients 1 (Fig. 1) and 5 (Fig. 5) were untreated. Patients 2—4 (Figs. 2—4) are cases of idiopathic scoliosis. Patients 2 and 4 had good and patient 3 fair results of treatment, without which a condition like that of Patient 1 could have developed. Patient 6 (Fig. 6) is also a case of idiopathic scoliosis treated with a good result. A condition like that of Patient 5 might have developed without adequate treatment. Patient 7 (Fig. 7) had juvenile idiopathic scoliosis and was given sufficiently early treatment with the Milwaukee brace until the time of surgical intervention, when the parents refused the operation. Treatment was discontinued and the deformity progressed to 142°. Patients 8 (Fig. 8) and 9 (Fig. 9) are cases of adolescent idiopathic scoliosis treated adequately and with good results. Patient 10 (Fig. 10) illustrates a case of idiopathic scoliosis treated early and with good correction of the deformity but with a major loss of correction on account of development of pseudarthroses in the fusion area. The pseudarthroses were treated with prolonged use of the Milwaukee brace. Patient 11 (Fig. 11) also illustrates a case with a major loss of correction and with progression of the scoliotic deformity during treatment. The fusion area was explored, but no pseudarthroses could be found. In spite of early treatment continued postoperatively with prolonged use of the Milwaukee brace, the result was poor. Without surgery the deformity might have grown even beyond the 55° found at the last follow-up examination. Patient 12 (Fig. 12) is a case of paralytic scoliosis with a good result of treatment. The fusion was done with supplementary autogenous iliac bone.

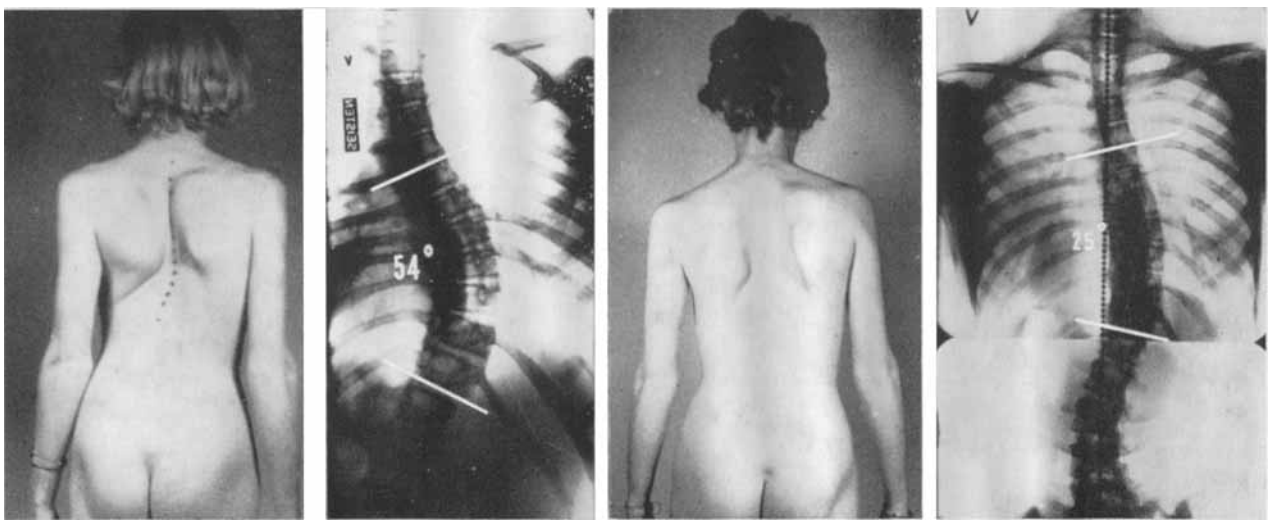




a b c

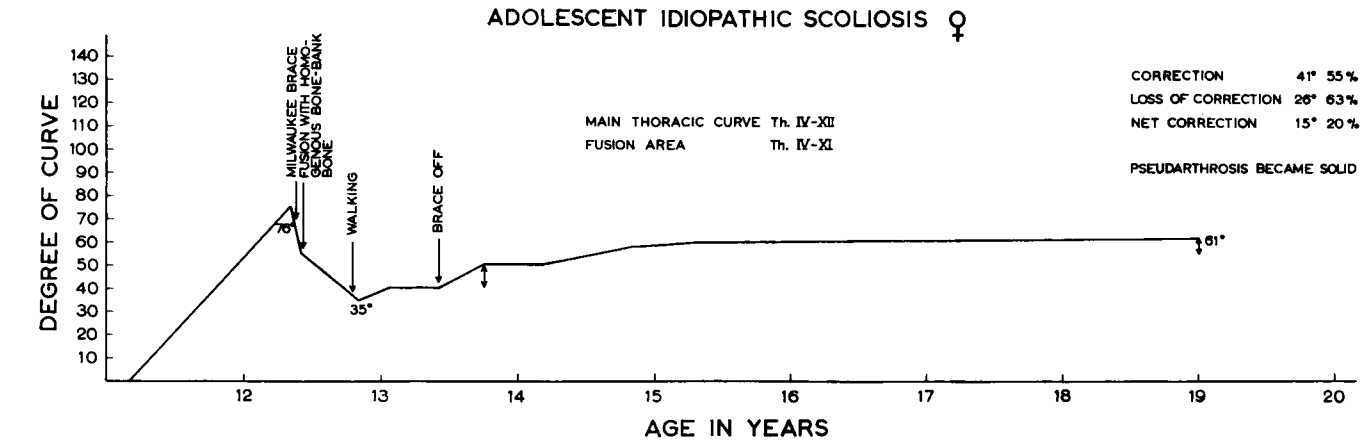
Fig 1. Patient 1. No treatment of the scoliotic spine. This patient had trouble with her cardiopulmonary system. **Note the severe deformity of the thorax.**

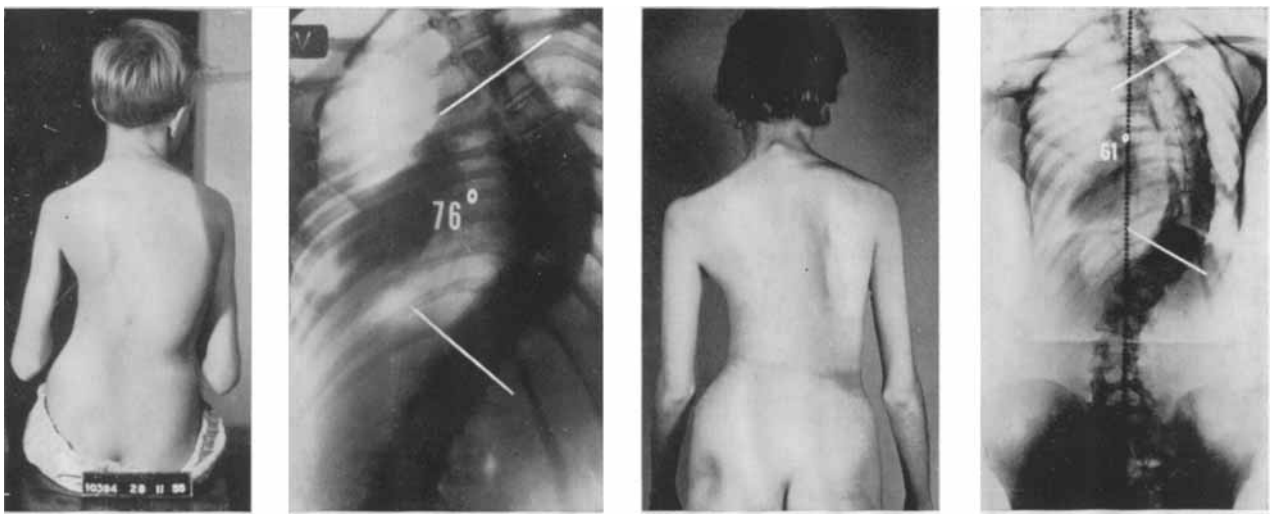




a b c d

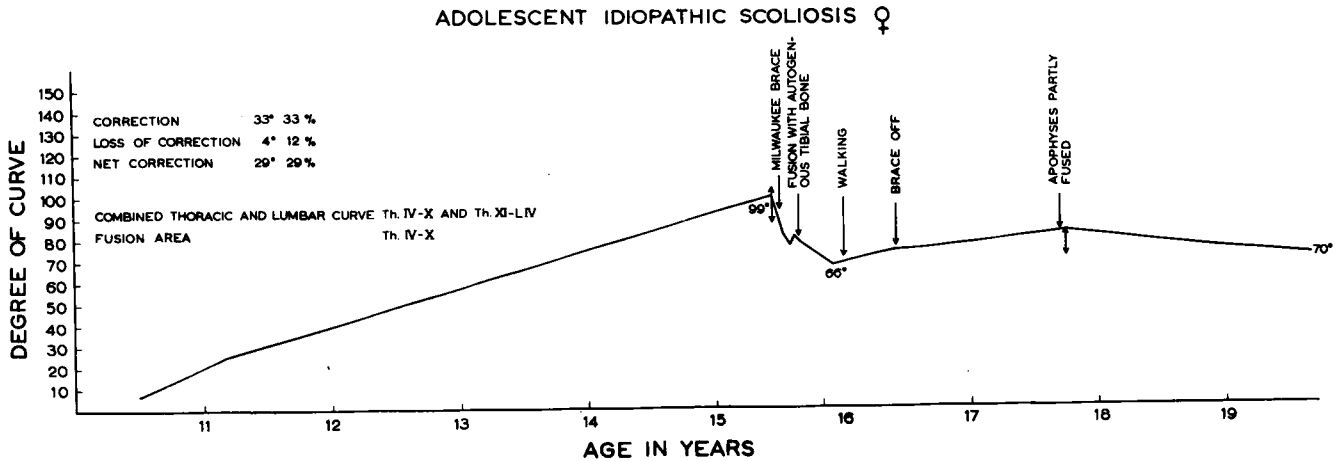
Fig. 2. Patient 2. a and b — Before treatment. c and d — At last follow-up examination. Note the good balance of the patient at the last follow-up examination. Good result of treatment.

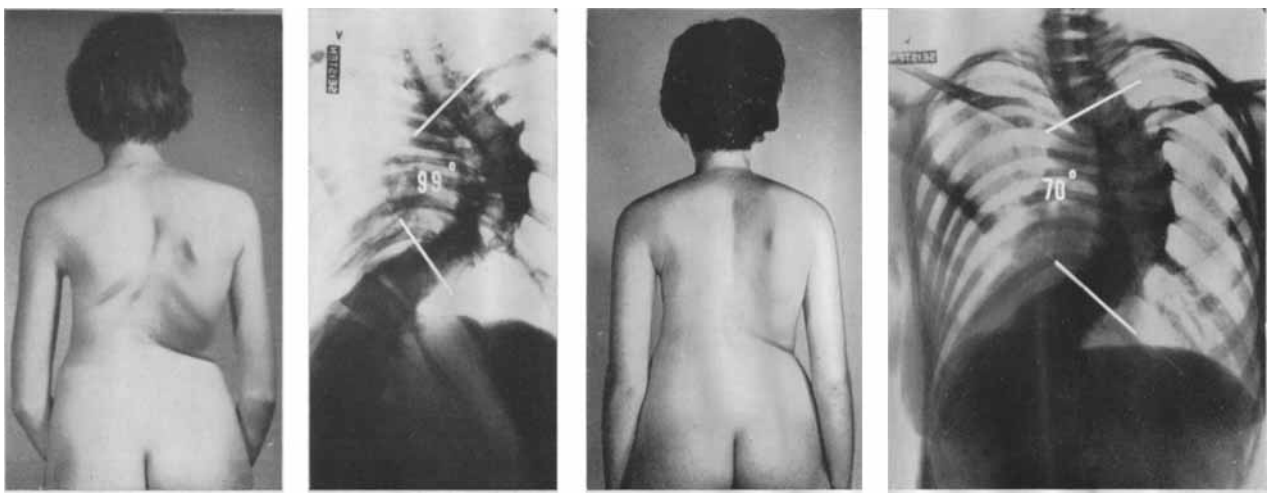




a b c d

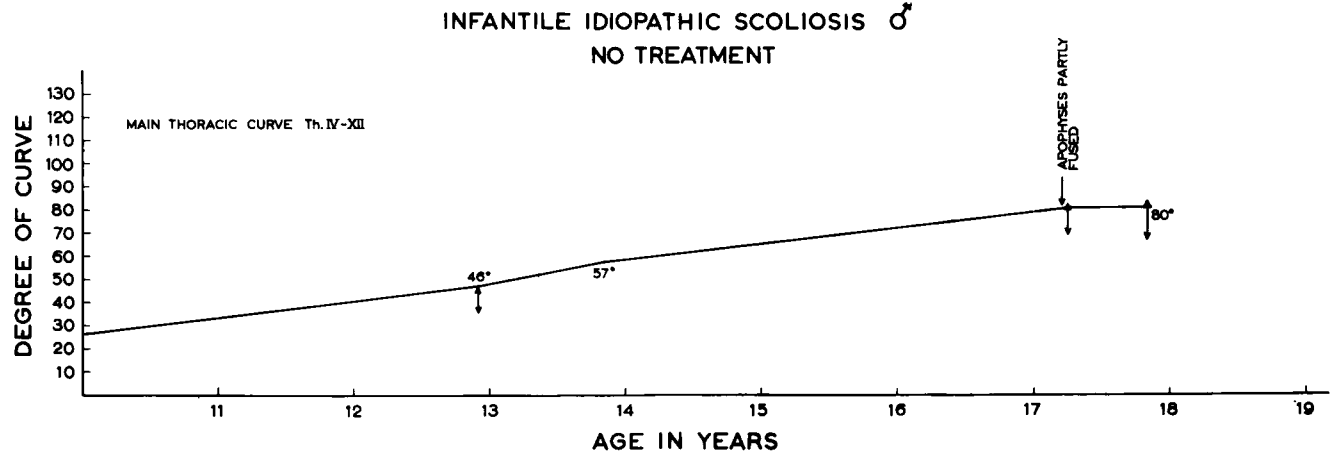
Fig. 3. Patient 3. a and b — Before treatment. c and d — At the last follow-up examination. Fusion was performed with bank bone and a pseudarthrosis developed in the fusion area resulting in loss of correction. The result of treatment was fair.

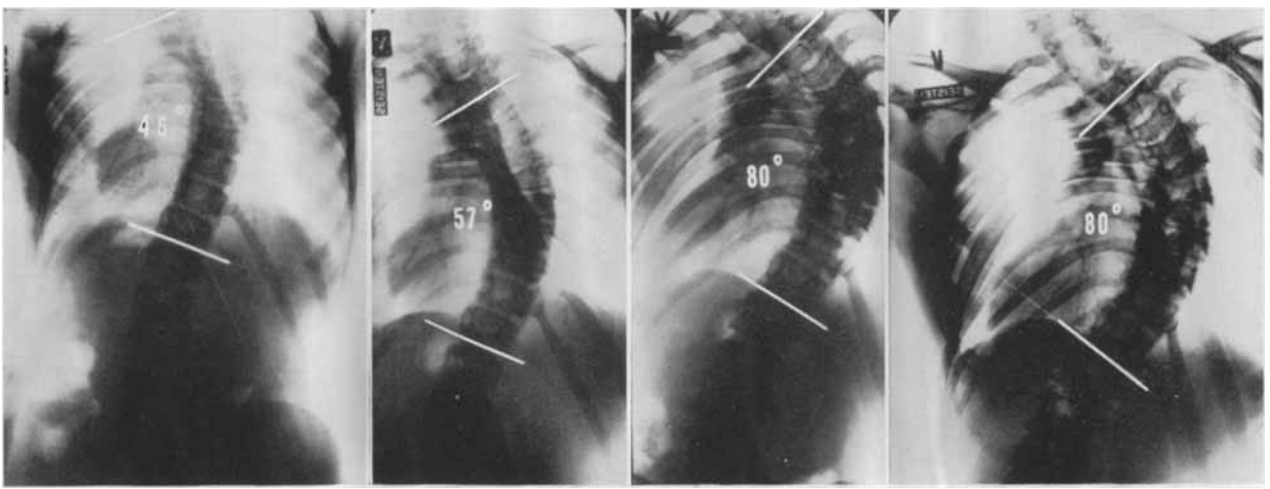




a b c d

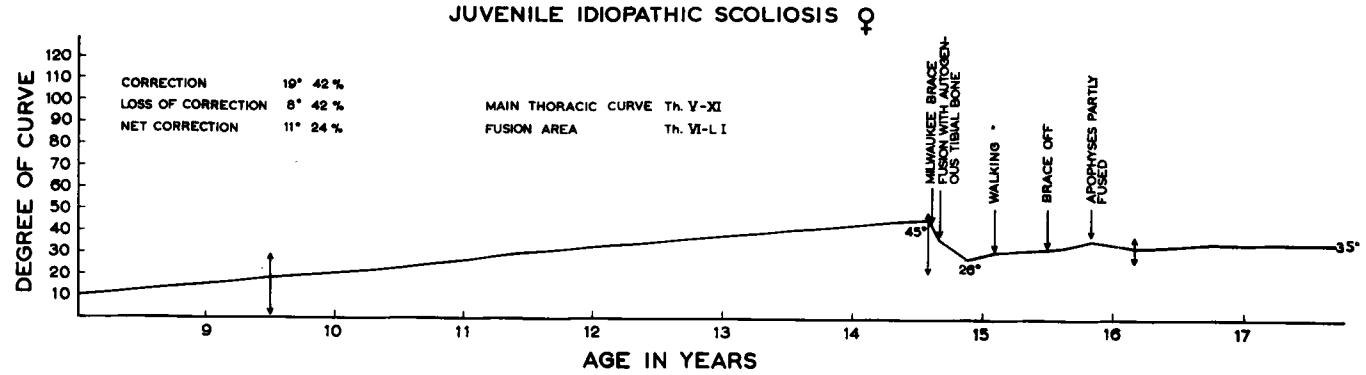
Fig. 4. Patient 4. a and b — Before treatment. Note the severe deformity. c and d — At last follow up examination. Good result of treatment with the patient in balance.

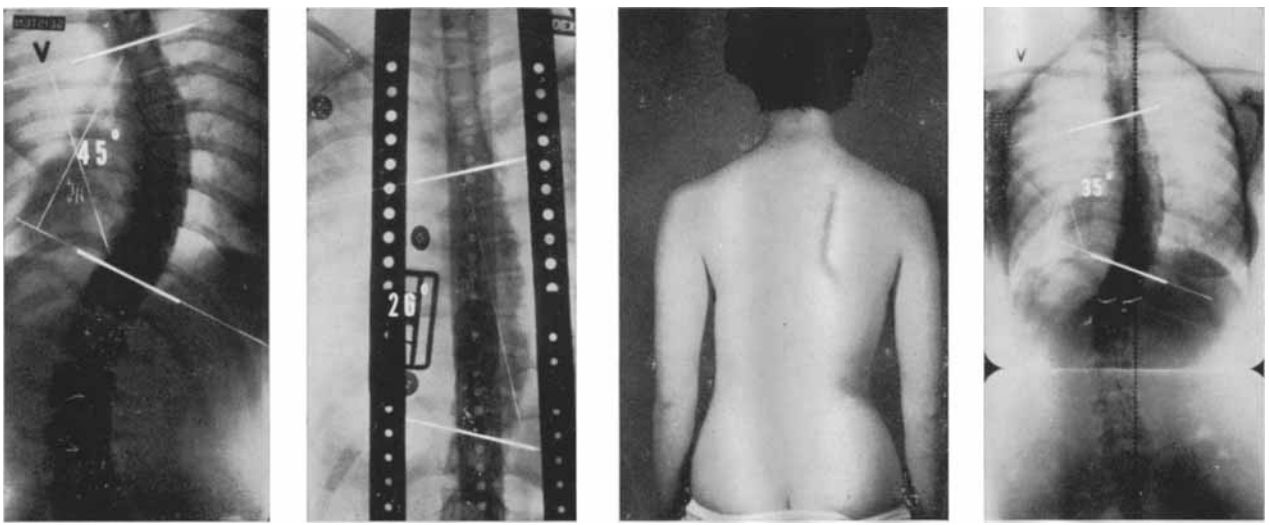




a b c d

Fig. 5. Patient 5. No treatment of the scoliotic spine. The patient was out of balance.





a b c d

Fig. 6. Patient 6. a — Before treatment. b — Corrected curvature. c and d — At last follow-up examination. Note the good cosmetic result.

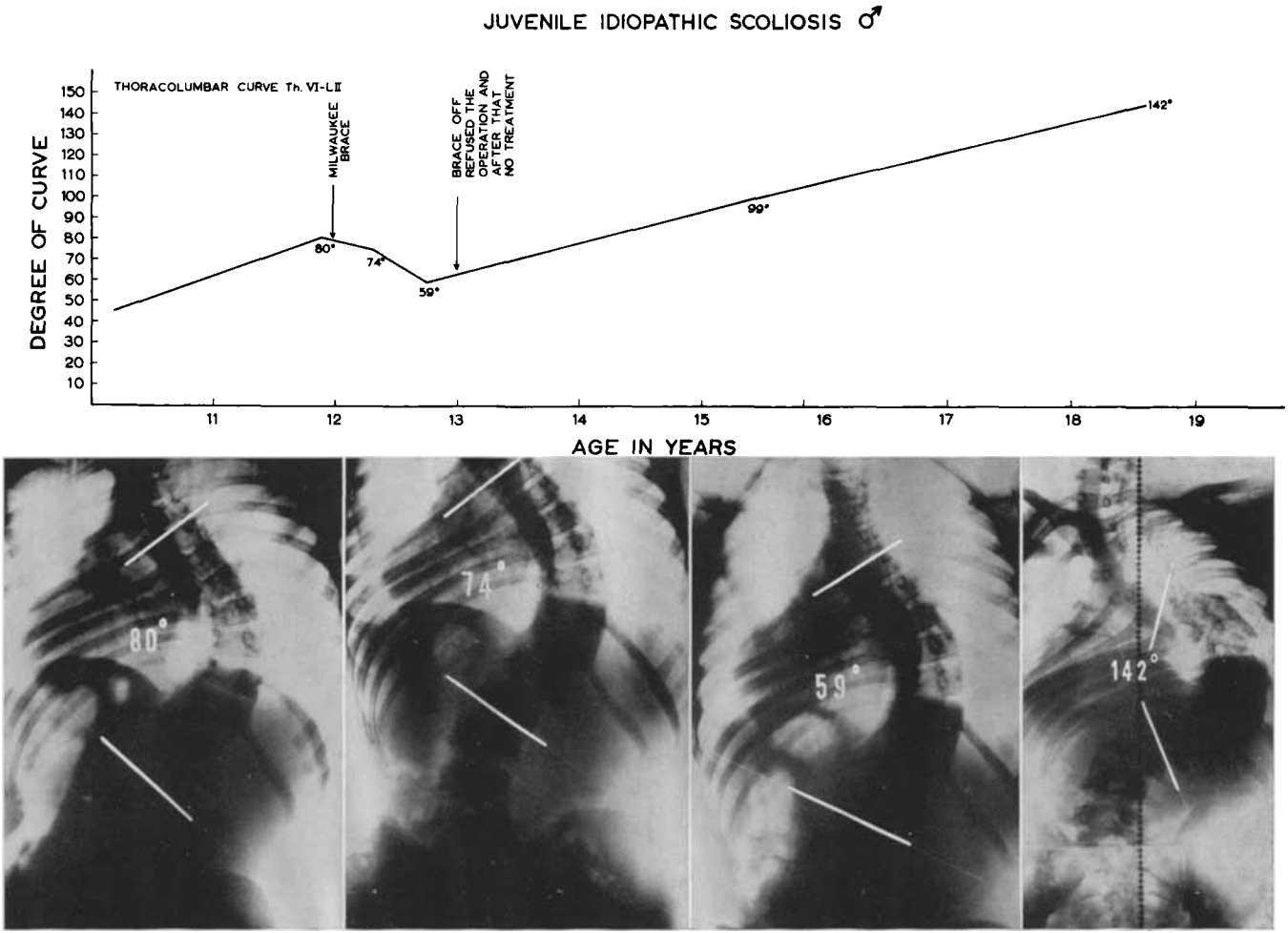
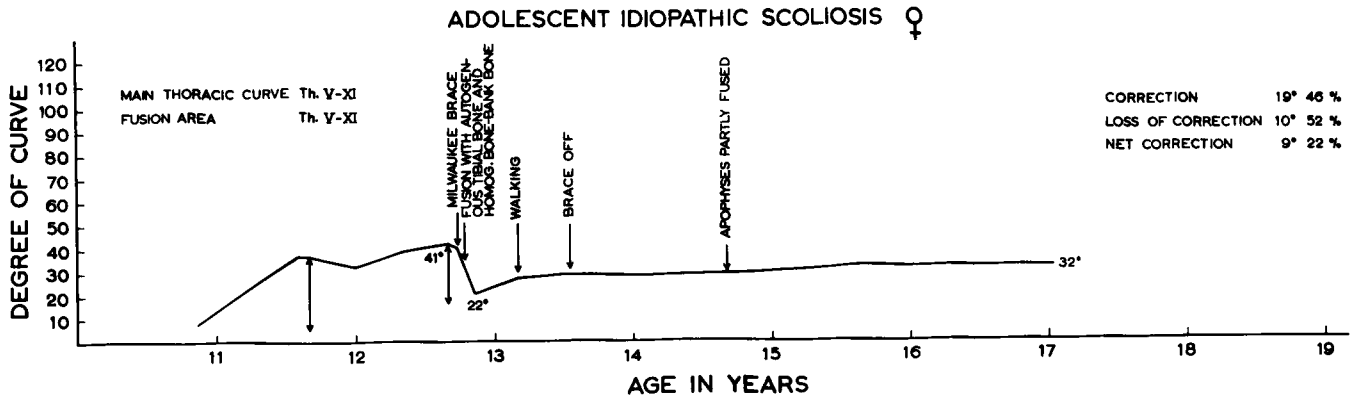
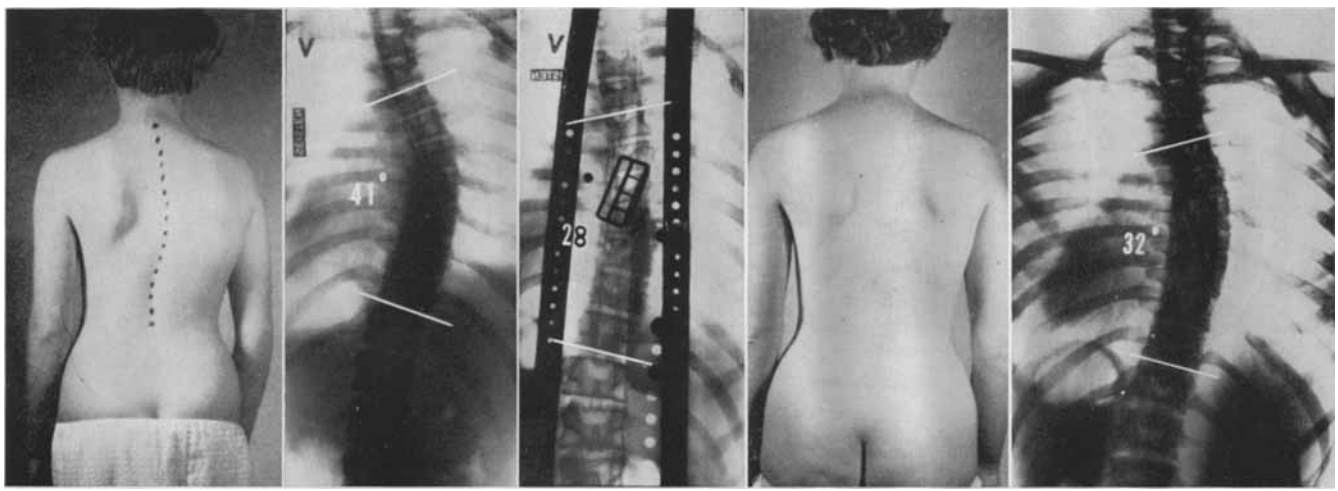


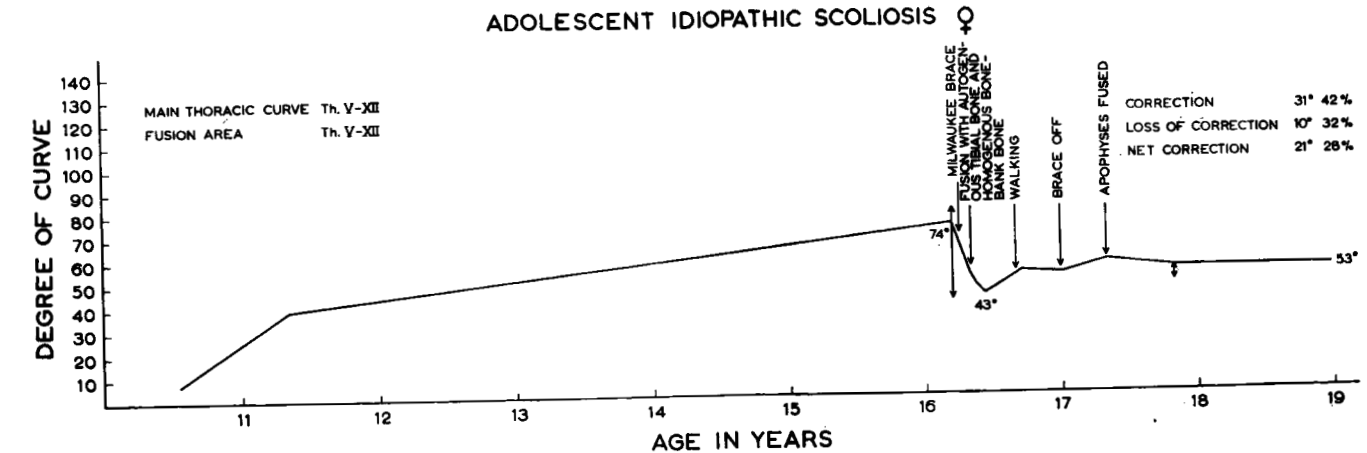
Fig. 7. Patient 7. a — Before treatment. c — A correction of 21° was achieved with the Milwaukee brace, but the parents refused the operation and discarded the brace, which resulted in progression of the deformity to 142° (d). Note the severe deformity at last examination.

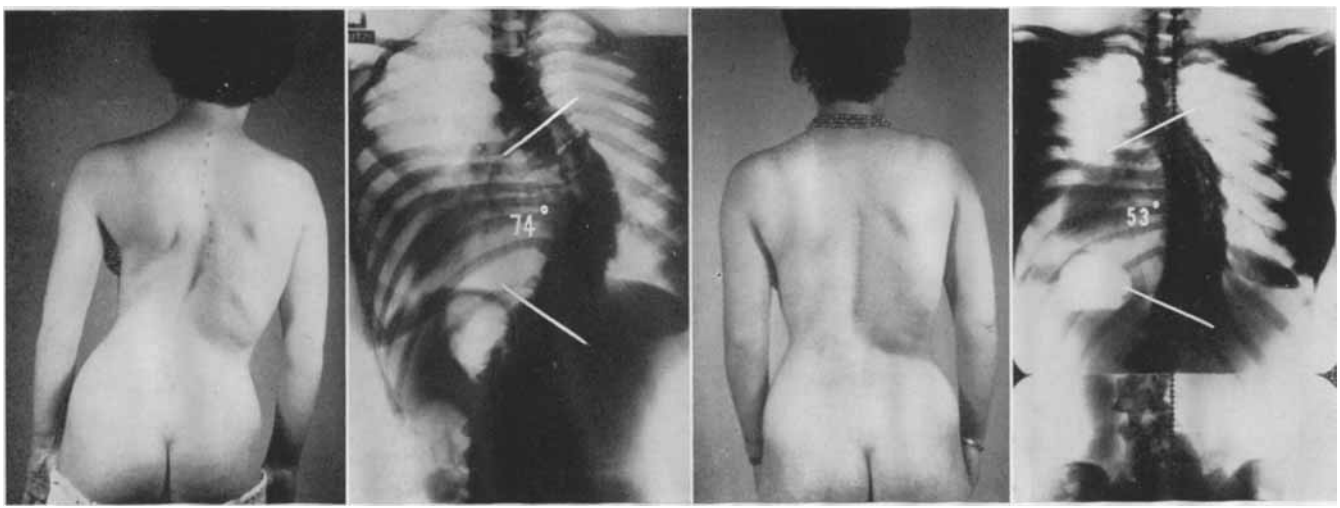




a b c d e

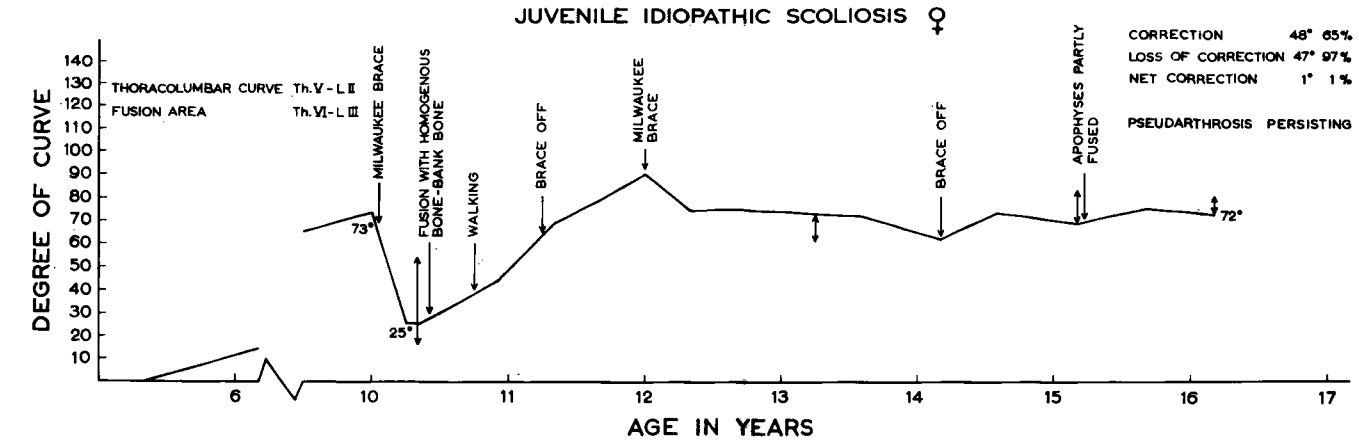
Fig. 8. Patient 8. a and b — Before treatment. c — Four months after operation. d and e — At last follow-up examination. Good result of treatment.





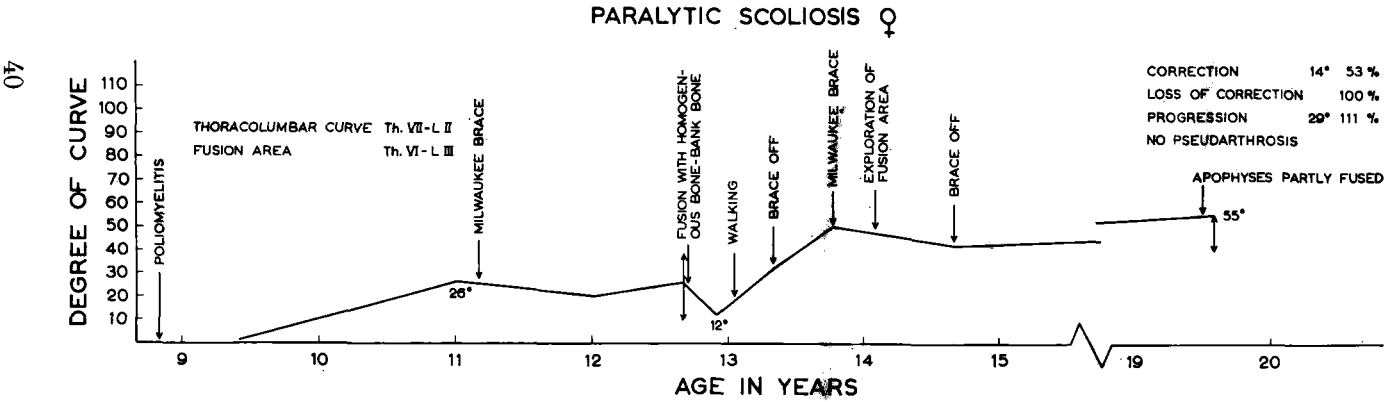
a b c d

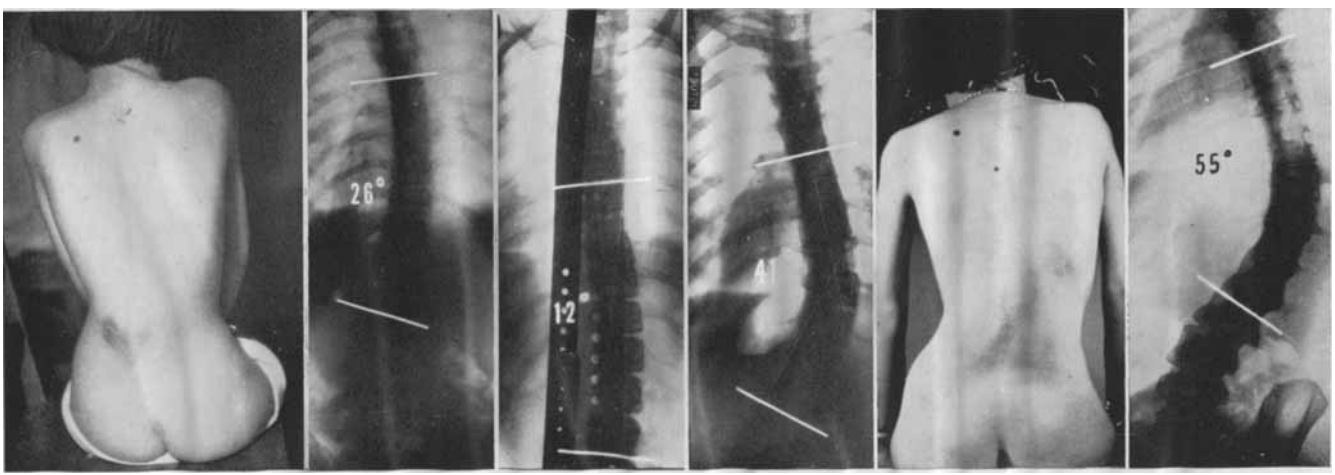
Fig. 9. Patient 9. Before treatment. Note that the patient is out of balance. c and d — At last follow-up examination. Good result of treatment.



a b c d

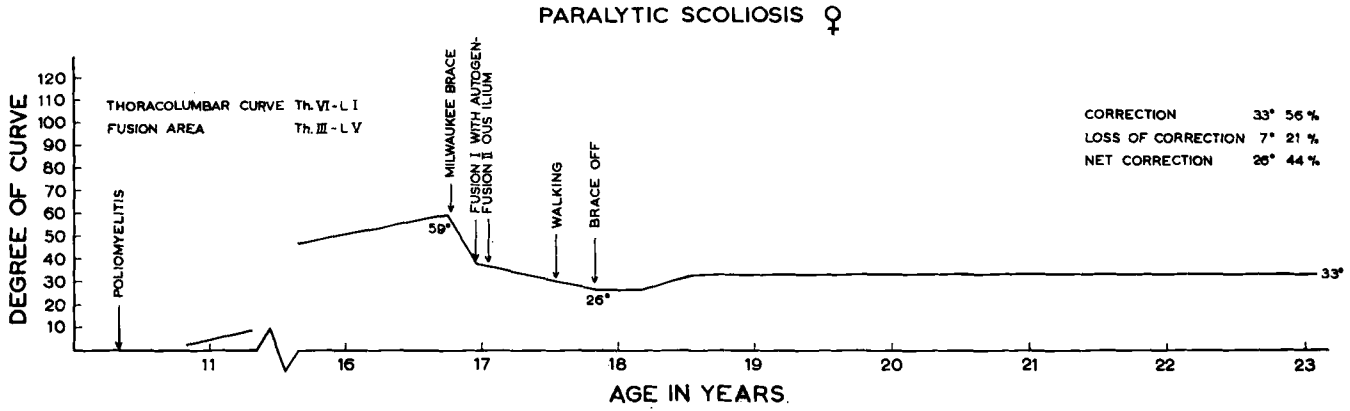
Fig. 10. Patient 10. a and b — Before treatment. c and d — At last follow-up examination, The correction was good, but the loss of correction was 97 per cent on account of the development of pseudarthroses. These were treated with prolonged use of the Milwaukee brace. The result of treatment was poor.

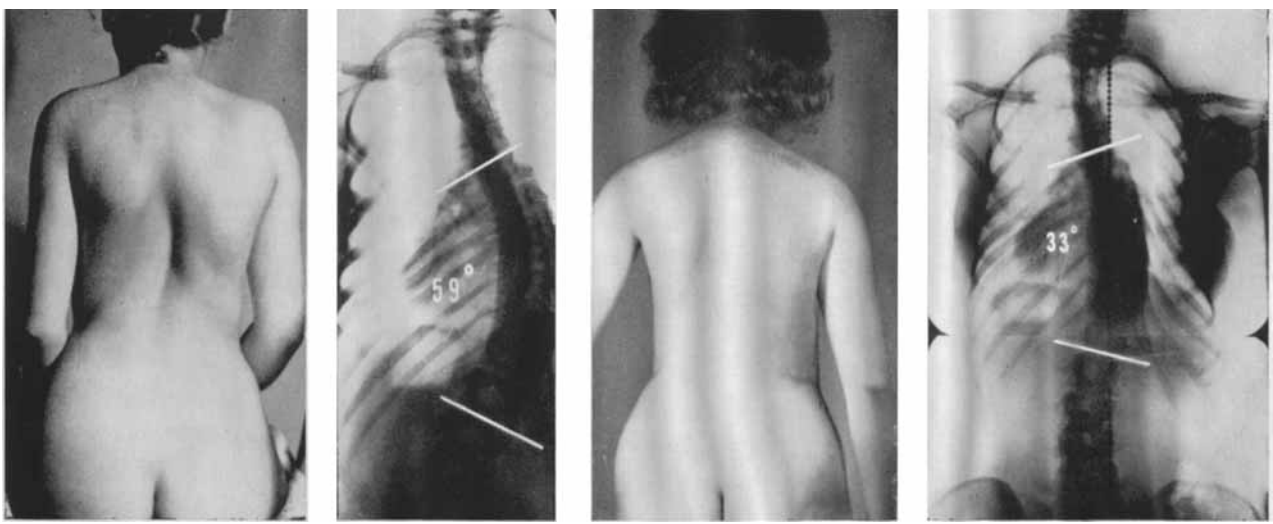




a b c d e f

Fig. 11. Patient 11. a and b — Before treatment. c — Corrected curvature. d — Deformity at the time when the brace was taken off. e and f — At last follow-up examination. Because of progression of the deformity the fusion area was explored, but no pseudarthrosis could be found. The result of treatment was poor.





a b c d

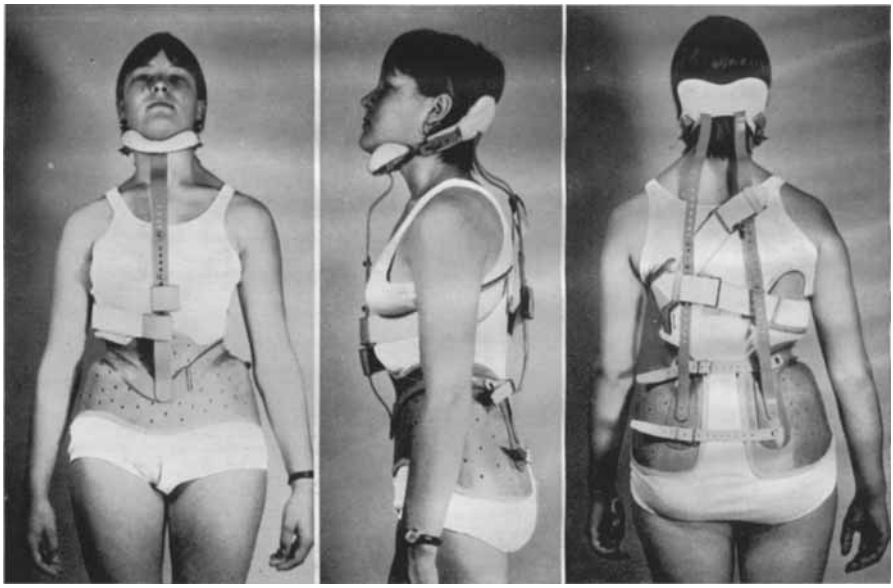
Fig. 12. Patient 12. a and b — Before treatment. c and d — At last follow-up examination. The result of treatment was good.

PRESENT METHOD OF TREATMENT

During the early years of treatment of scoliosis, cases with advanced deformities were frequently seen in Finland, and few therapeutic measures were taken to improve their condition. Such advanced deformities have become much rarer. They are seldom met with today, especially among patients who have profited from the present trend towards early treatment begun as soon as the curvature reaches an angle of 40 °—50 °.

Correction of Scoliotic Deformity

The severity of the deformity determines the onset of treatment with the Milwaukee brace irrespective of the patient's age. The brace is built according to the specifications of BLOUNT and SCHMIDT, and during its fitting the patient is hospitalized for a few days to confirm a good fit and to ensure that the brace is well tolerated (Fig. 13).



a b c

Fig. 13. Milwaukee Brace.

Parents are personally consulted, shown how to put on and take off the brace, and given detailed instructions as to its use. With adequate training the patients learn to wear it on all occasions, even at school.

Time of Surgical Intervention

The degree of the deformity together with the patient's skeletal age and general condition determine the time for operative treatment. If the deformity increases in spite of the treatment with the brace, surgery is undertaken. Otherwise one may wait for an increase of skeletal maturity or until appearance of the iliac apophyses. It is, however, frequently necessary to intervene earlier, as early as at 12 or 14 years of age if the deforming curvature attains an angle of 40° to 50°. Today the skeletal age is routinely determined and followed in every patient. Owing to their more advanced skeletal maturation, girls are operated on earlier than boys.

Determination of Fusion Area

In cases with three scoliotic curves, the middle or primary one is selected for fusion. When there are two primary curves, the upper or both are fused. In idiopathic scoliosis, the entire primary curvature from its top vertebra to the bottom one is fused. In paralytic scoliosis, the fusion is preferably extended one vertebra beyond the primary curve in both directions, the patient's balance permitting. Balance is one of the most important considerations in selecting the fusion area. In this respect, each case offers its own problems, and no general rules can be given. Attention must be paid to the length of the extremities, the position of the pelvis and the function of the joints, which all affect the determination of fusion length especially in patients with poliomyelitis. Generally, the area to be fused at one time comprises 5—8 vertebrae. Thus if the curvature extends over a long region the fusion must be carried out in two or even three stages.

Operative Technique

The brace is removed for the operation and replaced on the same or the following day. Tibial or iliac grafts are taken, if possible at the same operation. Tibial grafts have proved as good as iliac ones providing that enough cancellous bone is taken from the tibial condyle. The con-

dition of the iliac donor site may disturb postoperative treatment with the Milwaukee brace, but in severe poliomyelitic cases it is not always possible to get bone grafts from the tibia. The operation is carried out by means of the COBB modification of spinal fusion with meticulous soft-tissue excision and liberation and a wide exposure of the fusion area. Spinous processes are cut down. Vertebral laminae and, if possible, transverse processes are carefully decorticated with a razor-sharp hand gouge, the raised bone flaps being placed down next to each other over the fusion area the transverse end attached. Use of the mallet is avoided. Almost always the procedure is easily carried out on both sides providing that there is not too much rotational deformity. The operation does, however, take time. The fusion area is first covered with cancellous bone taken from the tibial condyle or from the ilium. Then, cortical bone grafts of suitable length and width either from the tibia or from the outer table of the ilium are placed over the entire fusion area mainly on the concavity. It is important that the tibial grafts are long enough and extend over the entire curvature to be fused. The extension of the Milwaukee brace involving the final correction is carried out during 10 days after the operation. Thereafter the brace must be well fitted. The patient is kept in bed for four months postoperatively.

Postoperative Treatment with the Milwaukee Brace

The patient visits the clinic once every two months for follow-up examinations, at which the condition and fit of the brace are inspected. If necessary, the brace is repaired or extended. The brace will be worn until the fusion is solid, and, if indicated, until vertebral growth is completed. The patient is allowed to return to school one month after the end of the period of recumbency. Use of the brace is gradually discontinued some 9 months after operation, and for the final month or two it is worn only by night. The brace has been found to cause dental protrusion. This usually calls for no further measures, as follow-ups have shown that in most patients the protruding teeth spontaneously return to their normal positions after the brace is given up. Very long postoperative treatment with the brace may necessitate dental prosthesis.

Roentgen Examinations and Photographs of the Patient

Roentgenography with the techniques described above is carried out with 2—5-month intervals before surgery, immediately before the operation, and postoperatively after one month, at the end of hospitalization, and at follow-ups with 2—5-month intervals until the definitive end of treatment. The patient is photographed before onset of treatment, preoperatively wearing the Milwaukee brace, at the end of the brace-wearing period some 9 months after surgery, and at the final follow-up examination. Further pictures are taken as suggested by changes in the deformity during treatment.

Search for Pseudarthroses

Before the patient leaves hospital some 4 months after the operation, the search for pseudarthroses is begun with roentgenography of the fusion area. Found pseudarthroses can be repaired surgically, if necessary. Renewed roentgenography at the end of the brace-wearing period usually reveals possible pseudarthroses. Roentgenograms made with the patient bending as well as oblique views are imperative, and tomography is helpful. Clinical examination is no less important (see above).

Treatment of Pseudarthroses

When pseudarthrosis has been found to cause loss of correction, surgical repair is indicated. When a found pseudarthrosis has not caused loss of correction, treatment with the Milwaukee brace is continued until consolidation or until the iliac apophyses have fully developed. After this, the deformity usually does not increase, irrespective of the consolidation of the pseudarthrosis. If the deformity goes on increasing, treatment with the brace must be resumed, or the pseudarthrosis repaired by surgery. The fusion area is explored and the pseudarthrosis resected and repaired with fresh autogenous bone grafts.

Follow-up Examinations and After Care

All patients must undergo regular follow-up examinations until the growth of the spine is completed. In several instances follow-ups have been carried out over many years. Even after treatment proper is con-

cluded, there are various social motives for regular examinations, say once a year for several years. Possible permanent disabilities are registered in the course of the follow-up, and special attention is paid to the patient's education and training. In Finland, all scoliotic patients aged 16 are, if indicated, given a full trade-school course free of charge. Follow-ups are thus suggested by, and carried out in connection with, the patient's education and training for a profession or trade. The aim both of treatment and of schooling is to turn the scoliotic patients into fully adjusted citizens, most of whom can live and work without having to rely on special measures of social welfare.

SUMMARY

The treatment of structural scoliosis in the Orthopaedic Hospital of The Invalid Foundation in Helsinki during the period 1947 to 1962 is reviewed on the basis of 197 cases of spinal fusion. Of these patients, 86 had idiopathic scoliosis, 99 had paralytic scoliosis secondary to poliomyelitis, and 12 were miscellaneous cases.

Good correction of the deformity was achieved with the Milwaukee brace when well fitted. The turnbuckle plaster cast of RISSER was used for correction from 1947 to 1954 in 42 cases, but this often increased the angle of both secondary curves, which was one of the motives for the adoption of the Milwaukee brace of BLOUNT and SCHMIDT in 1954. Since then, the brace has been used altogether for 155 patients.

The majority of the patients underwent operation between the ages of 12 and 15 years. It seemed wise to postpone the time of surgical intervention, but the development of the iliac apophyses and the vertebral growth had to be closely watched. The skeletal age of the patient was found to be an important factor in the planning of treatment.

The operative technique improved year by year with increasing experience. Three general types of fusion were employed by about 20 different surgeons. First, the original HIBBS fusion with articular facets fusion was used in 23 cases. Secondly, in 24 cases, the method of fusion was similar to this but did not involve destruction of the articular facets. Thirdly, since 1955—1956, the fusion was done by the COBB method,

in 96 patients with the addition of bone-bank bone, in 40 patients with autogenous bone, and in 14 patients with both together. The mean duration of the follow-up period was over 4 years, and for 57 patients over 6 years.

Autogenous bone was far superior to homogenous bone-bank bone as grafting material (see Tables 10 aud 12). Thus the results of treatment from 1947 to 1954 were poor when compared with the results achieved since 1959 and by present-day treatment. In idiopathic scoliosis, autogenous bone alone or together with bank bone was used as a graft in 24 patients and only 2 had pseudarthroses, but 16 out of the 50 patients grafted with bank bone had pseudarthroses (see Tables 13—15). In paralytic scoliosis, there were 14 cases with pseudarthroses out of 39 patients grafted with bank bone, but only 5 out of 26 patients grafted with autogenous bone had pseudarthroses (see Tables 16—18).

Pseudarthroses in the fusion area proved one of the main reasons for the loss of correction after spinal fusion. Thus in 46 out of 68 patients with a major loss of correction, pseudarthroses were responsible for the loss (Table 11). Altogether, 57 (29 per cent) out of 197 operated cases had pseudarthroses causing symptoms.

Good results were obtained in 63 cases out of 197. These patients had an average net correction of 23 per cent which corresponded to the good cosmetic result achieved. In 19 (48 per cent) out of 40 patients treated with autogenous bone as supplementary graft a good result was gained. Comparable results were obtained only in 25 (26 per cent) out of the 96 patients fused with the addition of bank bone.

Present Method of Treatment

The severity of the deformity determines the onset of treatment with the Milwaukee brace irrespective of the patient's age. A sufficient correction is achieved with the brace, and with adequate training the patient learns to wear it on all occasions, even at school.

The degree of the deformity together with the patient's skeletal age determine the time of surgical intervention. If the deforming curvature attains an angle of 40 ° to 50 °, surgery is undertaken, providing that the patient's skeletal age is over 12 years. Boys are operated on about one year later than girls. In idiopathic scoliosis, the entire primary curve is fused. In paralytic scoliosis, the fusion is extended one vertebra beyond the primary curvature in both directions, the patient's balance permitting.

Balance of the patient is an important consideration in determining the length of the fusion area.

The operation is carried out by means of the Cobb modification of spinal fusion. Only fresh tibial or iliac autogenous bone is used for grafting. The extension of the Milwaukee brace involving the final correction is carried out during the 10 days following the operation. The patient is kept in bed for 4 months postoperatively.

The brace will be worn until the fusion is solid, and, if indicated, until the vertebral growth is completed. In general, the use of the brace is gradually discontinued some 9 months after surgery.

Before the patient leaves hospital 4 months after the operation, the search for pseudarthroses is begun. Renewed roentgenography at the end of the brace-wearing period usually reveals possible pseudarthroses. If these have been found to cause loss of correction, surgical repair is indicated.

The patients are submitted to follow-up examinations until the growth of the spine is completed. All patients with scoliosis aged 16 are, if indicated, given a full trade-school course free of charge. Most of them can thus learn to live and work without having to rely on special measures of social welfare.

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