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SYMPOSIUM: NEW APPROACHES TO ALLOGRAFT TRANSPLANTATION

The Classic

The Use of Free Osteoplasty Together with Trials on Arthrodesis and Joint Transplantation [Die Verwendung der freien Knochenplastik nebst Versuchen über Gelenkversteifung und Gelenktransplantation] (Excerpted and translated by Drs. Christian-Dominik Peterlein and Richard A. Brand)

Erich Lexer

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Prof. Dr. Erich Lexer (1867–1937) is shown. Photograph reprinted with permission of Prof. Dr. Wolfgang Locher, Institut für Geschichte der Medizin der Ludwig-Maximilians-Universität.

Erich Lexer (1867–1937) was a leading early 20th century surgeon in Germany, specializing in orthopaedic, reconstructive and plastic surgery, and traumatology. He studied medicine in Würzburg and graduated in 1890. After a short period of studying anatomy, he started his surgical career in 1892 as a student of Ernst von Bergmann in Berlin. After twelve years as an investigator and surgeon he became professor of surgery in Königsberg in 1905. He moved to Jena in 1910, Freiburg in 1919, and Munich in 1928, where he became the successor to Sauerbruch.

Lexer was coauthor of the National Socialists law for the prevention of hereditary sick children; he wrote an article on the sterilization of disabled men. He also was a member of the "Allgemeine SS," a suborganization without active membership. Lexer belonged to a group of scientists who offered their knowledge to the National Socialists from the beginning, but his contributions to science have not been questioned. Lexer died in 1937 of an acute coronary occlusion.

Many of the operating techniques named after him, such as the Lexer-Kreske mammoplasty, remain in recent use [1, 2, 7]. His anatomic and clinical studies of patients with acute hematogenous osteomyelitis and also his work on bone transplantations have been the basis of the present understanding of these topics. Lexer was also especially concerned with problems of plastic surgery; he realized its importance not just for reconstruction after disfiguring injuries and diseases, but also the beneficial effects of cosmetic surgery. In 1931 he performed the first face lift in Germany. Many of his earlier operations were aimed at reconstructing facial defects.

The article we reproduce here was among his first on transplantation [3]. (The Editor notes a few portions of the text were difficult to understand, and a few sentences describing Lexer's methods remain obscure.) Lexer advocated and demonstrated the effectiveness of homografts and allografts for various sorts of fixation and reconstruction of limb and facial defects. "Later," he said, "I began thinking about the transplantation of an entire joint." His first patient was operated in November of 1907 and the second 4 months later. Both patients had an ankylosed knee from previous sepsis, and in both cases he transplanted an entire knee joint from a fresh (he emphasized they still needed to be warm) amputation. In one article in this symposium, Ranawat et al. [6] provide evidence that more limited osteochondral allografts need not be warm for long term survival, but rather cold-stored grafts offer advantages over frozen and thawed specimens. Lexer's conclusions seem guided more by empiricism than experiment. Remarkably, he obtained biopsy material from one subject because the patient developed adhesions with limited motion. Lexer remarked on the integrated tissue and "well-stained" cells in the cartilage. Long-term followup was not provided for either case. (Interestingly, long-term followup was not a practice at the time, and in fact was only grudgingly accepted by many after the pioneering work of Ernest Armory Codman [5]).

Lexer briefly described organ transplantation and referred to several previous animal experiments [4]. He recognized the organs "disintegrated" although he did not attempt to explain the reasons for organ failure specifically. However, in the context of other graft failures he remarkably recognized the presence of increased "serum and the cell proteins." "The clinician will be wise," he commented, "not to count on prematurely awakened hopes for some time to come. It is possible the outlook in homoplasty may be improved in some way or another, as has occurred in skin transplantation, and that it may lead us closer to the goal" [4]. The symposium we present in this issue describes efforts to continue to improve allograft transplantation a century after his pioneering efforts.

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References

1. Adour KK, Klein JC, Bell DN. Trigeminal neurotization of paralyzed facial musculature. Modification of the Lexer-Rosenthal surgical procedure. *Arch Otolaryngol.* 1979;105:13–16.
2. Knishevitskii VM. Modification of tenoplasty of the deep finger flexors by the Lexer technic [in Russian]. *Ortop Travmatol Protez.* 1962;23:10–15.
3. Lexer E. Die Verwendung der freien Knochenplastic nebst Versuchen über Gelenkversteifung und Gelenktransplatation. *Langenbecks Arch Klin Chir Ver Dtsch Z Chir.* 1908;86: 939–954
4. Lexer E. Free transplantation. *Ann Surg.* 1914;60:166–194.
5. Mallon B. *Ernest Amory Codman: The End Result of a Life in Medicine*. Philadelphia, PA: WB Saunders; 2000.
6. Ranawat AS, Vidal AF, Chen CT, Zelken JA, Turner AS, Williams RJ. Material properties of fresh cold-stored allografts for osteochondral defects at 1 year. *Clin Orthop Relat Res*. 2008;466. Doi:10.1007/s11999-008-0311-7.
7. Tamerin JA. The Lexer-Kraske mammaplasty: a reaffirmation. *Plast Reconstr Surg.* 1963;31:442–444.

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A great many osteoplastic operations using free bone graft assured my conviction that this method is becoming more important. Allow me therefore to report on cases where I used this free osteoplasty.

It is naturally used in common surgical interventions:

1. the filling of defects of the skull
2. the elevation of depressed areas of the craniofacial bones
3. the replacement of entire defects of medullary bones and the lower jaw
4. the healing of pseudarthrosis

It is then about new indications:

5. the fusion of paralytic joints by rodding adjacent bones
6. the substitution of large sections of medullary bones including articular condyles or the two epiphysis; and finally
7. trials of whole joint transplantation

Undoubtedly the choice of either dead or vital bone for transplantation is doubtless not unimportant in humans. At the beginning I used cadaveric bone that had been boiled for 24 hours. But its uses were comparatively limited. The graft had to be in intimate contact with bone forming tissue as demonstrated in the studies of Barth and Marchand. Placed under periosteum or into the medullary cavity, the bone integrates; but if larger defects are bridged without periosteum, the growth of the bony edges that ought to restore the gap is too slow, so that the remaining part resorbs. After extensive resection of the knee joint because of chondroma, to avoid shortening I tried to replace with a 20 cm piece of a cadaveric ulna. I rubbed sterile bone ash in the parts of the soft tissue without periosteum and also injected it about the graft after wound healing. But the intermuscular tissue that often initiates the periosteal callus in fractures did not initiate ossification, as would be expected from the studies of Barth. Indeed there was vigorous callus proliferation from the cut surfaces of the tibia and the femur, but it did not grow throughout the entire graft; the midportion of the graft resorbed and had to be removed after some months because of a purulent fistula.

It is notable that the cadaveric bone placed into the (vital) bone demonstrates different characteristics depending on whether it is adult or infant bone. After good integration, the former shows no alteration of shape on radiographs even after a long time period; whereas in infant or juvenile bone, the non-vital graft appears gnawed off sometimes within 4–6 months, so that you can observe considerable signs of resorption on the radiographs. This is presumably related to the larger abundance of vessels in the juvenile bone.

The best results are obtained by fresh, warm engrafted human bone. I have rarely obtained bone from the same human being because there was usually enough material available for fresh bone grafting from amputations due to dry gangrene in the elderly. I have never experienced failure with these fresh human bones if they were grafted along with adherent periosteum to replace diaphysis, metaphysis, and epiphysis—even in defects without their own periosteum ranging from 20 to 30 cm. I cannot report the histological details but the transplantation along with the periosteum is extraordinarily important in wide gaps without periosteum. I am not aware of the reasons for the importance of the periosteum in bone grafting, because I never obtained my grafts from sick people. It is possible that the freshly transplanted periosteum maintains its ossifying capacity as suggested by v. Mangoldt, Sultan, and later Axhausen as result of his inquiries. It is evident that callus proliferation from the edges of a defect is takes advantage of the gradual substitution of the graft. Moreover the adjacent periosteum is important in rapidly and deeply adhering to the surrounding, preventing the ingrowth of larger vessels onto the surface of the transplanted bone and thus protecting the bone from resorption.

The transplantation of periosteum is not necessary in defects with intact periosteum. I have seen with two periosteal layers (host and donor), a very vigorous bony excrescence develop. Concerning the bone marrow in the graft, I have observed that aseptic fever frequently develops in large grafts of medullary bone (from amputated limbs) when the transplanted bone contains marrow. These unpleasant, local systemic reactions are not related to bacterial infection. When the secretions were free of bacteria the integration succeeded despite the inflammation. I assumed resorption of detritus of the bone marrow was the reason for this phenomenon and subsequently removed the marrow with a spoon before implantation. In order to avoid dead space in the graft, the medullary cavity was filled with an iodoform packing. In these cases an inflammatory reaction did not occur.

I want to summarize the established applications of free osteoplasty in few words.

I have always closed defects of the skull—secondarily if traumatic but otherwise both primarily and secondarily—with free osteoplasty. It is easy to obtain sufficient graft from adjacent external plate in small cranial gaps; I have transplanted periosteal and cancellous plates from the distal femur of amputated legs with larger defects.

Thus large defects from 8 to 10 cm and 5 to 15 cm were grafted.

If a skin flap that is detached or dislocated from the skull defect includes periosteum there is no need for the graft to be covered by periosteum. In my mind, this approach is much easier than the using plates of bone including a periosteal layer. In saddle noses, in deeply depressed areas of a previously operated frontal sinus, in osseous defects of the craniofacial bones due to tuberculous osteitis, in plump and bulbous tips of the nose after total rhinoplasty, and in the slowly growing upper jaw in older children with cleft lip, I have undermined corresponding periosteal, bony, and cartilaginous pieces after short incisions of the soft tissue; these were freshly grafted from amputated limbs, or the tibia or rib of the same patient. It is known that there is a tendency to perform the complete rhinoplasty from arm tissue instead of that of the forehead. In the procedure of Israeli, the required bony piece that is grafted along with a pedicled skin flap is obtained from the ulna. Apart from the fact that this bony bar does not fit the Apertura piriformis—unlike the roof-shaped bony ridge described by Schimmelpfennig—this procedure is also disadvantageous because there is too much connective tissue between the bony bar and the skin so that a chronic edema occurs. This results in very bulbous noses that cannot be further improved by revision surgery. You can circumvent this problem easily by engrafting two wide periosteal bony plates of the same size under the skin of the forearm so that they can be later transplanted along with the flap and positioned as a roof shape onto the nose. Certainly, those bony plates should be entirely even and smooth because irregularities in thickness readily become noticeable because of the thin skin. Although I was pleased with the noses reconstructed in this manner, I once tried to form an entire nasal skeleton, similar to that of the nose of a mask. The graft was obtained from the distal femur of an amputated leg. The articular cartilage formed the bridge and the tip; the sidewalls were made from cancellous bone by means of shaping the inner parts with a reamer. This shaped graft was placed under a thin skin flap of the forearm with the future outer part against the skin and the future inner part against a muscular flap. After a healing process of three months, this prosthetic nose could be transplanted onto the face (as it happened, without any difficulties). The shape of this substituted nose was very good. You could see and feel its even contours through the thin skin. Perhaps it is possible to attain even better noses in this manner.

The treated defects of the medullary bones and the lower jaw resulted mostly from surgery and in one case from trauma. After resecting a tuberculous diaphysis, the implantation of periosteal bony bars provides very good results in short medullary bones according to W. Müller. I have obtained bone grafts from amputated limbs unlike Müller who obtains them from the ulna. Whereas the fixation of short diaphyseal medullary bones is performed only by skewering the graft into the epiphysis, a similar skewering or impaction cannot be recommended in defects of large medullary bones. Right from the beginning it is necessary to insert the graft in a very rigid and precise position. It should not translate or angulate which easily happens during skewering. It is recommended that both ends of the graft be similar in size to the bone being replaced substituted, each one held with one bony pin. This best consists of a piece of a 10 cm fresh fibula, that is embedded in periosteum, and gets engrafted one half each into the bone marrow cavity of the graft, which is incidentally filled with an iodoform packing. The protruding ends of the rods are placed into the bone marrow entrance. Thus the shape of the entire bone is reconstructed and the application of a fenestrated cast is very much facilitated. I have substituted several entirely defects devoid of periosteum from the upper arm, the thigh, the tibia and lower arm bones with fresh, if possible corresponding, bones in this manner; underneath defects of 25–30 cm size.

It is astonishing that even large-sized defects of large hollow bones without periosteum heal successfully also function well, and I have never failed with fresh material embedded in periosteum, despite the size of the grafts. It is curious to me, that such trials were not performed more often.

[Text abridged]

Once I grafted a corresponding segment of a cadaveric jawbone after resection of one-half of the lower jaw due to carcinoma because I did not want to resect a rib in an elderly patient and there was no material available from amputee. After precise suture of the mucosa, I inserted the well fitting graft into the defect and fixed it with wires. The patient was able to open his mouth from the outset. A fistula later developed after healing without inflammation. Later the cancer recurred and the patient was not sent back to hospital by the physician. In a second case, I substituted an 8 cm part of a lower jaw with a piece of a tibia with periosteum from a shank amputated because of sarcoma. Although these trials sometimes fail because of inflammatory agents from the mucosa they are still recommended. Where successful one can circumvent the problems with a prosthesis; a failure is not worse than bridging over the defect with a wire or metal braces that later often have to be removed as well. Corresponding curved parts of ribs, taken from the same patient, are most suitable if there is no amputated limb available.

In pseudarthrosis combined with marked displacement of the bony ends I have used the rodding method similar to the fixation of grafts in large medullary bones. First you place the rod into the medullary cavity of one end then you normally must open the other using a shaped splint that is embedded with periosteum to place the rod into the other medullary cavity as well. The construct is held with the detached splint and a cerclage wire. Even in pseudarthrosis of the femoral neck which are difficult to treat, I twice tried to stabilize the fracture by means of rodding. One reduces the fracture on the Schede table as well as possible and approaching from ventral to have good exposure, create a channel through the trochanter and the femoral neck to the femoral head with a reamer. Then the channel will be filled with a strong bony rod; once I used a fresh fibula covered with periosteum from an amputated leg and the second time I used a large bony bar from the tibia of the patient. This method is easier than nailing with better results concerning the local wound, because there is no need to expose the fracture on all sides. Although these first two cases were not successful due to some failures, I still recommend such attempts.

The rodding of the pseudarthrosis of the femoral neck resulted in further, similar applications, namely the fusion of paralytic joints; especially the ankle joint, which I have rodded 19 times and the knee which I have ankylosed 4 times.

I wanted to developed a method that easier and more successful than the usual arthrodesis; which is a comparatively grievous operation because of frequent failure in malacic bone and it lasts longer than the tendinous fixation of the foot. I tried the following method: in order to ankylose the foot (Art. Talo-cruralis and Art. Talo-calcanea) one first aligns the foot it in the correct position and then makes a plantar skin incision of 3 cm length at the ventral part of the calcaneus down to bone. The wound edge, the aponeurosis, and the tendon of the flexor brevis muscle are retracted and a reamer placed against the inferior surface of the calcaneus and a channel is reamed through the calcaneus and talus. As soon as the reamer reaches the distal end of the tibia, both subtalar joints are fixed. After removal of the reamer, the bony rod must be immediately positioned.

The rod is tamped into placed with strikes of hammer as deep as the reamer advanced; then any excess rod is removed with a Luer forceps so that the rod fits flush with the inferior surface of the calcaneus. The small skin lesion can then be closed by 1–2 stitches and loosely approximated so that the fat coming out of the bone can reach the surgical dressing. The operation ends with the application of a leg splint to avoid loss of correction of the paralyzed foot, and can be completed in 5 minutes if everything is prepared beforehand. The fixation achieved by this operation has so far held. The first case, from 2 years ago, demonstrates complete consolidation. It is more difficult to ankylose the knee joint by means of rodding. I have implanted in one or two rods from the tibial tuberosity after creating an overhang with a chisel.

[Text abridged]

Over time, the rodding with cadaveric bone has had variable results in comparison with those with fresh bone that was taken for the most from the fibula of amputated legs or of the patients own fibula in paralyzed legs. Ankle joints that were fused with fresh bone could be loaded soon after surgery, whereas those rodded with cadaveric bone had pain for a longer time. Moreover, sometimes the scar drained a serous material after 2 or 3 weeks while the bone was healing. The fistulae later healed. Radiographs demonstrated that the cadaveric bone was somewhat anomalous with the ends failing. One could see loss of the contours also in freshly engrafted bones, but also an obvious thickening of the cortical bone that later on incorporates into the structure of the fixed bone. The appearance of the (fresh) rod in the joint spaces is interesting, as demonstrated in my first case that was operated two years ago. After 2 years the broadened rod blended into the trabecular network of the adjacent bone; but was thinned in the joints, especially in the ankle joint. But you could see the joint space contained smooth bony trabecular emanating from the rod. The vessels that grow in from the joint capsule into the joint space and the rod probably induce a stronger resorption than those inside the bone. Perhaps these vessels totally destroy the articular cartilage and hereby induce the bony adhesion. Several animal experiments from my resident Frangenheim ought to clarify these interpretations after a longer observation period.

[Text abridged]

Later, I began thinking about the transplantation of an entire joint.

The first patient was operated on 11/02/1907, that is to say 7 months ago, and the second person was operated 4 month ago. In both cases the indication was a synostosis of the knee with a marked flexion contracture due to purulent infection in the former case and tuberculosis in the second. For exposure on the ventral side I used a long, U-shaped approach; the lower end of which extended to the tibial tuberosity to reflect the remaining ligament patellae and the joint capsule together with the flap. But there was only one ligament in the first case; the capsule was destroyed in both cases. After exposure of the synostosis, the soft parts, including the collateral tendons and those in the popliteal fossa, were sharply detached from the bone. The scarred, degenerated periosteum was left on the bone. After that the entire are was detached as a wedge to correct the flexed position. In both cases there was an extended defect of approximately three fingerbreadths in size when the shank was extended. The knee joint of a freshly amputated leg was taken for replacement. The transplanted parts consisted of the total articular surface and bones, measure approximately 1.5 fingerbreadths in thickness from the epiphysis. Both bony parts were kept together with the cruciate ligaments; the menisci were resected in the first case, in the second case they remained attached to the collateral capsule. Both epiphyseal parts were fixed closely with the corresponding bones by pins and, in the second case by wire sutures. The ligamentum patellae was reattached onto the periosteum. Complete incorporation occurred in both cases. The radiographs, obtained from time to time, demonstrated a vigorous callus proliferation from the bony ends overgrowing the epiphyseal parts and the articular surfaces remained entirely smooth. In the first case there was no progress concerning passive range of motion. This was because of re-adhesion of the patella I had released but unfortunately not undermined during surgery. Therefore the flap was opened again after three month to resect the patella. This was a welcome opportunity to explore the status of the grafted joint. All parts were in a good condition. The cartilage appeared good and even; some blood clots in the joint space were easily removed. The epiphyseal parts were united with the bone so that the slightest movement was not possible. The cruciate ligaments were also in a good condition and even bled after making small incisions. I was not able to help taking a thin slice of the lower epiphysis with a chisel for microscopic examination. Thus it was removed in a manner to contain articular cartilage, cancellous bone of the donor epiphysis, and the border of union with the tibia. It demonstrated that the union was caused by the formation of dense connective tissue and new bone and that the articular cartilage contained well-stained cells, like those in the vascular cancellous bone. These findings can be regarded as a histological integration. In both patients some range of motion was obtained through active and passive exercises. In the first patient, it was possible to flex the shank passively up to 45 degrees. There was no pain either in walking or in standing.

[Text abridged]

But I am not going to develop concepts furthermore. This note will be supplemented in a detailed report later on, and I just wanted to report that the transplantation of an entire joint had succeeded. This is an important because similar animal experiments have failed until now.

At the end I will again summarize the basic principles of free bone graft transplantation, and that with these methods many more will be found as they come to be accepted. But one must implant fresh warm bone with periosteum and without mechanical or chemical preparation and quickly after remove. One can obtain such material effectively from amputations (particularly cases of dry gangrene without infection).

[Supplemental Website Materials; readers should note a copy of the original text in German is available with the online version of CORR.]