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ON TRANSPLANTATION OF CANCELLOUS BONE FROM THE ILIAC CREST

BY

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INTRODUCTION

The treatment of haematogenous and fracture osteomyelitis, pseudarthroses, facial skeletal defects and other bony lesions has always aroused considerable interest. Numerous clinical and experimental papers on these subjects have appeared.

Although there are still unsolved problems and divergent opinions on the subject, it may generally be said that good results depend mainly on the radical removal of all diseased tissue, adequate skin and soft tissue covering and transplantation of bone to the defect.

Living autogenous bone transplants can be classified in the following way:

1) transplants of whole bone (*Ollier* 1860, *Eloisser* 1920, *Sauerbruch* 1922, *Graham & Riordan* 1948, *van Nes* 1948).
2) osteo-periostal transplants (*Delagenière* 1921, *Mathieu* 1926, *Campbell* 1931).
3) transplant of cortical bone with or without periosteum, usually taken from the tibial diaphysis (*Maragliano* 1919, *Albee* 1913, *Bristow* 1934).
4) cortical bone chips (*McEven* 1912, *Osgood* 1926, *Bull* 1928).
5) block-grafts of cancellous bone, usually taken from the

iliac crest (*Lindemann* 1916, *Partsch* 1922, *Putti* 1929, *Albee* 1929, *Hybinette* 1932, *Lance* 1926).

6) block-grafts of cancellous bone + chips, usually taken from the iliac crest, or, more rarely, from the greater trochanter (*Partsch* 1922, *Schumm* 1929, *Matti* 1932, 1936, 1939, *Henderson* 1933, *Mowlem* 1941-44).
7) cortical block transplants + cancellous chips.

Only the main methods and not all the variations in technique are mentioned. Thus the os novum technique, cortico-cancellous sliding grafts, and other modifications are not grouped separately.

In this paper the indications for and the results of the two last methods, particularly that of cancellous chip grafts from the ilium are discussed.

Earlier Clinical Investigations.

Block grafts of cancellous iliac bone are generally said to have been introduced by *Lindemann* in 1926. About the same time *Gillies* and his co-workers bega to use block grafts for the treatment of *mandibular defects.* In 1927 *Partsch* reported one case of mandibular defect treated with a cancellous graft from the ilium, and in 1927 one further case. In 1932 *Matti* reported that he had started using cancellous grafts during the first world war. *Risdon* recommended their use in 1922, *Ivy & Epes* in 1927—all for mandibular defects.

In recent years there have been many publications which have generally confirmed the value of cancellous chip grafts for the mandible, e.g. *Cuthbert* (1944), *Converse* (1945), *Blocker* and *Weis* (1946), *Clarkson, Wilson & Lawrie* (1946), *Blocker* (1948), *Blocker & Stout* (1949).

In 1932 *Matti* published an experimental work on transplantation of cancellous bone from the pelvis, the trochanter, and the femoral diaphysis. In 1936, in a clinical work on the treatment of pseudarthroses, he reported the use of cancellous bone from the trochanter, and in 1939, in a paper on arthrodesis of the hip, the use of cancellous bone from the iliac crest.

Although plastic surgeons have agreed from the beginning on the value of cancellous bone grafts, *McIndoe,* in 1941, was the first to stress that cancellous bone from the ilium is the most suitable for *plastic operations* on the face and skull. He prefers block grafts.

The indications for purely plastic grafting operations have been described by *Stuart Gordon* (1946) and *Macomber* (1946). Both authors

believe that autogenous cancellous chips give better results than other material (cartilage, allo-transplants, and bank-bone).

Especially due to *Mowlem*'s papers (1941-44) the indications for the use of cancellous bone chips were widened. In recent years they have been increasingly used in surgery of the jaw, in plastic surgery, and in limb surgery and orthopaedics.

In the treatment of *osteomyelitis*, whether haematogenous or following fractures and gunshot-wounds, all writers stress the importance of radical removal of all diseased tissues, and some also call attention to the importance of a solid skin and soft-tissue covering. In all series the percentage of primary healing has been about 90. (*Coleman, Bateman, Dale & Starr* 1946, *Abbott, Bost, Schottstaedt, Stern & McCorkle* 1946, *Carpenter, Rosenfeld & Mech* 1946, *Higgs* 1946, *Moon* 1944, *Robertson & Barron* 1946).

In 1948 *Hogeman* reported the first Scandinavian series of nine cases of whom seven had osteitis or osteomyelitis, and two pseudarthrosis. One had been observed for eleven months, two for six months, and the rest for less than three months. In two cases with partial skin necrosis the granulating surface was grafted three to four weeks after the first operation. There had so far been no evidence of relapse.

Key in 1943, and *Dick* in 1948 used iliac chips for *pseudarthroses*, and for arthrodesis of various joints, especially where stability could be obtained without the use of a cortical graft. *Dick* stresses that any correction of the position must be performed early, because by the fourteenth day union is often so far advanced that correction is difficult.

Higgs (1946) and *Bishop, Stauffer & Swenson* (1947) prefer to combine cortical tibial grafts with ilium chips in the treatment of pseudarthroses. Higgs used this combination in 40 out of 60 cases, and found that healing occurred twice as fast as when cortical transplants were used alone.

For pseudarthroses *Horwitz & Lambert* (1947) prefer to combine iliac grafts with a Lane's plate or vitallium screws, since he found that bone grafts when used alone gave 83 % union, and when combined with fixation material gave 90 % union. In these views they differ from the majority of authors, who generally agree that, as far as possible, it is best to use bone grafts alone, in particular cancellous bone grafts. Supplementary plating or bolting should only be used if fixation and immobilisation cannot be obtained in any other way.

Karlën (1944) uses cancellous chips and block grafts for *athrodesis* of the hip.

King (1948) uses block grafts and iliac chips for *spinal fusion* and reports satisfactory consolidation in 90 % of cases. This is confirmed by experiments performed by *Ghormley & Stuck*, and confirmed clinically by *Break & Basom* (1943).

Earlier Experimental Works.

The clinical results of cancellous grafts show a healing percentage of 90-95 %, as compared with 80-85 % for other forms of bone grafting. It has not been possible to confirm these clinical results experimentally, mainly because of our insufficient knowledge of the biology of bone growth and of the main factors influencing it. For this reason "pure" experiments are very difficult to plain.

The numerous investigations with different types of transplants—periosteal, endosteal and cancellous bone, marrow, extracts, os purum and bank bone—have shown that all have some osteogenetic effect. (*Mayer & Wechner* 1914, *de Josselin de Jong & van der Kemp* 1928, *Orell & Engström* 1943, *Lexer* 1924, *Brooks* 1917, *Bachkirzev & Nemilov* 1912, *Policard & Leriche* 1928, *Levander* 1938, *Annersten* 1940, *Hellstadius* 1943, *Bertelsen* 1944).

Various views have been put forward as to which type has the greatest osteogenetic effect. Especially regarding the relative values of cancellous and cortical bone are the authors divided.

There is no doubt about the osteogenetic effect of cancellous bone, though some investigators believe that this effect is less than in cortical bone (*Hellstadius* 1943 a. o.), while others believe that cancellous bone, especially in the form of chips, has the greater osteogenetic effect (*Partsch* 1922, *Matti* 1932, *Mowlem* 1943).

Marchand (1901) believed that after transplantation cancellous grafts died and were absorbed. He, however, used homotransplants from the femoral condyles of dead dogs and implanted them into the frontal bones of young dogs.

Partsch (1922) showed that iliac cancellous bone was still living three weeks after transplantations to the mandible.

Matti (1932) believed that cancellous bone had a better chance of survival, because the vessels grow more easily into cancellous transplants to join with the vessels of the transplant. *Mowlem* is of the same opinion. *Matti* also states that cancellous bone is more resistant to infection in the tissues than cortical bone.

The views of *Partsch, Matti* and *Mowlem* remained unopposed until *Stuart Gordon,* working with the bone cytologist *Ham,* published the results of a large-scale experimental work in dogs. They inserted small grafts which they removed after different intervals. They showed that the grafts were gradually absorbed and replaced by new bone tissue. Only a small part of the new bone appeared to be formed from the graft itself—perhaps from the marrow cells—while the greater part was formed by the recipient tissue which was stimulated to form bone by the presence of the cancellous graft.

These results agree with those of *Bertelsen,* who continued *Levander*'s and *Annersten*'s investigations into the induction of bone and cartilage

formation in muscles. He showed that extracts of the marrow of young bone induced cartilage and bone formation at the site of injection twice as often as extracts of periosteum, epiphysis, and cortical bone.

Abbott, Schottstaedt, Saunders, & Bost (1947) transplanted cancellous bone both with and without periosteum and also combined cortical and cancellous grafts (ribs) to the abdominal wall of dogs and rabbits. They, like *Gordon* and *Ham*, found that all mature elements died, while the endosteal cells with osteogenetic properties alone survived. Cancellous bone had the greatest osteogenetic activity.

Thus both clinical and experimental observations, which show the importance of the red bone marrow for new bone formation, are available. Clinical work has also shown that cancellous bone gives better results than cortical bone. Recent experimental work must also be regarded as supporting this view.

OWN MATERIAL

29 cases have been treated since 1947. All were given post-operative penicillin for three days or until their temperatures were normal. Infected cases were also given preoperative penicillin.

A. 9 cases of *chronic haematogenous osteomyelitis*.. The most important details are shown in table 1, pag. 486.

Thus the majority of the cases were of very long standing. In the above table only chisellings are included among previous operations, not scraping of sinuses or simple sequestrectomies. Case No. 7 had had a resection of the knee-joint.

5 cases had sinuses. In 6 direct suture seemed justifiable after mobilisation of the skin. In 2 the skin was sutured after a counter incision and advancement of the flap. In one case, where primary direct suture was tried, a cross-leg-flap was necessary later. See Fig. 1.

Thus the attitude to plastic skin surgery was conservative, and it is possible that our experience will lead us to be more radical in the future.

2 cases, Nos. 817/49 and 2035/47, have not been included in the material since they were only treated for residual discharge from unstable ulcerating scars, although the bone process was healed. Both healed after cross-leg-flap.

In all cases the bone focus was treated by radical chiselling,

TABLE 1

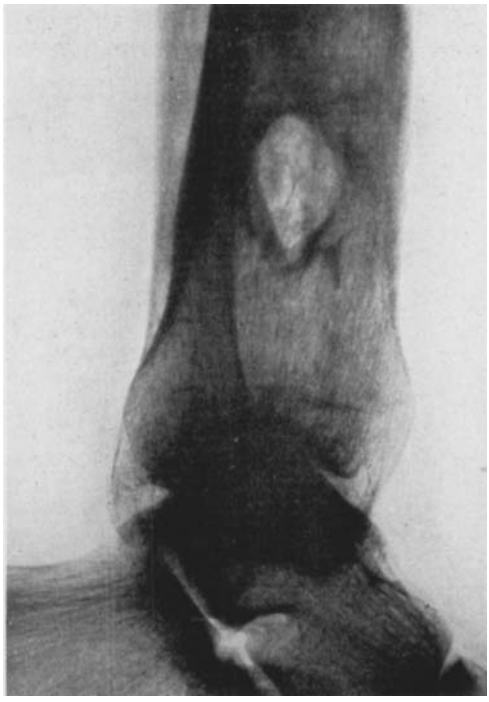
Chronic haematogenous osteomyelitis.

	Nr.	Age	Sex	Site	Preoperative duration	Number of previous operations	Sinus	Skin covering
1.	174/48	39 years	M	tibia	20 years	4	14 years	cross-leg-flap
2.	1500/48	37 „	M	tibia	22 „	3	÷	direct suture
3.	1702/48	33 „	M	femur	16 „	2	16 years	bridge flap
4.	401/49	17 „	M	femur	4 „	3	÷	direct suture
5.	623/49	31 „	F	humerus	15 „	3	15 years	direct suture
6.	629/49	16 „	M	tibia	5 „	1	5 „	bridge flap
7.	1158/49	62 „	M	tibia	48 „	3	÷	direct suture
8.	1362/49	71 „	F	tibia	2 „	0	÷	direct suture
9.	1517/49	12 „	M	femur	4 „	1	4 years	direct suture

Fig. 1.

and the cavities were saucerized and packed with cancellous chips from the crest and all of the ilium. Fig. 2 shows the radiograph of a case with an active focus before operation, shortly after grafting and after healing. Preoperatively there had been a discharging sinus.

The follow-up period is still very short, since up till 1948 the routine method in this department was packing with penicillin and sulfathiazole. 3 cases had been observed for less than 6 months post-operatively, 2 for between 6 and 7 months, and only 4 for more than 1 year. No case has a sinus or any residual process on the radiograph. In 1 case (No. 8) the leg was amputated, 5 months after the osteomyelitis operation, for tuberculosis of the ankle-joint. This case also had a spina ventosa but neither the anatomical findings nor the microscopic appearance of the specimen obtained at operation showed any evidence of tuberculosis in the tibial focus, nor



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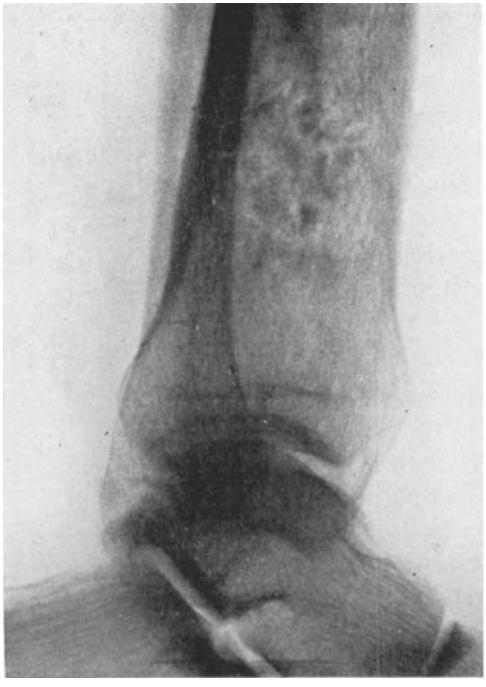

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Fig. 2.

any connection between the completely healed operation area and the tuberculous focus in the ankle.

In one case discharge persisted for 6 months, and then ceased after a small sequestrum of the size and shape of a chip had been discharged. In another case a sinus which had not been excised continued to discharge. It was on the medial side of the thigh, while the operation had been performed on the lateral side. This sinus has recently been excised. There was no clinical or radiographic evidence of activity in the bone.

We are inclined to attribute these complications to insufficient radical treatment of the skin, rather than to the bone grafting method.

B. *3 cases of infected pseudarthrosis with fracture-osteomyelitis.* Table 2, pag. 490.

In cases 10 and 11 pseudarthroses had been treated previously by cortical bone grafts and had also had several sequestrectomies. Case 12, which was rather a case of delayed union due to the osteomyelitis, had been treated earlier with an intramedullary Kirschner wire.

In case 12 cancellous chips were used alone. In case 11 they were combined with a block graft from the iliac crest, and in case 10 with a tibial graft.

All three cases have healed without sinus formation. They have been followed for 1 to 2½ years. Case 11 had a discharge from several small fistulae until 3 small sequestra (ununited cancellous chips) were discharged. The sinuses then closed. In this case the covering skin was thin, tight and chronically eczematous.

C. *3 cases of uninfected pseudarthrosis.* Table 3, pag. 490.

In case 13 a sliding graft and ilium chips were used. In case 14 both a whole graft and chips from the ilium and a vitallium screw. In case 15 a local cortical graft, iliac chips and two vitallium screws.

Cases 13 and 14 are clinically and radiologically consolidated, but case 15 is still not united 9 months after operation.

TABLE 2

	No.	Age	Sex	Site	Preoperative duration	Number of previous operations	Sinus	Skin covering
10.	1119/47	37 years	M	humerus	3 years	3	3 years	direct suture
11.	1530/48	44 „	M	tibia	24 „	2	1½ „	direct suture
12.	1604/48	16 „	M	tibia	7 months	1	7 months	direct suture

TABLE 3

	No.	Age	Sex	Site	Preoperative duration	Number of previous operations	Skin covering
13.	739/47	36 years	M	II metacarpal	2½ years	0	direct suture
14.	1216/47	23 „	M	tibia	6 months	0	direct suture
15.	2373/48	46 „	M	femur	1½ years	6	direct suture

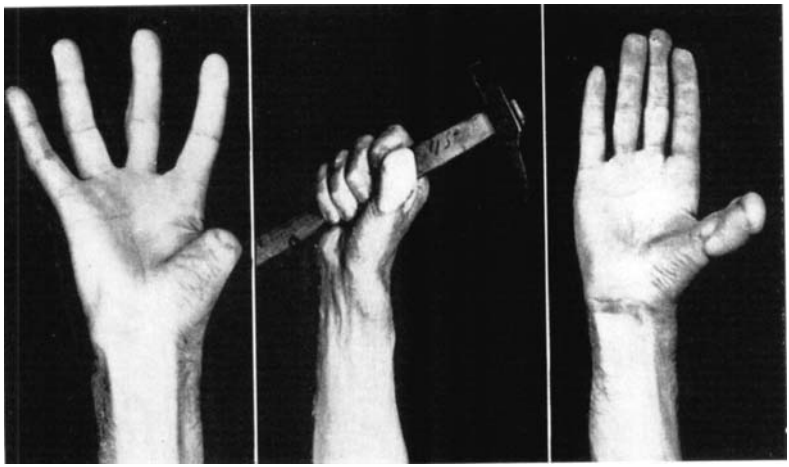

Fig. 3.

This case has previously had 6 chisellings for osteomyelitis from 17 to 3 years before admission. The fracture was 18 months old. At follow-up he can bear weight on the leg. He works as manager of a factory and uses a stick for walking, but the he feels unsteadiness and there is 20 degrees' angulation, open posteriorly, at the fracture line. There was already 10 degrees' preoperative angulation. Radiographically—using special views—there is bony contact posteriorly for a small finger's breadth. The rest of the fracture line is not filled in, though there is no sclerosis of the edges. Thus there is still a possibility of consolidation, but we now realize that the cortical, stabilizing graft should not have been taken from pathological, sclerotic bone.

In these 3 cases there was no difficulty with the skin covering. It is well known that the skin may be important for consolidation in cases of delayed union and for a satisfactory result in pseudarthrosis operations. This is illustrated by another case from this department.

A man (nr. 1449/47), age 42 years, has had a compound infected fracture of the tibia for 2½ years. A sequestrectomy had been performed in 1945, chiselling and packing with local chips in 1946, chiselling and packing with penicillin and sulfathiazole in April 1947. In July 1947 there was still a pseudarthrosis with a sinus, and the patient favoured amputation in order to shorten his illness. The sinus and poor skin

TABLE 4

	No.	Age	Sex	Site	Diagnosis	Operation
16.	436/48	52 years	M	C 4 — T 1	Spondylosis deformans with root compression	H-shaped pieces of ilium + ilium chips
17.	668/48	30 „	F	L 4 — S 1	Tuberculosis of the 5th lumbar vertebra	H-shaped pieces of ilium + ilium chips
18.	1053/49	53 „	F	Hip	Necrosis of the femoral head after fracture	Nailing arthrodesis ilium graft, and juxta- and intraarticular chips
19.	1415/49	38 „	M	right thumb	Traumatic amputation of the right thumb	Skin tube from the abdomen, iliac graft and tendon suture. 3 months later arthrodesis between transplant and metacarpal graft using iliac chips and a

Fig. 4.

were excised, the bone was drilled and a dermatome graft 4 by 8 cm was applied. Five weeks later the skin was solidly healed. There was no sinus, and the fracture was clinically firm.

D. *Arthrodesis, 4 cases.*

All cases showed bony union. The result in case 19 is shown in fig. 3.

The functional results are good except in case no. 16, in which the patient has pain below the level of fusion as well as in the lower thoracic spine, where the spondylosis is progressing.

It is doubtful whether the operation was indicated in this case, but the patient's condition was intolerable because of pain in the neck and throat. A rhizotomy of the 2nd and 3rd cervical nerves had previously been done by the neurosurgeons for the same reason.

E. *Cases of correction of facial skeletal defects.* Table 5, pag. 494.

Follow-up examinations have found the patients satisfied

TABLE 5
(Cases in which grafts or chips were used alone, i.e. nose plastics are not included)

	No.	Age	Sex	Region	Diagnosis	Operation
20.	1098/48	26 years	F	Forehead	Defect after resection of frontal osteoma	Ilium graft and chips
21.	1151/48	41 „	F	Infraorbital	Sequelae of fracture of the zygoma	Ilium graft and chips
22.	603/49	37 „	F	Forehead	Sequelae of frontal sinusitis	Ilium graft and chips
23.	613/49	16 „	F	Forehead, maxilla and mandible	Facial hemiatrophy	Ilium graft, chips + corium, fat & fascia graft
24.	713/49	29 „	M	Forehead	Sequelae of frontal sinusitis	Ilium graft and chips
25.	911/49	47 „	M	Infraorbital	Sequelae of orbital lesion	Chips
26.	1017/49	28 „	M	Nose & forehead	Congenital deformity	Ilium graft and chips

TABLE 6

	No.	Age	Sex	Region	Diagnosis	Operation
27.	234/49	27 years	F	Phalanx	Enchondroma	Enucleation, ilium chips
28.	1511/49	24 „	M	Femur	Fibrous dysplasia	Enucleation, chips
29.	1321/49	33 „	F	Ischium	Chondromyxosarcoma	Excision of the ischium and part of the pubis and acetabulum; ilium graft + chips

with the results. "Re-touching" operations have so far been necessary in two cases; thus a small corner of the transplant was absorbed in case 20. It was re-grafted. Case 22 was rather over-corrected because of this experience, but reabsorption did not occur and secondary chiselling of the excessive bone was necessary. Case 23 see fig. 4.

F. *Bone defects after operations for tumours and cysts, 3 cases.* Table 6, pag. 495.

In case 27 there is clinical and radiographic union. The other two cases are too recent.

To summarize, cancellous bone chips from the ilium have been used in 29 cases, sometimes combined with whole grafts, which were mainly also taken from the ilium. Vitallium screws were also used in two cases. Nine cases have been observed for less than six months. Of the remaining twenty cases there is clinical and radiographic union in all but one.

SUMMARY

Clinical and experimental work on bone grafting is reviewed, and our own experience is described.

29 cases are reported. Cancellous ilium chips were used in all; in some they were combined with block grafts, mainly taken from the ilium. Vitallium screws were also used in two cases. All cases received postoperative penicillin treatment. 9 cases have been observed for less than 6 months. Of the remaining 20, 19 show clinical and radiographic union.

9 cases of long-standing haematogenous chronic osteomyelitis were treated. The bone focus was widened and saucerized and packed with cancellous chips. Solid skin covering must be provided in these cases. The observation period is over 1 year in only 4 cases. 2 had persistent discharge, both without radiographic evidence of activity in the bone. From one a sequestrum resembling a chip was removed, in another the sinus was excised. In both, the discharge stopped. We attribute these complications to poor skin covering.

3 cases of infected pseudarthroses were treated in the same way. All of them healed, 1, with poor skin covering, only after the discharge of 3 small sequestra. 3 cases with uninfected pseudarthroses were treated by cancellous chips combined with a local cortical graft, an ilium graft, and an ilium graft + vitallium screws, respectively. 2 are clinically and radiographically consolidated, 1 shows only partial union 9 months after operation.

In 4 cases the method was used for arthrodesis, all show bony ankylosis.

In 7 cases cancellous chips were used for defects of the facial bones with satisfactory results.

In 3 cases cancellous grafts were used for bone defects following excisions of tumours and cysts. 1 is united; in the other 2 the observation time is too short.

RESUME

Le travail clinique et expérimental de la transplantation osseuse est passée en revue et les propres expériences de l'auteur décrites.

29 cas sont rapportés. Des fragments spongieux d'os iliaque ont été utilisés dans tous les cas; de plus, des greffes osseuses, prélevées principalement de l'os iliaque ont été utilisées dans certains cas et des vis de vitallium dans deux. On a donné de la péniciline à tous les malades avant et après l'opération. 9 cas ont été observés pendant une période inférieure à six mois. Sur les 20 autres, on a constaté chez 19 une consolidation clinique et radiographique.

9 cas d'ostéomyélite hématogène chronique anciens ont été traités ; on a pratiqué un currettage étendu du foyer intra-osseux que l'on a ensuite empli de fragments d'os spongieux. Il faut veiller à ce qu'il y ait dans ces cas une solide couche *dermique*. La période d'observation s'est étendue sur plus d'un an dans 4 cas seulement. Dans 2 cas il y a eu suppuration persistante bien qu'il ne semblait pas y avoir d'infection osseuse active. Un cas s'est guéri après extraction d'un séquestre

et l'autre après excision du sinus. Nous attribuons ces complications à une couverture imparfaite dermique.

3 cas de pseudarthrose avec infection ont été traités de la même manière ; tous ont été guéris, l'un après extraction de trois petits séquestres.

3 cas de pseudarthrose sans infection ont été traités par fragments d'os spongieux combinés respectivement avec une greffe corticale locale, une greffe d'os iliaque et une greffe d'os iliaque + vis de vitallium. 2 montrent une consolidation clinique et radiographique ; chez un autre la jonction n'est que partielle neuf mois après l'opération.

Dans 4 cas la méthode a été appliquée contre l'arthrodèse : il y avait chez tous de l'ankylose osseuse.

Dans 7 cas on utilisa des fragments d'os spongieux pour réparer des os de la face défectueux et l'on obtint des résultats satisfaisants.

Dans 3 cas des greffes d'os spongieux ont été utilisées pour réparer des os à la suite d'ablation de tumeurs ou de kystes. Il y a eu jonction dans un cas. Dans les deux autres la période d'observation est trop courte.

ZUSAMMENFASSUNG

Das klinische und experimentelle Werk über Knochentransplantation wird besprochen und die eigenen Erfahrungen der Verfassern werden beschrieben.

29 Fälle werden mitgeteilt. Spongiöses Gewebe vom Ileum wurde in allen Fällen verwendet. Ausserdem wurden in einigen Fällen solide Spangen, meist vom Ileum entnommen, und in zwei Fällen Vitalliumschrauben gebraucht. Alle Fälle erhielten prä- und postoperativ Penicillin. In 9 Fällen war die Beobachtungsdauer kürzer als 6 Monate. Von den 20, zeigen 19 klinische und röntgenologische knöcherne Heilung.

9 Fälle von lang bestehender hämatogener Osteomyelitis wurden behandelt. Der Knochenherd wurde breit ausgemeisselt und mit spongiösem Knochengewebe gefüllt. Für eine Deckung mit solider Haut muss in diesen Fällen gesorgt wer-

den. Die Beobachtungsperiode ist nur in 4 Fällen über ein Jahr. 2 Fälle zeigten persistierende Sekretion, obwohl keine Anzeichen für eine aktive Infektion im Knochen vorhanden war. Ein Fall heilte nach Entfernung eines Sequesters, der wie einer der transplantierten Knochenspähne aussah. Der andre Fall heilte nach Excision der Fistel. Man sucht die Ursache dieser Komplikationen in ungenügender Hautdeckung.

3 Fälle von infizierter Pseudarthrose wurden in derselben Weise behandelt. Alle heilten, einer erst, nachdem drei kleine Sequester ausgestossen worden waren.

3 Fälle von nicht infizierten Pseudarthrosen wurden mit spongiösen Knochenspähnen, kombiniert mit lokalem Kortikalisspahn respektive mit Ileumspahn und Ileumspahn mit Vitalliumschraube, behandelt. Zwei sind klinisch und röntgenologisch konsolidiert. Einer zeigt nur teilweise Vereinigung 9 Monate nach der Operation.

In 4 Fällen wurde die Methode zur Arthrodese benutzt. Alle zeigen knöcherne Ankylose.

In 7 Fällen wurden spongiöse Knochenspähnchen benützt um Defekte der Gesichtsknochen zu reparieren, mit zufriedenstellendem Resultat.

In 3 Fällen wurden spongiöse Knochenspähne verwendet bei Defekten die der Excision von Tumoren und Zysten folgten. Ein Fall zeigt Heilung. In den anderen beiden Fällen ist die Beobachtungszeit zu kurz.

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