

ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM No. 102

FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION
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END RESULTS IN THE TREATMENT OF SCOLIOSIS

A SURVEY OF 57 CASES

MUNKSGAARD
COPENHAGEN 1967

PRINTED IN FINLAND
Oy WEILIN+GÖÖS Ab
HELSINKI 1967

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INTRODUCTION

In most cases, a patient with progressive structural scoliosis needs surgical treatment in order to maintain the correction of the scoliotic deformity once it has been achieved. All the main methods for correction of a scoliotic curvature in use to-day are good, *e.g.* the Milwaukee brace (3), the Risser localizer body cast (14), the Abbott molded body cast (1), the progressive elongation, derotation and lateral flexion of the spine by Cotrel (6), but which of the operative techniques is the most likely to guarantee the permanency of the correction? This has been a difficult question since 1952, the year when Cobb presented his technique for spinal fusion (5). This question was also one of the main problems at the 10th congress of S.I.C.O.T. in Paris in 1966. As has been stressed, it is necessary to have a reliable assessment of the results of treatment in order to evaluate the usefulness of the actual methods *in casu*. For an evaluation of the results of treatment, sufficiently long periods of observations are imperative, because a reliable evaluation of the results cannot be made before the completion of vertebral growth of the patient.

An investigation into the treatment of scoliosis before 1962 at the Orthopaedic Hospital of The Invalid Foundation showed clearly that the results varied greatly, depending on the different methods of spinal fusion (12, 13). The scoliotic spine was corrected with the aid of a Milwaukee brace, but in many cases the correction was lost after the operation. The fusion was not rigid enough, the pseudarthrosis rate was high and was one of the important reasons for the failure to maintain the correction. Here, the quality of the bone grafts used for fusion proved to be of decisive importance. Bone-bank bone gave poorer results, reported earlier from other countries (2, 8). The results were more satisfactory with autogenous bone grafts, but the results of treatment varied even with this, depending on the different methods of handling the autogenous bone grafts. Bone tissue is sensitive to several factors outside the organism, such as soft tissues. Its structure and vitality can easily be destroyed. Therefore, bone tissue must always be handled with great care. In the use of bone tissue as transplantation material in orthopaedic procedures, the vitality of the bone grafts can at least be partly preserved, provided that the bone grafts are transposed in a fresh condition, *i.e.* that the transposition is done immediately. This opinion is clearly confirmed by the experimental investigations on the technique of bone transplantation made by Puranen (11). As a result of these observations the following report seems justified.

MATERIAL AND METHODS OF TREATMENT

Material

The data are based on the analysis of 57 patients with scoliosis (Table 1) operated on at the Orthopaedic Hospital of The Invalid Foundation in Helsinki during the period 1962—1964. Of these patients, 38 were girls and 19 boys.

TABLE 1
CLASSIFICATION OF SCOLIOSIS

Scoliosis	No. of Cases	Infantile Under 5 years	Juvenile 5—8 years	Adolescent Over 10 years	Cervico-thoracic Curve	Main Thoracic Curve	Thoro-lumbar Curve	Combined Thoracic and Lumbar Curve	Main Lumbar Curve
Idiopathic	26	1	4	21		23	3		
Paralytic	23				1	5	13	3	1
Miscellaneous*	8					4	3		1
Total	57				1	32	19	3	2

*Congenital anomaly 6 cases

Marfan's syndrome 1 case

After thoracotomy 1 case

Precorrection Curvature

Before treatment, the 26 patients with idiopathic scoliosis had an average angle of curvature of 58° by Cobb measurement. The 23 patients with paralytic scoliosis after poliomyelitis had an average curvature of 69°, the 8 patients with congenital scoliosis 68°, the patient with Marfan's syndrome a curvature of 83°, and the patient with a thoracic scoliosis after an operation because of patent ductus arteriosus, a curvature of 62°.

Age at Time of Surgical Intervention

The average calendar age of the patients at the time of surgical intervention was 14 years and 11 months (Table 2). The skeletal age of the patients was determined by roentgenograms of the hands before treatment, after the operation and in connection with the follow-up exam-

inations. The skeletal age was 1 to 2 years behind the calendar age in 26 patients at the beginning of the treatment, in 2 cases the skeletal age was 1 year in advance, and for 29 patients the skeletal age corresponded to the calendar age.

T A B L E 2
AGE OF PATIENTS

Scoliosis	No. of cases	Average age at time of spinal fusion	Average age at completion of vertebral growth	Average age at last follow-up examination
Idiopathic	26	14 years 11 months	16 years 1 month	17 years 5 months
Paralytic	23	14 years 10 months	16 years 5 months	17 years 9 months
Congenital	8	15 years 5 months	16 years 11 months	17 years 10 months
Marfan's syndrome	1	15 years 7 months	17 years	17 years
After thoracotomy	1	14 years 2 months	16 years 3 months	16 years 3 months
Total	57	14 years 11 months	16 years 4 months	17 years 7 months

Age at Completion of Vertebral Growth

In connection with the roentgenographic surveys the capping of the iliac apophyses was noted. With continued growth, the apophyses made contact with the ilium medially near the sacrum. When this attachment or complete ossification has taken place, the vertebral growth was considered to be completed, according to the report of Risser (15). The average calendar age of the patients at the completion of vertebral growth (Table 2) was 16 years and 4 months, which is high in comparison with bone growths of patients in warm countries (15). The slow bone growth might influence the treatment by making it more difficult. A patient with a long bone growth period seems to show a greater tendency towards a progression of the deformity. The treatment should also be planned accordingly.

Follow-up Time

The average calendar age of the patients at the last follow-up examination was 17 years and 7 months (Table 2). Accordingly, the last follow-up examination was undertaken 1 year and 3 months after the termination of the vertebral growth. Thus the results presented here are end results and in this respect reliable.

Correction of Scoliotic Deformity

Preoperative correction of the deformity was carried out in all cases by the Milwaukee brace, in the making of which we have gained more experience thanks to Walter Blount, who has visited our clinic several times and has shown us the correct way of making good braces. The Milwaukee brace is not an extension apparatus of the trunk, even though the head support is kept high, except during the first two weeks after the operation. The patient can always raise his head from the support, exercising and strengthening the muscles of his back. This active exercise in the brace, generally together with two properly placed pads, corrects the scoliotic deformity of the spine. The major pad was placed low enough. Special attention was paid to the balance of the patient. A good Milwaukee brace keeps the body of the patient in balance. In some cases protruding teeth were treated by an orthodontist, but there were generally no problems with dental protrusion.

Fifteen patients were treated for more than 2 years with the Milwaukee brace before surgical intervention because of early onset of the deformity, five patients for one year, eight patients for 3 to 8 months. In 29 cases the preoperative treatment with the brace lasted only 1 to 2 months, which sufficed to familiarize the patient with the brace. The brace was removed before the operation and reapplied on the day after the operation. During the following two weeks, the brace was extended every day if possible, and with this the final correction was achieved. The treatment with the Milwaukee brace after spinal fusion continued for 9 months in 30 patients, 10 months in 11 patients, 11 months in 4 patients, 12 months in 4 patients, and for more than one year in 5 patients. In 3 cases the treatment was continued for only 7 months.

Operative Technique

Thirteen patients had a two-stage procedure and one a three-stage procedure. On 43 patients the operation was performed in one stage.

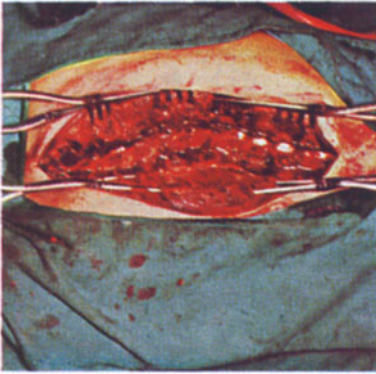


Fig. 1. Approach



Fig. 2. Decortication



Fig. 3. Cortical grafts from tibia



Fig. 4. Cortical grafts from tibia



Fig. 5. Cancellous bone from tibial condyle

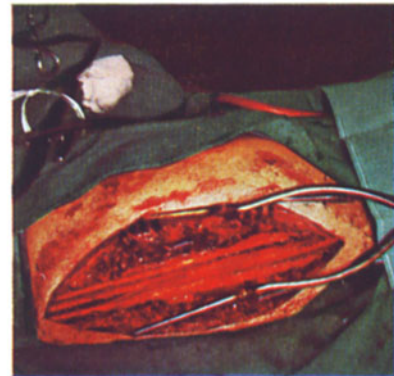


Fig. 6. Bone grafts inserted

The average calendar age of the patients at the time of surgical intervention was 14 years and 11 months (Table 2).

The spinal fusion was carried out by 11 different surgeons using the Cobb modification and adding substantial amounts of autogenous tibial bone grafts into the fusion area. In 10 cases the bone grafts were taken from the tibia two weeks prior to the spinal operation and stored in a bone bank. In 17 instances, the tibial cortical grafts and spongy bone were taken first and placed in a bowl. The leg wound was closed. Only then was the scoliotic spine approached and the area to be fused prepared. The grafts were then inserted.

In 32 cases, the operation was carried out according to the method currently in use at the Orthopaedic Hospital of The Invalid Foundation. To begin with, the scoliotic spine was exposed (Fig. 1) and the area to be fused prepared with careful soft-tissue excision and liberation, with a wide exposure of the curvature. Spinous processes were cut down and cleaved. Vertebral laminae and transverse processes were decorticated with a razor-sharp hand gouge without using a mallet (Fig. 2). The raised bone flaps were placed face down next to each other over the area to be fused, the transverse end attached. The procedure was carried out on both sides. Then three or four cortical grafts of suitable length and width were taken from the tibia (Figs. 3 and 4) and enough cancellous bone from the tibial condyle (Fig. 5) and inserted immediately, the cancellous bone under, between and over the cortical grafts (Fig. 6). The tibial cortical grafts should be both strong and long enough and extend over the entire curvature to be fused, mainly on the concave side. Then the wound in the back was closed, and finally the wound in the leg. This order for covering the grafts as soon as possible was used in order to preserve the vitality of the bony tissue. There were no complications or wound infections. The correction of a fixed scoliotic curvature could after the operation be effected more easily because when preparing the area to be fused, tight ligaments on the concave side were discised. The patient was kept recumbent for 4 months post operatively.

RESULTS OF TREATMENT

The Cobb method of measurement of the scoliotic deformity was used. The precorrection curvature was the maximum curvature before treatment with the patient standing, the corrected curvature was the minimum curvature after correction about 2 weeks postoperatively with the patient supine, and the final curvature was the curvature at the last follow-up examination with the patient standing.

The mean duration of the time from the operation to the last follow-up examination was 2 years and 8 months. The data were obtained from the author's personal observations at the follow-up examinations of patients treated at this hospital. Vertebral growth was complete in all patients at the time of the last follow-up examination (Table 2).

Idiopathic, Paralytic, and Miscellaneous Cases of Scoliosis

The results of treatment are given in Tables 3—5. In 26 patients with idiopathic scoliosis, the average initial correction was 25° , or 46 per cent, with an average precorrection curvature of 58° . The average final correction was 15° or 24 per cent, and the average loss of correction 10° (Table 3). In 23 patients with paralytic scoliosis after polio, the average initial correction was 28° , or 42 per cent, with an average precorrection curvature of 69° . The average final correction was 11° , or 15 per cent, and the average loss of correction 17° . In 6 cases with congenital scoliosis, the average initial correction was 28° , or 41 per cent, with an average precorrection curvature of 68° . The average final correction was 17° , or 25 per cent, and the average loss of correction 11° (Table 3). Pseudarthroses occurred in 11 out of 57 cases, *i.e.* 19 per cent. In the series before 1962 (13), the frequency of pseudarthroses was 29 per cent in 197 cases.

Tables 4 and 5 give the results of treatment correlated with the different methods of transplanting autogenous bone grafts in spinal fusion in all 57 patients. Direct grafting with fresh autogenous tibial bone seems to be superior to the two other types of grafting. In only one case of direct bone grafting did pseudarthroses occur in the fusion area. The frequency of pseudarthroses was surprisingly high in those patients in whom at operation the bone grafts were taken before surgical intervention on the spine and placed in a bowl, in readiness for later transplantation (Table 4). In an experimental investigation on the technique of bone transplantation, Puranen discusses the possible reason for the development of

pseudarthroses. According to him, bone tissue in vital form cannot withstand exposure to air outside the organism, but after 1 or 2 hours behaves like bank bone, *i.e.* like dead tissue (11). The average loss of correction was only 9° in the 32 patients with direct bone grafting,

TABLE 3
CORRECTION OBTAINED FOLLOWING SURGERY

Scoliosis	No. of cases	Average precorrection curvature	Average final correction		Average loss of correction	No. of patients with pseudarthroses
		Degrees	Degrees	Per cent	Degrees	
Idiopathic	26	58	15	24	10	2
Paralytic	23	69	11	15	17	9
Congenital	6	68	17	25	11	
Marfan's syndrome	1	83	25	30	5	
After thoracotomy	1	62	19	26	8	
Total	57					11

TABLE 4
THE RESULT OF TREATMENT CORRELATED WITH THE TYPE OF BONE ADDED
IDIOPATHIC, PARALYTIC, AND MISCELLANEOUS CASES OF SCOLIOSIS

Type of fusion and of bone added	No. of cases	Average precorrection curvature	Average Final correction		Average loss of Correction	No. of patients with pseudarthrosis
		Degrees	Degrees	Per cent	Degrees	
Cobb-type fusion with banked autogenous tibial bone	10	72	13	18	17	3
Cobb-type fusion with autogenous tibial bone kept in the open air 1—2 hours	15	69	9	13	18	7
Cobb-type fusion with fresh autogenous tibial bone	32	58	16	27	9	1
Total	57					11

whereas the average loss of correction was 17° in 10 patients with banked autogenous bone grafts, and 18° in 15 patients with the bone grafts kept in a bowl for 1 to 2 hours before transplantation. It therefore seems reasonable to suppose that the freshly excised bone tissue was transplanted, at least partly, in a vital condition, an assumption which is also supported by Puranen's investigation (11).

The clinical result was good in 40 patients out of 57, with good improvement also demonstrable roentgenographically. With fresh, directly transplanted, bone grafts a good result of treatment was noted in 29 out of 32 cases (figs. 7 and 8). With bone grafts that had been stored in a bone bank for two weeks, a good result was obtained in half the cases only. When the bone grafts had been kept outside the organism in a bowl for 1 to 2 hours, good results were achieved in only 6 cases out of 15. The average loss of correction was only 8° in 29 patients with fresh bone grafts transplanted directly (Table 5). Taking into consideration the fact that the corrected curvature was measured with the patient supine and the final curvature with the patient standing, the loss of correction was slight.

TABLE 5

**FORTY CASES WITH GOOD RESULT OF TREATMENT CORRELATED WITH THE
TYPE OF BONE ADDED
IDIOPATHIC, PARALYTIC, AND MISCELLANEOUS CASES OF SCOLIOSIS**

Type of bone added	No. of cases with good result	Average final correction		Average loss of correction
		Degrees	Per cent	Degrees
Banked autogenous tibial bone	5 out of 10	19	28	11
Autogenous tibial bone kept in the open air 1—2 hours	6 out of 15	19	25	10
Fresh autogenous tibial bone	29 out of 32	17	29	8
Total	40 out of 57	18	28	9

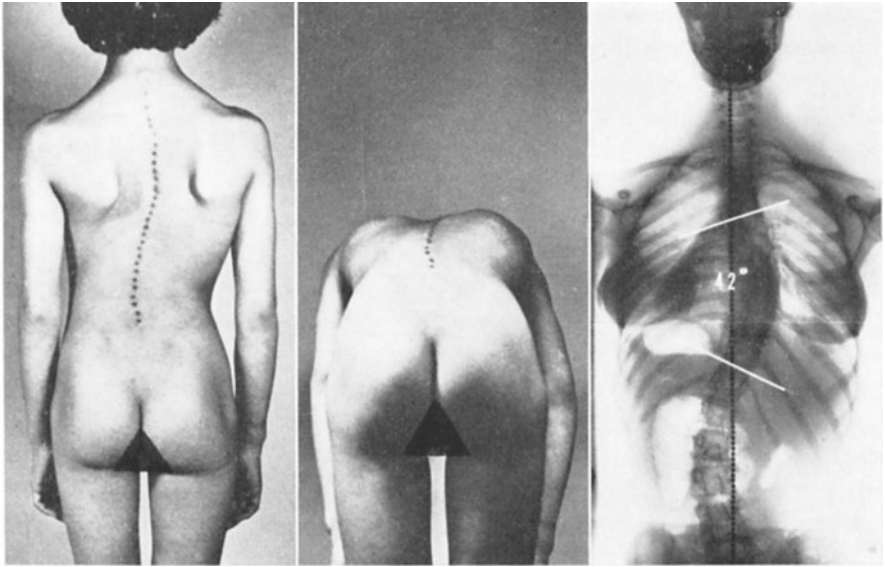


Fig. 7. Adolescent idiopathic scoliosis. Girl aged 13 years 10 months at the time of Cobb-type fusion with additional fresh autogenous tibial bone.

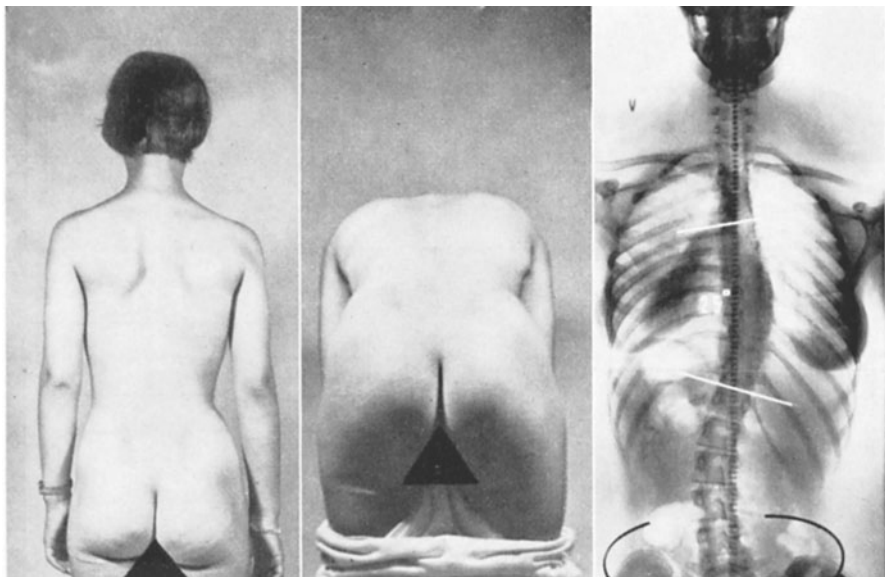


Fig. 8. The same girl 2 years after spinal fusion. Initial correction 20° or 48 per cent, final correction 17° or 40 per cent, loss of correction 3.

Causes of Loss of Correction in 17 Patients

In 9 cases, pseudarthroses in the fusion area were the reason for an average loss of correction of 20°. In 5 patients, the spinal fusion was too short, with an average loss of correction of 26°. The reason for the loss of correction remained unknown in 3 cases with an average loss of 25°.

Idiopathic Scoliosis

The results of treatment are given in Table 6. The average loss of correction was only 8° in 18 patients fused with fresh autogenous bone grafts transplanted directly. There were only 5 patients in the series with banked autogenous bone grafts with an average loss of correction of 16°, and 3 patients in the series with autogenous bone grafts kept in the open air for 1 to 2 hours before grafting with an average loss of correction of 13° and pseudarthroses in one case in each group. No conclusion can be drawn, but fresh autografts seem to give a more solid fusion.

TABLE 6

IDIOPATHIC SCOLIOSIS

THE RESULT OF TREATMENT CORRELATED WITH THE TYPE OF BONE ADDED

Type of fusion and of bone added	No. of cases	Average final correction		Average loss of correction	No. of patients with pseudarthroses
		Degrees	Per cent	Degrees	
Cobb-type fusion with banked autogenous tibial bone	5	12	18	16	1
Cobb-type fusion with autogenous tibial bone kept in the open air 1—2 hours	3	17	23	13	1
Cobb-type fusion with fresh autogenous tibial bone	18	15	28	8	
Total	26	15	24	10	2

Paralytic Scoliosis

The results of treatment are given in Table 7. Altogether, there were 9 patients with pseudarthroses in the fusion area out of 23 with a paralytic scoliosis after polio. Six of them were operated on with supplementary autogenous tibial bone kept in the open air for 1 to 2 hours before transplantation, the average loss of correction being correspondingly high, 19° in 10 patients. With fresh bonegrafts transplanted immediately, the average loss of correction was 12° in 8 patients, and only in one patient did pseudarthroses in the fusion area occur. In the treatment of paralytic scoliosis there are many factors affecting the end results. The present material is too small to permit the drawing of conclusions.

TABLE 7

PARALYTIC SCOLIOSIS THE RESULT OF TREATMENT CORRELATED WITH THE TYPE OF BONE ADDED

Type of fusion and of bone added	No. of cases	Average final correction		Average loss of correction	No. of patients with pseudarthroses
		Degrees	Per cent	Degrees	
Cobb-type fusion with banked autogenous tibial bone	5	14	19	18	2
Cobb-type fusion with autogenous tibial bone kept in the open air 1—2 hours	10	7	9	19	6
Cobb-type fusion with fresh autogenous tibial bone	8	14	21	12	1
Total	23	11	15	17	9

DISCUSSION

According to the reports presented at the 10th Congress of S.I.C.O.T. in Paris in 1966, concerning the end results in the treatment of idiopathic scoliosis, good results were achieved by different methods. The results of treatment with Harrington instrumentation presented by Moe corresponded to the results with Risser localizer cast correction and spinal fusion presented in 1964 (9). The chief advantage of the Harrington instrumental correction seemed to lie in earlier permissible ambulation, but more severe cases could be treated well with this method (10). Only time can show what happens to these instruments in the spine. Cortrel corrected the scoliotic deformity with walking jackets moulded to the thorax, combining traction with derotation, in young children. In cases of scoliosis towards the end of growth, he used progressive elongation of the spine. The results were good (6). For spinal fusion, he used two operative techniques, autogenous iliac bone grafts on a carefully prepared spinal bed, or additional massive cortical heterografts, in the same way as Stagnara and Desbrosses (16). A good correction of the scoliotic deformity was achieved with the method of muscle alloplasty presented by Gruca (7), but the non-surgical method of treatment of idiopathic scoliosis with the Milwaukee brace presented by Blount, also gave good results (4). Nevertheless, there are always cases with scoliosis in which one method might be the method of choice. Therefore, all methods in use to-day should be well known to everyone treating patients with scoliosis. But this is hardly possible at present. With a method giving good results in one surgeon's hands the results may be poor when it is used by another. A poor result in the treatment of scoliosis is always disastrous. This supports going on with one or two wellknown methods in the treatment of scoliosis. The results will be good, even if not the best possible.

In the present material, the method of choice was correction of the scoliotic deformity with the Milwaukee brace, and, in order to maintain the corrected position, the Cobb-type spinal fusion with additional fresh autogenous tibial bone grafts. The results were good in 29 cases out of 32, and the average loss of correction was only 8° (Table 5). The method is simple and easy to carry out by anyone treating patients with scoliosis surgically. It should be mentioned that 6 different surgeons carried out the operation in these 29 cases. Simplicity is one of the great advantages in this surgical method in the treatment of scoliosis.

SUMMARY

The treatment of progressive structural scoliosis in the Orthopaedic Hospital of The Invalid Foundation in Helsinki is reviewed on the basis of 57 cases of spinal fusion. The patients were operated on during the period 1962—1964. Of these patients, 26 had idiopathic scoliosis, 23 paralytic scoliosis after polio, 6 had congenital anomalies in the spine, one suffered from Marfan's syndrome, and one had a scoliosis after an operation because of patent ductus arteriosus.

The average precorrection curvature was 58° in idiopathic scoliosis, 69° in paralytic scoliosis, and 68° in congenital scoliosis. The average calendar age of the patients at the time of spinal fusion was 14 years and 11 months, at the completion of vertebral growth 16 years and 4 months, and at the last follow-up examination 17 years and 7 months. The mean duration of the time from the operation to the last follow-up examination was 2 years and 8 months.

Preoperative correction of the deformity was carried out in all cases by the Milwaukee brace. In all cases, the spinal fusion was carried out by the Cobb modification by adding substantial amounts of autogenous bone grafts into the fusion area. In 10 cases, the bone grafts were taken from the tibia two weeks prior to the spinal operation and stored in a bone bank. In 17 cases, the tibial cortical grafts and spongy bone was taken before surgical intervention on the spine and placed in a bowl for 1 to 2 hours, in readiness for later transplantation. In 32 cases, the operation was carried out according to the current method used at this hospital. To begin with, the spinal bed was prepared. Then the tibial cortical grafts and cancellous bone from the condyle were taken and inserted immediately. No complications occurred.

In 26 patients with idiopathic scoliosis of 58° , the average initial correction was 25° , or 46 per cent, the average final correction 15° , or 24 per cent, and the average loss of correction 10° . In 23 patients with paralytic scoliosis of 69° , the average initial correction was 28° , or 42 per cent, the average final correction 11° , or 15 per cent, and the average loss of correction 17° . In 6 cases with congenital scoliosis of 68° , the average initial correction was 28° , or 41 per cent, the average final correction 17° , or 25 per cent, and the average loss of correction 11° .

Direct grafting with fresh autogenous tibial bone seemed to be superior to the two other types of grafting. In only one case out of 32 with direct bone grafting, did pseudarthroses occur in the fusion area. The frequency of pseudarthroses was surprisingly high, in 7 out of 15 patients, when the

bone grafts were taken before surgical intervention on the spine and placed in a bowl, in readiness for later transplatation. With banked autogenous tibial bone grafts pseudarthroses occurred in 3 cases out of 10. Similarly, the average loss of correction was only 9° in 32 patients with direct bone grafting, 17° in 10 patients with banked autogenous bone grafts, and 18° in 15 patients with the grafts kept in the open air for 1 to 2 hours.

The clinical result was good in 40 patients out of 57, with good improvement also demonstrable roetgenographically. With fresh, directly transplanted bone grafts, a good result of treatment was noted in 29 out of 32 cases, the average final correction being 17° or 29 per cent, and the average loss of correction only 8° . With bone grafts stored in a bone bank for two weeks, a good result was gained in half the cases only, and with grafts kept outside the organism in a bowl for 1 to 2 hours, in only 6 cases out of 15.

The methods of treatment of scoliosis in use to-day are discussed.

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