

CONTRIBUTION TO THE TECHNIQUE IN FUSION OPERATIONS ON THE SPINE

BY

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The methods employed in most fusion operations on the spine consist, as is known, in fixing the arches or spinous processes to each other by transplantations of bone. The success of these fusion operations depends upon how far we succeed in securing the formation of a coherent and sufficiently solid bridge of new bone between the vertebral arches. The many operative methods that have been proposed and the new ones that are constantly being introduced are indicative of the difficulty of this task, and the varying methods which we have employed tell the same story. Our experiences and results are limited to 48 fixation operations which have been performed in the period from the autumn of 1939 until now, namely, 26 for tuberculous spondylitis, 9 for spondylolysis and spondylolisthesis, 3 for scoliosis, 2 for occupational lumbago, 3 for paralytic scoliosis after poliomyelitis, 2 after laminectomy performed in cases of herniated intervertebral disc and 3 for juvenile kyphosis.

The results of our operations are judged clinically by the degree of fixation attained and roentgenologically by the quantity of newlyformed bone around the transplanted bone. As regards the effectivity of the operations, which depends on the new-formation of bone, it is, of course, only the roentgenological findings that have been of importance. In the lumbar parts it has been easy to judge of the results, in the thoracic parts more difficult. For at the latter place in the lateral picture the ribs will hide the space between the spinous processes. In

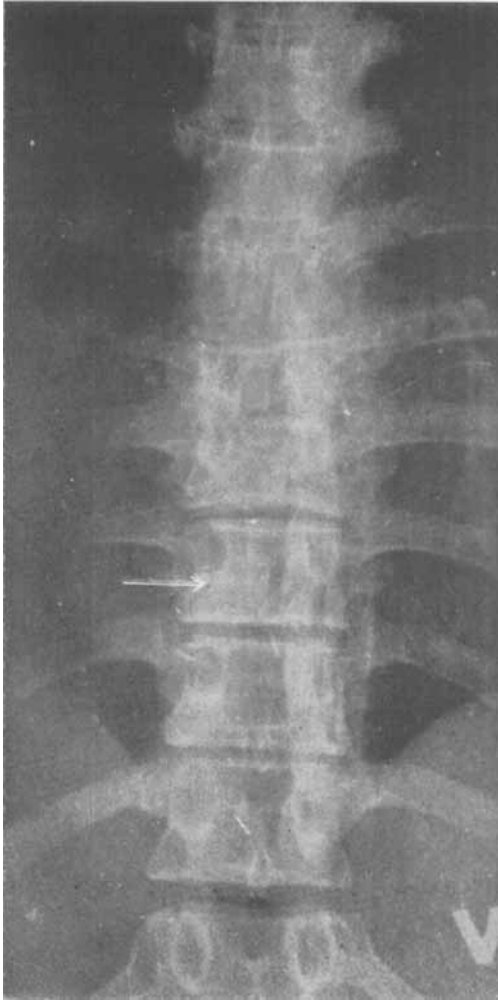


Fig. 1 a.

judging about the roentgenogram many will be tempted to regard a rapid disappearance of the grafts as a bad sign. Meanwhile, we possess sufficiently many proofs, both experimental and clinical, that every transplanted bone, whether large or small, thick or thin, will die and that after transplantation there

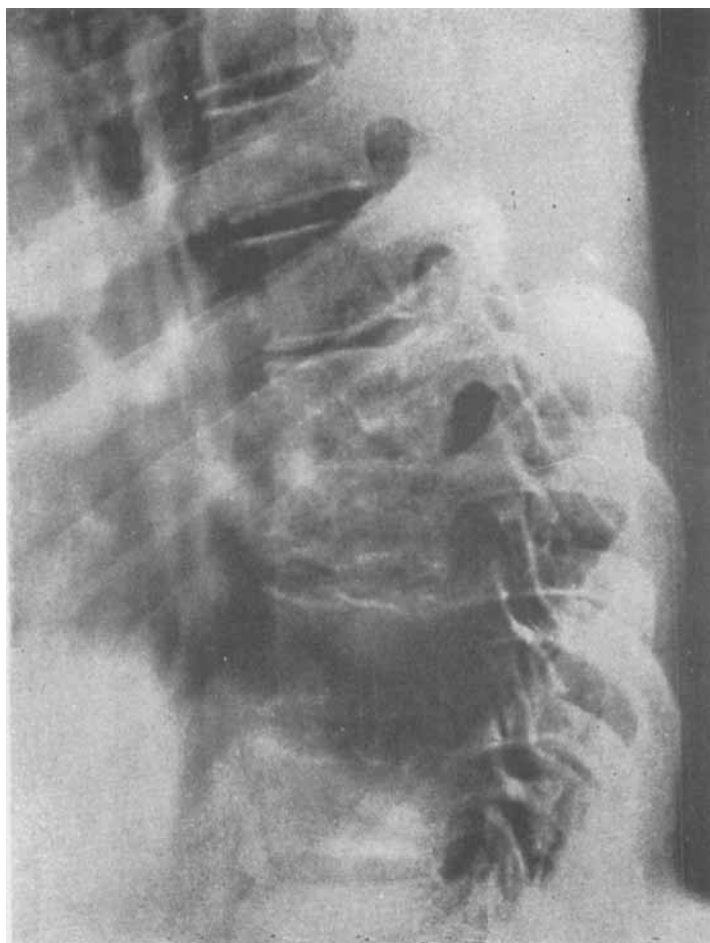


Fig. 1 b.

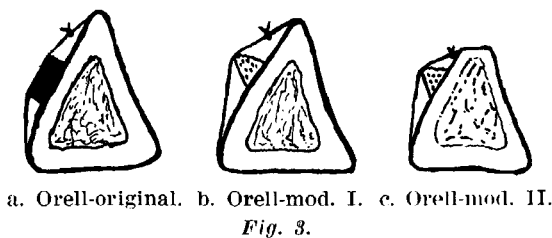
comes no growth of osteoblasts from the Haverian canals and that the calcium in the necrotic grafts plays no rôle as regards the regeneration of the bone. The necrotic grafts must gradually be replaced by living bone through substitution processes, which will take a longer time according as the transplanted bones are large and more massive. Such necrotic massive grafts which have lost the cells and the structure of living bone, and for the



Fig. 2.

most part consist only of lime, will give to the roentgenogram some suggestion of solidity and strength, but represent, in the literal sense of the term, "a whited sepulchre". If the grafts disappear rapidly, this fact must be taken as a sign that the substitution processes have set in at a comparatively early point of time, and this should be hailed with satisfaction, provided it attended by signs of the formation of new bone.

As an example of how altogether difficult the roentgenological judgment of the new-formation of bone really is I refer to Fig. 1 a and b, radiographs (antero-posterior and lateral views) of the dorsal spine from a patient with spondylitis of Th. VII-VIII, subjected on 12/3-1943 to what we call a modified Orell fusion operation, performed over the *right* half of the arches in the lower part of the dorsal spine. As the X-rays revealed no new-formation of bone 6 months after this operation, there was on 11/7-1944, nine months later, performed an original fusion oper-



ation, which it was intended to make bilateral. When we were working in on the old operation field to the *right* of the spinous processes, we came upon a coherent, although thin, bridge of newly formed bone, which the X-ray picture (Fig. 1), taken on 5/9-1945, nearly two years after the first and more than one year after the second operation, was hardly able to reveal. The conclusion to be drawn herefrom must be that, if we discover on the roentgenogram signs of new-formation of bone, we may then be certain that it *is* there. This, however, does not mean that the quantity of newly-formed bone is sufficient for our purpose.

We have been prompt in passing judgment on a method of operation, have rejected it and tried a new path, if the roentgenogram 6 months after the operation has not revealed sufficient quantities of newly-formed bone-tissue between the arches. For we are of opinion that, if the operative treatment, for instance, in case of spondylitis, is to compete with the conservative, then the time of treatment must be shortened to an essential degree.

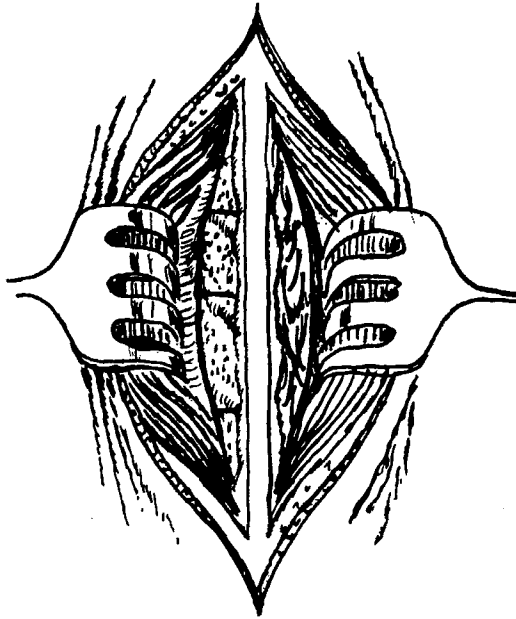
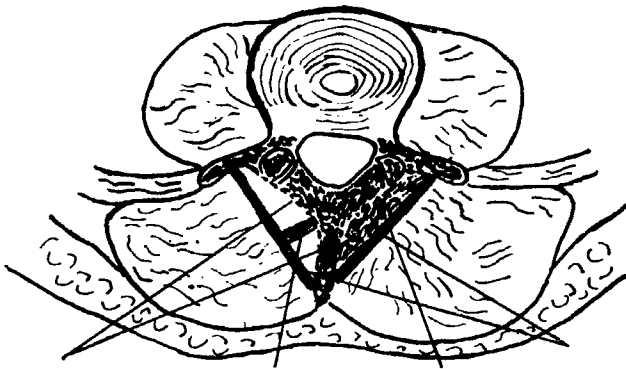


Fig. 4 a.



Decorticated arches and spinous processes Stretchers Bone-shavings Semiflexible tibiagraft

Fig. 4 b.

Section of the Lumbar Spine. On the left side the muscles are kept out from the decorticated spinous processes and arches by a semiflexible bone-graft and stretchers. On the right side the space between the semiflexible graft and the spinous processes and arches is filled with bone-shavings (the method now in use).

TABLE 1.
The figures indicating case-numbers.

Method	6 mths p. o.		More than 6 mths p. o.		Symptoms
	Röntgenol. new-format. of bone	Clinical fixation	Röntgenol. new-format. of bone	Clinical fixation	
Albee	-4.6.9.11.12.7.	+4.6. -9.11.12.7.	+6.9.12.7.	+6.12. -7.	-6.12. +9.7.
Albee mod.....	-8.	+8.	+8. -10.14.	+8.10.14.	-8.14. +10.
Thin Albee grafts in grooves.....	+13.17.	+13.15.17.	+13.	+13.	-13.17.
Albee transplants over decorticated arches.....	+27.28. -31.36.	+27.28.31.36.			
Orell, mod.	+5. -1.19.20.22.	+1.5.19.20. -22.	+19. -22.	+5.19. -1.22.	-5. +1.22.
Semiflexible chips + stretchers....	+18.21.24.26. -23.25.	+18.21.23.24.26.	+21.24.26. -23.	+21.23.24. -26.	-21.23.24.
Semiflexible chips + small chips ..	+22.29.30.32.34. 35.38.41.42.44. -9.10.	+23.30.32.33. 34.40.41.42.	+22.29.30.32. 33.35.38.40.	+22.30.32.35. 38.40. -29.33.	-22.29.30.32. 35.38. +33.40.
Hibbs	-3.	+3.	-3.	+3.	+3.
Brittain.....	+37.	-37.			

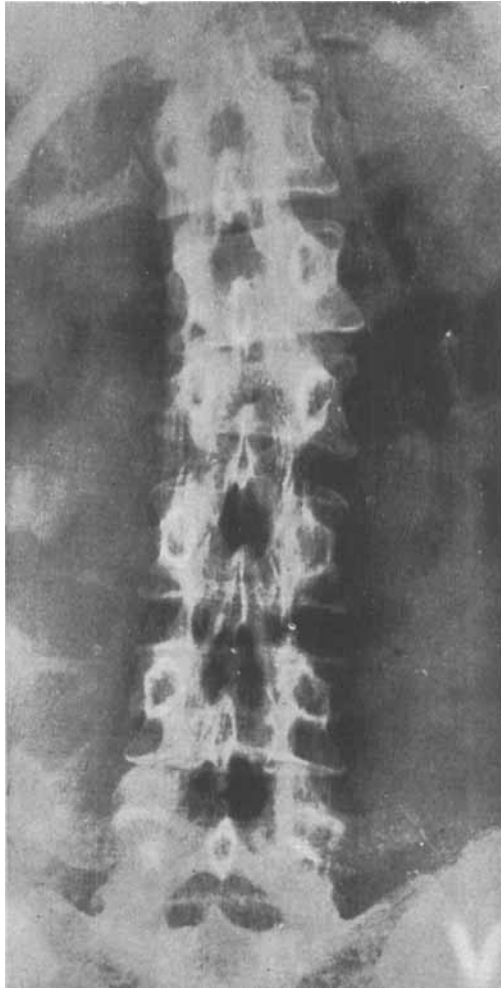


Fig. 5 a.

In the choice of a method of operation, especially in case of spondylitis, attention must be paid to the importance of making the operation little injurious as possible. It is not so much the regard to the patient's general condition that renders this desirable, but rather the danger of activating and spreading the local process of disease.



Fig. 5 b.

Our first fusion operations were carried out by Albee's method. This method we have now abandoned. In the first place, it is difficult to get an Albee graft to adapt itself in such manner that it gets a good hold on the spinous process of the healthy vertebrae above and below. In the second place, such a graft

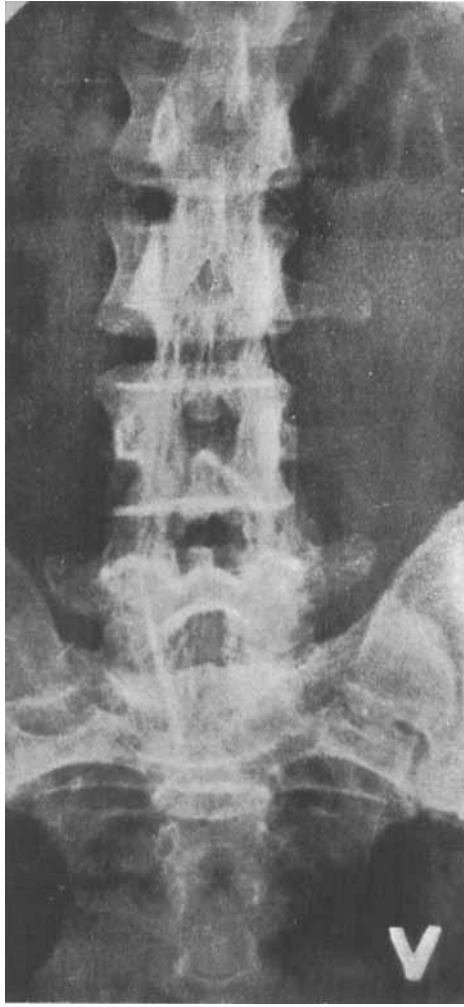


Fig. 6 a.

represents what I have above designated "a whited sepulchre". Such a thick piece of bone may, no doubt, for a long time look quite well in the roentgenogram, but during the first time after being transferred it represents nothing else than the osteogenetic factor in the regeneration process that should lead to formation



Fig. 6 b.

of new bone-tissue. It is only the regenerative impulses on the surface of such a thick piece of bone that come into action, while the central parts simply retard and hinder the substitution process that should lead to the formation of a bridge of living bone-tissue between the spinous processes. The consequence is

*Fig. 7 a.*

that, if the patient is not immobilized for months or years afterwards, we experience what may be seen in our and other investigators' material, namely, that the graft gets loose and is absorbed without new-formation of bone precisely at the places where it ought to have the strongest grip, but where, as has been said above, it is in the operation most difficult to ensure



Fig. 7 b.

a firm hold for it, namely, in the healthy vertebrae above and below. Confiding in the good effect of the operation we allow these patients operated by Albee's method to get up after some months and the result is a progression of the pathological process. Fig. 2, the last X-ray picture taken of a patient who had undergone the Albee operation in November 1942 and who has

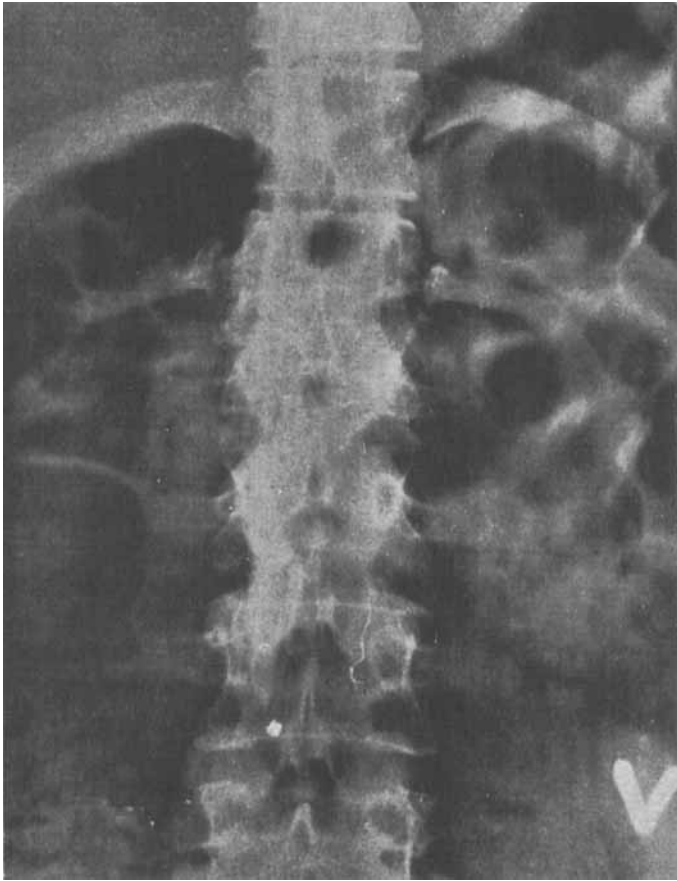


Fig. 8 a.

been X-rayed for control in August 1944, in December 1944 and in March 1945, shows all these results in one and the same picture: absorption of the graft, progression of the disease, with increasing gibbus, and loss of grip for the graft in the vertebra immediately above.

We have performed 6 original Albee transplantations (Table 1). Six months later we have not in a single case found signs of new-formation of bone, and clinical fixation was seen

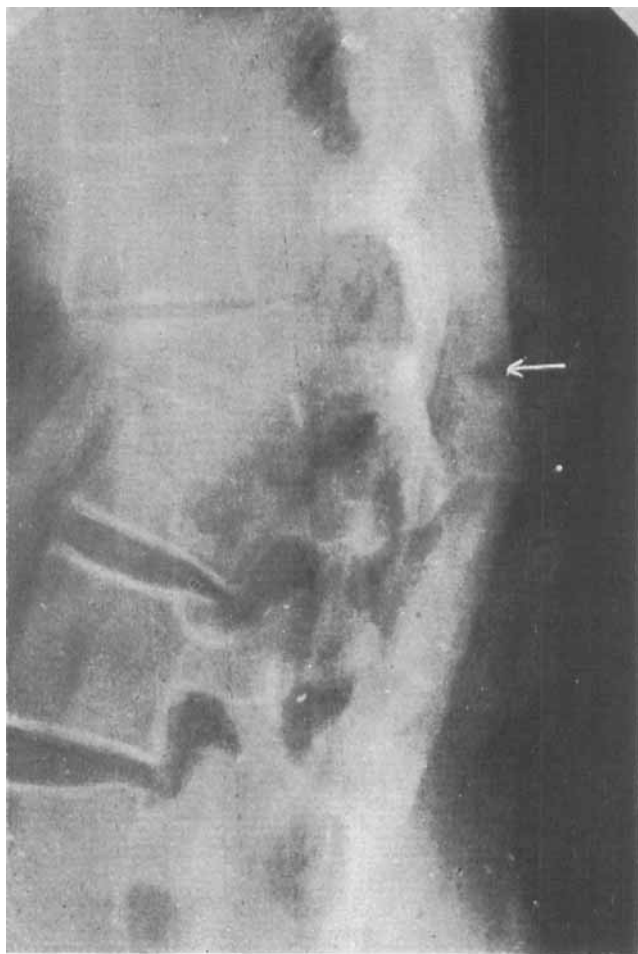
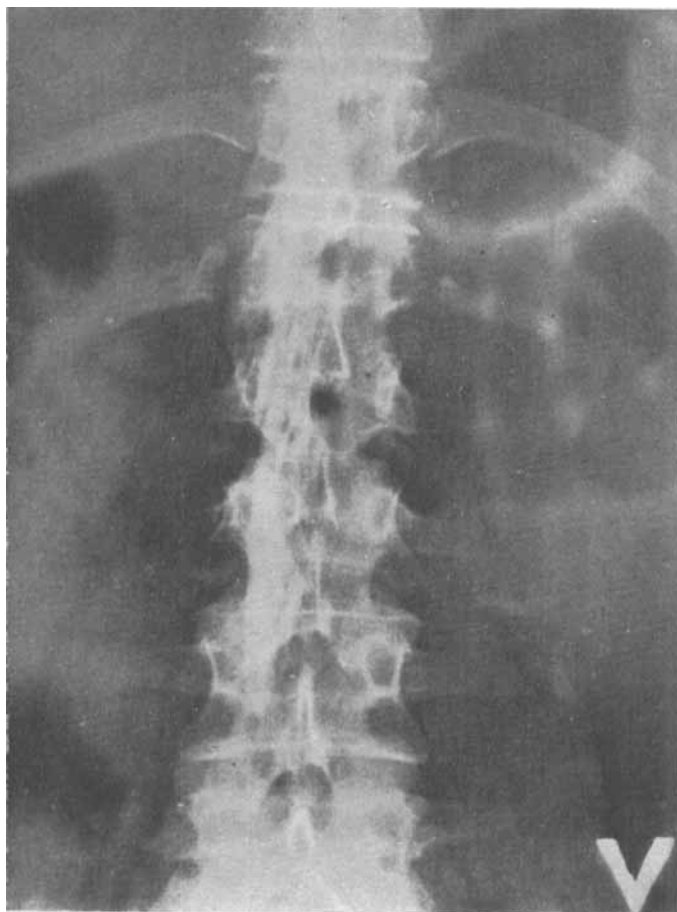


Fig. 8 b.

in only 2 of the cases. The results turn out to be rather different, however, if we examine the patients a somewhat longer time after the operation. Out of 4 patients we then find on the roentgenogram undoubted new-formation of bone in three and doubtful in one. Clinical fixation was found in 2, no fixation in 1, and symptoms with signs of progression in 2.

If we modify Albee's operation by using a thin instead of a

*Fig. 9 a.*

thick graft from the tibia, the result will apparently be still worse (Table 1). If we employ two such thin grafts and insert them in grooves chiselled in the base of the proc. spin., after removing the outermost parts of these latter, the result will be a little better (Table 1). By this last modification, however, the muscles on each side of the spinous processes will be loosened, and this is an essential point as regards the final result, and

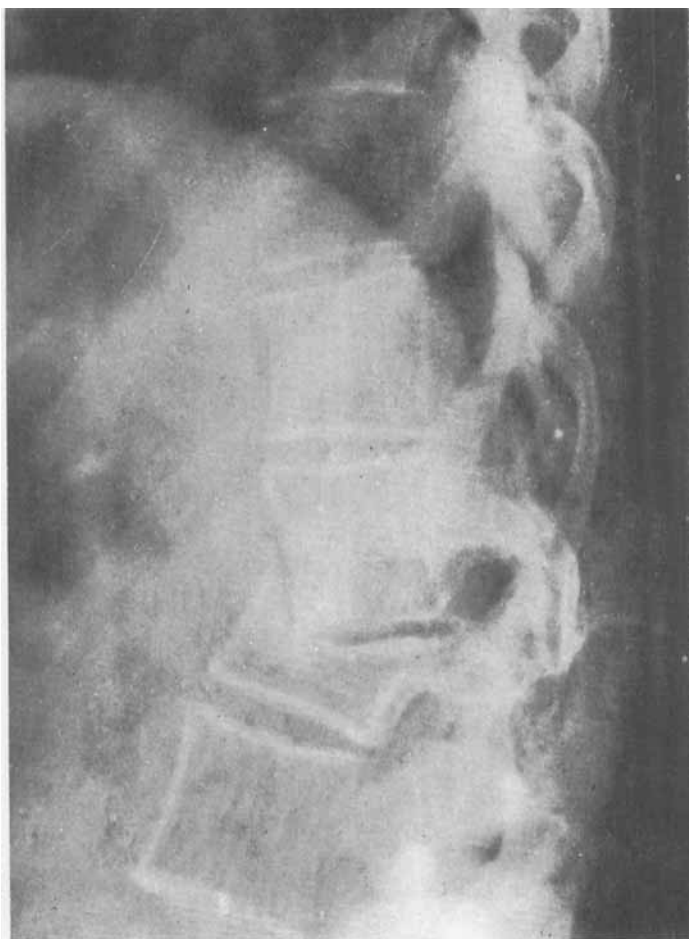


Fig. 9 b.

one to which I shall later revert. We have performed 3 modified Albee and 3 operations using two thin grafts in grooves. In none of the three belonging to the first category—Albee's operation with thin chips of bone—did we find newly-formed bone after 6 months and later on we found such bone only in one case. In all the three cases of the second category, however, where 2 thin

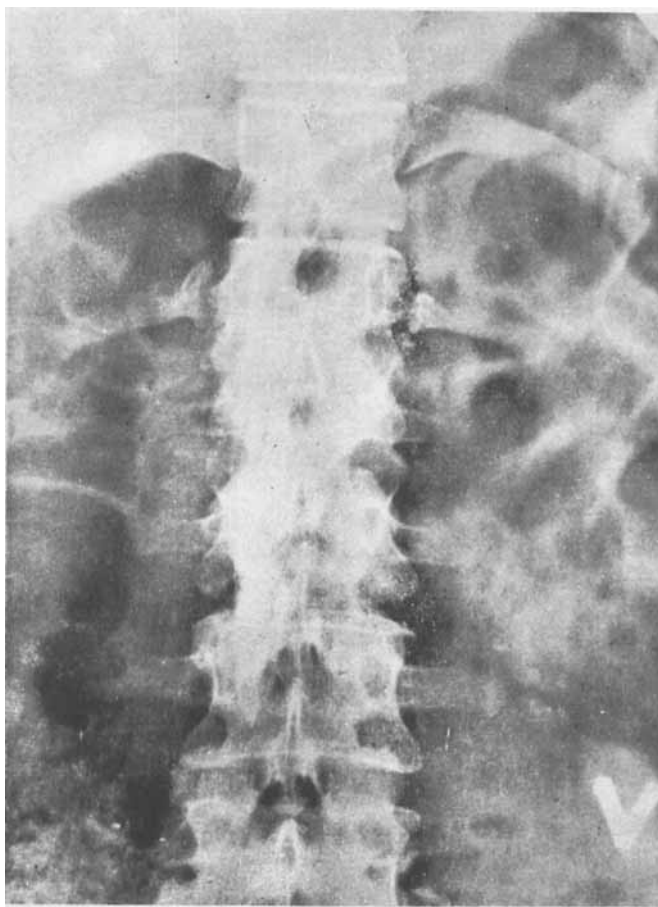


Fig. 10 a.

chips placed in grooves were employed, clinical fixation was found after 6 months and in two there was new-formation of bone.

With these latter may be classified, as regards the results, the group of operations we performed in the manner that thick Albee grafts were placed over the arches after the muscles had been loosened therefrom. There were 4 of such cases, two being performed after laminectomy for herniated intervertebral discs

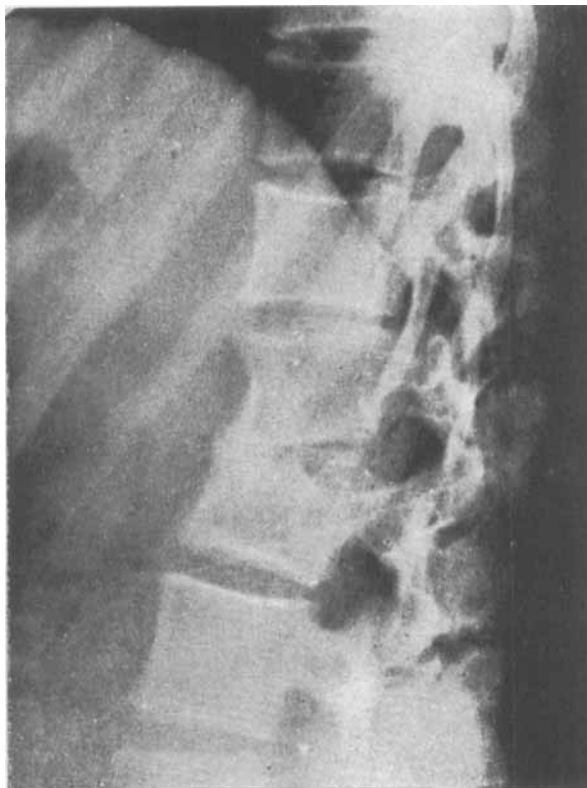


Fig. 10 b.

(Table 1). In two of these cases small shavings from the tibial corticalis were laid over the thick grafts. In all these cases clinical fixation was found after 6 months and in two of them there were signs of new-formation of bone.

In 1942 *Scante Orell* published his new method of treatment for tuberculous spondylitis. His operation is, as we know, divided into sections. In the first stage a piece of dead bone, *os purum*, deprived of fat, connective tissue and proteins, was inserted under the loosened periosteum on the medial surface of the tibia (Fig. 3 a), and this should in Orell's opinion lead in the course of 1 or 2 months to formation of new bone, *os novum*. After the lapse of that period the second part of the

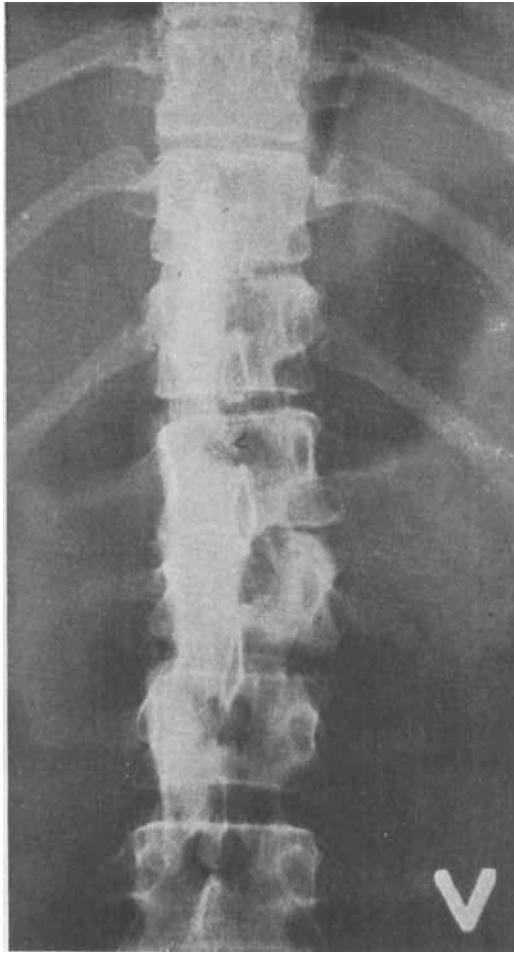


Fig. 11 a.

operation is performed, the actual fixation operation, which consists in transferring this os novum, cut into strips, to the surface of the decorticated arches on the vertebrae it is desired to fuse. Together with this os novum are also transferred small shavings of bone from the tibial corticalis. The subsequent treatment consists in 2 and 3 months' immobilisation in plaster-bed, whereafter the patient wears a plaster corset for two months

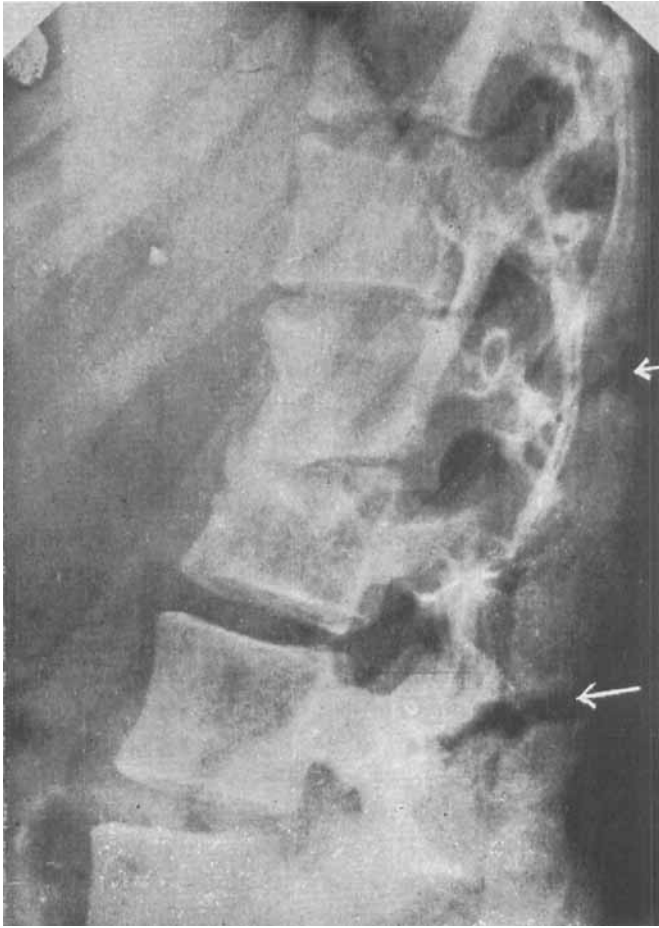


Fig. 11 b.

and a leather corset until the regeneration of the bone is completed.

We hoped that this operation would prove to be an ideal form of treatment, both because it was sufficiently lenient and should lead to rapid new-formation of bone. We have not, however, performed more than one operation after Orell's original method and only the first part thereof. For after this first operation we met with the same experience as others have done,

namely, that the so-called *os novum* which we found around the inserted piece of *os purum* consisted of nothing else than poorly vascularized connective tissue with little or no new-formed osteoid tissue. This was, after all, nothing else than what we might expect. For we know that transplantation of dead bone does not lead to formation of new bone. That Orell nevertheless succeeded in attaining formation of osteoid tissue in the first part of the operation is in our opinion not due to the inserted *os purum*, but to the scraping of the tibial corticalis. Thereby are liberated osteogenetic elements which ooze out into the mesenchymal matrix produced by the bleeding that attends the loosening of the periosteum. This theory formed the basis for the modifications which we now proceeded to adopt in the application of Orell's method. As the *os purum* in our opinion represented nothing more than a foreign body, the task of which was to keep the periosteal envelope raised and in that way to create space for formation of the mesenchymal matrix, we proceeded to keep the periosteum up by means of supporting splinters of bone chiselled out of the anterior edge of the tibia (Fig. 3 b). In later operations we elected to use instead of splinters a coherent piece of bone taken from the edge of the tibia (Fig. 3 c). Through these modifications of the first part of Orell's operation we succeeded, firstly in keeping the periosteum raised. Secondly, through the chiselling out of the splinters of bone from the tibia, and still more through the coherent bar of bone, osteogenetic elements were produced on a far larger scale than by the scraping of the corticalis which Orell adopted in the first part of his operation. As a sign that our theory on this point was correct we succeeded through this modification, in contrast to Orell's original method, in obtaining large quantities of osteoid tissue after the lapse of 4 weeks. The second part of the operation consisted, as in Orell's operation, in depositing strips of this osteoid tissue, *os novum*, together with small chips of bone, upon the decorticated arches. At this point of time we were aware that the transference of this *os novum*, whether it was obtained by Orell's original method or by our modification thereof, would result in the same thing as the transfer of any

other transplant, namely, in necrosis of the osteoid tissue but we had hoped that the dissolution of the os novum would liberate large quantities of osteogenetic elements, especially because we thought that the substitution of such young osteoid tissue would take place much more rapidly than with fully developed tissue. Our subsequent results came to show that, although we had transferred large quantities of this young bone tissue, such was not the case. Of the 5 patients operated with use of this modification of Orell's method X-ray examination 6 months later revealed new-formation of bone in only one, while clinical fixation was found in 4 of them (Table 1). Subsequent investigations showed that this clinical fixation in one spondylitic had evidently been due only to contracture, seeing that it was found to have disappeared and there did not come any new-formation of bone in any except one patient. Thereby we had also established that the first part of Orell's operation, whether in the original or in modified form, had no justification.

Nevertheless, Orell's roentgenograms and preparations show that in the second part of the operation it was found possible to produce bridges of new-formed bone between the arches. The explanation of this must be that the decortication which takes place, or, indeed, merely the loosening of the muscles from the spinous processes and the arches, together with the transference of small chips of bone during the second part of the operation, represents a sufficiently great mobilisation of osteogenetic elements, while at the same time the decortication of the arches occasions hemorrhage, so that a mesenchymal matrix is thereby produced.

In his own criticism of Orell's os purum + os novum operation, employed in the treatment of pseudo-arthritis, *Levander* says that we must ask ourselves why we should take the round-about course of first producing a periosteal formation of new bone, when with merely a few strokes of the chisel at any part of the skeleton we can obtain living bone-tissue in sufficient quantities. That the periosteal new-formation of bone is without justification has been proved by our results. Meanwhile, we have come to the conclusion that decortication of the arches, which

should correspond to the chisel-strokes mentioned by Levander, is not enough to produce sufficiently solid bridges of bone between the arches, although, it is true, osteogenetic elements are thereby liberated and these are supplemented by transference of chips of bone. We found that the problem in fixation operations of this kind was to secure a sufficiently large space for formation of the mesenchymal matrix. If this is not done, the muscles loosened from the spinous processes and arches and held aside during the decortication will afterwards return to their original place, press the transplants down upon the underlying parts, spread them outwards and interpose themselves between them. This latter circumstance will render difficult the erection of a coherent bridge of bone between the arches in the same degree as the interposition of muscles hinders the healing of a fracture.

Our task was therefore to secure a space in which the process of new-formation of bone could take place unhindered. This we attained in the first instance by laying a semiflexible slice of bone covered with periosteum from the tibia out towards the muscles which are loosened from the spinous process and the arches and keeping these muscles out by means of small pieces of bone, likewise taken from the tibia and stretched out between the spinous processes and the semiflexible piece of bone periosteum. This I have tried to indicate on the left side of the spinous processes in Fig. 4. The results of this form of fixation operation were encouraging (Table 1). After 6 months clinical fixation was found in all six cases and in four the X-rays showed signs of formation of new bone in the space we had provided.

Likewise this result failed in our opinion to satisfy the demands which I have previously set up for fusion operations on the spine. We had, it is true, succeeded in providing a space for the erection of a bridge over the arches, but we believed that the decortication of the arches and the transferred bone-substance did not furnish a sufficiency of bone-regenerative elements for the process of construction. On the basis of these considerations we arrived at the method of fusion we now employ. This consists, like the previous method, in first creating a space for the mesenchymal matrix. The space between the

slice of bone that keeps the muscles out and the spinous process is then filled with bone-shavings from the tibial corticalis. Fig. 4 (indicated on the right side of the spinous processes). Out into this space thus filled with shavings oozes blood from the decorticated arches and forms the mother-substance for the mesenchyma which constitutes the primary material for formation of new bone. From the bone-shavings and the decorticated arches come the bone-regenerating elements. Thereby are created the necessary conditions for an active formation of new bone. This method, which we now employ in all our fixation operations on the spine, represents nothing else than Levander's principle for treatment of fractures and pseudo-arthritis, as applied in the second stage of Orell's fixation operation in spondylitis, and it satisfies the demands we must make for such an operation, namely, solid, coherent and rapid formation of new bone in the least injurious manner. In cases of spondylitis the operation is as a rule performed on each side of the spinous processes and transplantation material must then be taken from the tibia on both sides.

Some special advantages of the method shall here be emphasized: The entire operation is carried out in local anesthesia. It is simple and not severe. It can with the greatest facility be performed in cases of the most extreme deformity of the spine. As we can, within certain limits, obtain sufficiently long and sufficiently many grafts from the tibia, we can by this method, in contrast to Orell's method effect fixation of larger areas in the column. Thus, in case of spondylitis it is desirable to extend the bridge of bone farther than to the nearest healthy vertebrae above and below, especially if the roentgenogram gives reason to suspect a tendency of the pathological process to extend to the neighbouring parts along the ligamentum long. ant. In case of juvenile kyphosis and in paralytic and non-paralytic scoliosis the method can for the same reason be employed with advantage, because the fusion in such cases must embrace so many vertebrae. The aftertreatment will be of short duration, thanks to rapid setting-in of the process of substitution and to active regeneration of the bone. As strain on the spine at an early

point of time does not disturb, but rather promotes this process, the patients can get up after 6 weeks. The duration of the subsequent treatment with plaster-corset will be comparatively short, but varies for each individual and is dependent on the degree of bone-regeneration found on X-ray examination.

We have performed 19 operations by this method, six of which have been done so recently that the results cannot yet be judged (Table 1). In 11 of the remaining 13 cases new-formation of solid bridges of bone over the arches is found 6 months after the operation and in 12 out of 13 after a longer time. First I will point to the roentgenogram taken 6 weeks after the operation in a case of spondylitis (Fig. 5 a) where, as we see, new-formation of bone around the small transplants has already begun. This is not rare finding. The patient had been lying in a plaster bed and at the time when the X-ray picture was taken, 13/7-1945, she got a plaster corset, which she was to wear for 3 months. Next I will point to the roentgenograms from a patient with spondylolysis (Fig. 6 a, b), taken 6 weeks after the operation where we can still distinctly see the separate grafts and a little new-formation of bone around them. The next picture, taken 3½ months later (Fig. 7 a, b) shows that the contours of the separate transplants have disappeared and are replaced by commergent masses of bone. At this time clinical fixation had been attained and immobilisation by use of corset had been discontinued.

Meanwhile, there is no reason to conceal the fact that in a couple of cases this method has not been effective. In one of these the patient was a woman aged 20 with spondylitis in L III. A unilateral operation was performed. Nine months later a solid bridge had been formed over the arches. One year afterwards she fell on her back and fractured the bridge (Fig. 8 a, b). It is to be noted that the fracture came at a place corresponding to the site of the diseased vertebra. She had to be immobilized with plaster corset for 4 months, after which time the fracture of the bridge was found to have healed (Fig. 9 a, b). Such abnormal strains can naturally not be withstood even by the strongest bone-tissue. In conclusion I shall, however, mention the case of

a woman aged 20, with spondylitis in L I-L II, where 10 months after a unilateral operation we had apparently succeeded in getting a solid bridge of bone over the arches, but without clinical fixation (Fig. 10 a, b). We ought to have noted on the lateral picture the fissures which had just barely begun to appear in the new-formed bone above and below the affected vertebra. She began to work in an office and got symptoms in the spine, and six weeks later we can note the fissures in the bridge both on the frontal and on the lateral picture (Fig. 11 a, b). She has now continuously worn a corset during 6 months after the discovery of these fissures, but it actually seems as if there has arisen a kind of pseudo-arthritis, for the fissures show no tendency to close up.

This case and similar cases where other methods have been employed go to prove the truth of what I stated in the beginning, namely, that the task of trying to secure fusion of the spine by operation is a very difficult one, but it is a task that is well worth attempting, for this operation, like other operations to obtain ankylosis, has its justification in a large number of diseases.

SUMMARY

The author describes the results of 48 operations for fusion of the spine, carried out in the surgical section of the Troms and Tromsø hospital from the autumn of 1939 to September 1945.

The roentgenological detection of new-formed bone is taken as basis for the judgment of the results. It is demanded of an operation method of this kind that in the course of six months there shall be formed a sufficiently solid bridge of new-formed bone between the arches.

The author has abandoned Albee's method because it does not satisfy this demand and he maintains that the use of thick transplants hinders the building up of living bone-tissue between the arches.

The author discusses Orell's fixation operation in cases of

tuberculous spondylitis and adopts a modification of the first stage of that operation with the object of obtaining a larger quantity of osteoid tissue—*os novum*. The results of the second stage, the actual fixation operation, show, however, that Orell's two-stage operation, either in the original or in modified form, has no justification.

Finally the author has arrived at his own method, which consists primarily in providing a space over the arches where the new-formation of bone may proceed unhindered. Secondly, his object has been to provide that this space is filled with the elements from which the new bone-tissue is to develop. The author points out the simplicity and advantages of the method and refers to the good results that have been attained.

RÉSUMÉ

L'auteur expose les résultats de 48 opérations de fixation à la columna, faites dans le service chirurgical de l'Hôpital Municipal et Départemental à Tromsø entre automne 1939 et septembre 1945.

La démonstration par rayons X d'os nouveau fait la base de la critique des résultats. On exige d'une méthode opératoire de ce genre qu'au bout de 6 mois un pont assez massif d'os nouveau se soit établi entre les arcs.

L'auteur a abandonné la méthode d'Albee parce qu'elle ne remplit pas ces exigences, et il met en relief que l'emploi de transplantés osseux épais empêche la formation de tissu osseux vif entre les arcs.

L'auteur mentionne l'opération de fixation d'Orell et désigne une modification de la première séance de cette opération, dont le but est d'obtenir de plus grandes quantités de tissu ostéoïde, *os novum*. Les résultats de la seconde séance, l'opération de fixation proprement dite, montrent cependant que l'opération d'Orell en deux séances dans sa forme originale ou modifiée n'est point justifiée.

Finalement, l'auteur est arrivé à sa propre méthode qui consiste, en premier lieu, à procurer un espace au-dessus des

arcs, où la formation nouvelle d'os se puisse produire librement. En second lieu, sa tâche a été de prendre soin que cet espace soit rempli des éléments desquels le tissu osseux nouveau se développera. L'auteur met en lumière la simplicité et les avantages de la méthode et montre sur les bons résultats obtenus.

ZUSAMMEFASSUNG

Der Verfasser setzt auseinander die Ergebnisse von 48 Fixationsoperationen an der Columna, welche an der chirurgischen Abteilung des städtischen Krankenhauses Tromsø vom Herbst 1939 bis September 1945 ausgeführt wurden.

Die röntgenologische Nachweisung neugebildeten Knochens ist der Beurteilung der Ergebnisse zugrunde gelegt. Es wird die Forderung an eine Operationsmethode dieser Art gestellt, dass im Laufe von 6 Monaten eine hinreichend massive Brücke zwischen den Bogen gebildet sein soll.

Der Verfasser hat die Methode Albee verlassen, weil sie diese Forderungen nicht erfüllt, und hebt hervor, dass die Verwendung von dicken Knochentransplantaten den Aufbau lebendigen Knochengewebes zwischen den Bogen behindert.

Der Verfasser erwähnt Orells Fixationsoperation bei tuberkulöser Spondylitis und führt eine Modifikation der ersten Seance dieser Operation an, deren Absicht es ist, grössere Mengen osteoiden Gewebes, os novum, zu erzielen. Die Ergebnisse der zweiten Seance, der eigentlichen Fixationsoperation, zeigen jedoch, dass Orells Operation in zwei Seancen in originaler oder modifizierter Form keine Berechtigung hat.

Schliesslich ist der Verfasser zu seiner eigenen Methode gekommen, welche erstens darin besteht, einen Raum über den Bogen herzustellen, wo die Neubildung von Knochen unbehindert erfolgen kann. Zweitens ist es seine Aufgabe gewesen, dafür zu sorgen, dass dieser Raum mit den Elementen gefüllt wird, aus denen sich das neue Knochengewebe entwickeln soll. Der Verfasser hebt die Einfachheit und die Vorteile der Methode hervor und weist auf die erzielten Erfolge hin.

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