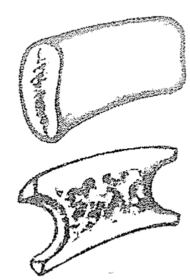
18. *Choice of Bone and Its Fate*

As already noted, first choice of the bone graft donor area is not unanimous. Autogenous is preferred by most over homologous grafts, as stated by Stellmach in 1964:

> Experiences with preserved bone were not successful since the bone graft did not survive.

Rib, iliac crest, tibia and vomer all have their champions. Yet there is argument even as to the type of graft and its placement.

RIB



Some surgeons prefer full-thickness while others split the rib and some insist on the addition of chips. David Matthews described a special tailoring of split ribs struts to fit into the alveolar defect. In the young, rib is thin and lean with very little cancellous bone; hence, probably, its reported partial absorption in early primary grafting. In general, costal bone can be spared without undue sacrifice since the rib will regenerate in its periosteal sleeve. With proper instruments, up to 60 cm. of rib, or 120 cm. of split rib, can be removed through a 5 cm. incision. Opening the pleura is a hazard that should occur rarely and can be handled with positive pressure anesthesia. Split rib is a good choice in bone grafting and has stood the test of time. Because there have been problems, including resorption, the work of Joseph Reichman, L. Kerr and L. A. Whitaker of the University of Pennsylvania, studying the fate of autogenous rib grafts in rabbits, is of interest.

The various types of rib graft were inserted into a subperiosteal pocket and the animals injected with vital dyes and then killed and examined. It was found that split rib with the marrow facing bone healed the best. Bone chips (1 mm. in length) were almost completely resorbed. Split ribs with the marrow in contact with soft tissue and full-thickness rib demonstrated poor healing and a high rate of resorption.

ILIUM

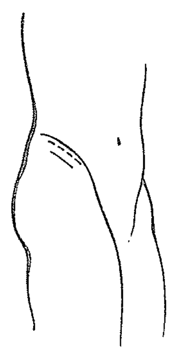
The crest of the ilium in the young offers poor material, and surgery here is considered by some surgeons a threat to growing centers. Georgiade, Pickrell and Quinn prefer cancellous bone from an area inferior to the iliac crest. They feel:

> There is probably more rapid calcification with new bone formation when this type of graft is used.

The ilium offers an excellent source after the age of 10 to 12 years and especially in the adult, but the discomfort and general morbidity have been greater than with the rib.

Hogeman, Jacobsson and Sarnäs of the University Hospital, Malmö, Sweden, noted in 1972 that in bone grafts to the maxilla

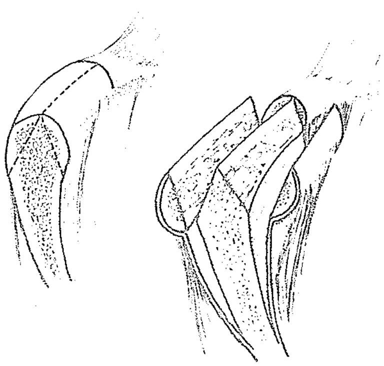
> The use of grafts from the iliac crest instead of from the ribs raised the frequency of successful operations from 34% to 58% and with subsequent addition of a buccal bar ["a spongy bone graft on the buccal side of the alveolar ridge to cover the defect"], to 98%.



In 1974 Schmid, Widmaier, Reichert and Stein expressed preference for compact and spongy layers of hip bone, stating:

> Rib implants are considered less useful because of the small amount of bone and especially spongiosa obtainable in a small child.

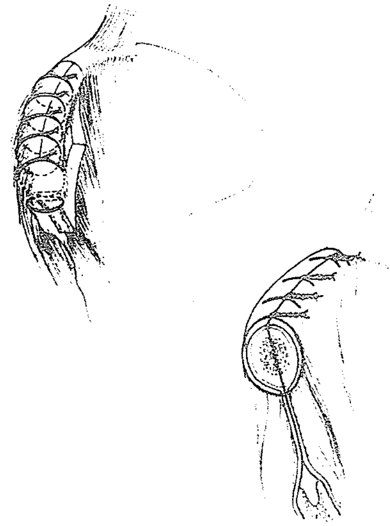
Tessier's method of harvesting iliac bone is described by S. A. Wolfe of Miami, who has used the method more than 100 times without complications of bleeding, infection or contour deformity, and with less discomfort.



> The skin incision, about 5–6 cm. long, is made several cm. below the longer incision through iliac crest periosteum. Two oblique cuts reflect the lips of the iliac crest, behind the anterior superior spine, and periosteum is reflected

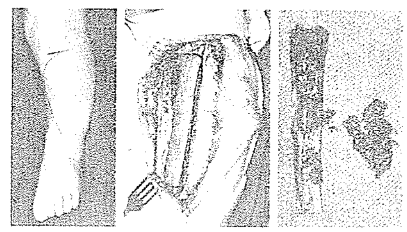
from inner and outer surfaces of the ilium. Tessier's retractors fit perfectly to expose the central bone which will be harvested, and both cortical plates can be taken if needed. Extra cancellous bone is taken with a curette.

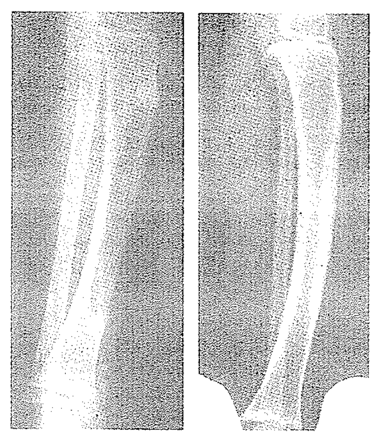
The site is generally drained with a hemovac, and the lips of the crest are wired firmly together. I have begun using a final wire to figure-of-eight these coapted lips to the intact anterior superior spine. A hole is made in the spine with an ice pick–like instrument (Walter Lorenz). The beauty of this method is that the hip is *solid,* there is no post-op movement of broken bone or torn muscle, and the patient can generally walk the first or second post-op day.



TIBIA

In young infants of pre-weight-bearing age, a medial, slightly curved incision, as designed by Johanson and Ohlsson, *Acta Chirurgica Scandinavica* 1961, gives excellent exposure of the tibial shaft, offering a large supply (50 cc. or more) of cancellous bone. A cortical segment is removed, and the desired quantity of cancellous bone and marrow can be taken and packed into the cleft. The line of incision, the tibial cortical segment chiseled free to be removed and the bone graft with extra bone marrow are shown. Radiographs of the tibia present the defect two weeks after removal of the graft with periosteal bone formation beginning and healing only three months later. Visible scars and the possibility of a short leg have reduced this donor area's popularity.





VOMER

Vomer in the projecting premaxilla has an economic advantage but offers a limited supply. The chance of the surgeon's being overzealous in this quest for bone might result in retropositioning of the premaxilla too far.

SKULL

In infants and children skull also is a source of bone for grafting. Under the age of 3, complete regeneration occurs even when large quantities of full-thickness skull are taken.

Of course, the vascularity and functional position of the bed, the type of graft and its size all influence the destiny of the bone grafts.

Manchester of Auckland, New Zealand, stated in Melbourne in 1971:

> I claimed many years ago and repeat today, that a bone graft takes and remains just as a skin graft does.

Ivy, paralleling the long life of his bone grafts and in just as good shape, stated in Montreal:

> I saw one of my bone grafts the other day at Mount Dora and that is 48 years since it was transplanted! I maintain that once you get the bone graft into good position with a successful take, it will remain there in good shape and without change.

Joss and Broadway of Norwich, England, in 1966 made a three-month tour of European bone grafting centers under the auspices of the Council of Europe and reported:

> In many of these centres the grafts, after a while, resorbed in the alveolar region, leaving only a small strut of bone joining the segments at the level of the nasal floor.

They therefore considered that the question of having teeth erupt into the graft had, perhaps, been overstressed.

This was like turning a pair of foxes loose in the chicken coop, and feathers and fur have been flying ever since. Johanson, a fighting cock of the coop, bared his spurs and attacked the intruders several years later:

> I want to come back to this report of Joss, which I really thought was a very irritating one, where it was stated that in most of the countries he visited (among others, my own clinic, *late at night*) the primary bone graft, the onlay graft, just disappeared. I have never used, in my whole series, an onlay graft.

And still later:

> It was said by Joss . . . that he never saw a case where the bone graft had survived or remained as a bone graft. All of them were absorbed, he said. We thought this was very funny, because in our series we had never seen a case

like this. We have never demonstrated a case to him, so we wondered where he got this knowledge.

Kriens of Hamburg accepted the challenge but noted that the process of bone grafting was still being improved. He described the evolution of the Schuchardt primary osteoplasty. First, a strong strut was used to hold the alveolar segments apart, but later partial resorption of the graft was seen. As Schuchardt and Kriens noted that small struts had a rare tooth bud making its way into the graft with subsequent alveolar collapse, they were stimulated to increase the amount of bone. As many layers as possible were inserted between the alveolar stumps, and the pocket was filled further with chips. Since transplanted costal bone has no inherent growth potential, intrusion of tooth germs was considered important. In fact, where a tooth bud entered the graft in about three months, resorption of the bone was no longer a problem. Kriens ended with a provocative teaser:

The effort to stimulate regional bone growth by the transplantation of epiphyseal cartilage may add another chapter to the story of primary osteoplasty.

At the 1969 Chicago Cleft Symposium, Colonel Haskell Gruber of the U.S. Air Force referred to his young series of 125 bone grafts:

We find that in a period of 6–8 weeks, the bone graft as such disappears, and then within a period of 12–20 weeks, you suddenly begin to see bone laid down. We feel that the organic salts are removed and the inorganic matrix remains and upon this base new bone is laid down. We have done a great many x-ray studies of these. We find we don't have alveolar bone . . . we have maxillary bone. . . . Our oldest case is now 4½ years of age, and in the primary dentition, and the bone has remained.

Matthews responded:

I agree entirely with Colonel Gruber that this bone is not the bone that was originally put there. I think the orthopaedic surgeons settled years ago that this is a re-occurrence of bone on a matrix which was provided by the original graft.

In 1964 Stellmach had made a similar statement:

Autogenous bone becomes transformed with the first two years after grafting. The new structure is similar to the neighboring bone.

In fact, as early as 1961 Johanson and Rockert, using microradiography to study autogenous tibial and iliac bone grafts to the palate, contradicted Holmstrand's 1957 findings that all evidence from study of bone grafts

> pointed to the replacing bone assuming the same ultrastructure as the original transplant.

Johanson and Rockert found that the excessive tissue of the graft was absorbed and not remineralized. The rest of the graft lost its original structure and was transformed to the same structures as adjacent palatal bone, showing good adaptation of the graft to functional demands.

As his concluding statement during the 1969 Chicago Cleft Symposium, Johanson reported having opened a six-year-old bone graft:

> The area where the bone graft was looked exactly as if it was a non-clefted case.

Colonel Gruber then asked Johanson why he advised bone grafting after orthodontics and whether it had been successful with the permanent dentition resulting in good occlusion and arch alignment. Johanson answered:

> We feel that when the orthodontist has finished his work and we add bone to the alveolus that you do not have to look at these cases any more from a prosthodontic point of view.

Tom Cronin of Houston, having given some of his bone grafting statistics, suggested that the method of grafting must be important:

> When we just put in the onlay graft, we often seemed to have very little bone left later, but by putting in more bone in wedge grafts, the grafts seemed to remain fairly well as shown by repeated x-rays over several years.

David Matthews of London backed Cronin:

> My bone graft is only put into the alveolar gap. It is indeed a strut or a wedge. . . . I found in 31.5% of cases teeth growing into the gap. . . . I would think it impossible for a dental follicle to grow into a static, well-established bone plate, but it can and does grow into this new bone, and I can show you pictures of the teeth growing into the bone.

which he has done in the primary bone grafting chapter

BIOLOGY OF BONE GRAFTS AND FACTORS INFLUENCING THE SURVIVAL

S. A. Wolfe, craniofacial surgeon at the University of Miami, discussed the biology of bone grafts.

Transplanted bone survives. There is no doubt of this to anyone who has had the opportunity to reoperate in an area in which he has previously put a bone graft. Whether or not this is the same bone that was put in is still a matter of debate. It is likely that some of the individual cancellous cells with osteogenic potential do survive (Boyce), but it is also evident that one can put in only the mineral matrix, as in freeze-dried or boiled bone, and eventually have invasion and inhabitation by osteocytic cells. And just as there is constant turnover of cells and collagen in a skin graft, a bone graft is metabolically active and has constant cellular and matrix turnover. A good bit of work remains to be done with radioisotope-labelled cancellous bone to clarify exactly what is happening.

Factors important to maximal survival of the bone graft:

1. First, the type of bone used. There is a higher percentage of take (persistence of the volume of the transplant) with grafts which are largely cancellous, as opposed to cortical. Thus, a higher portion of an iliac graft can be expected to survive in comparison with a rib graft, since a larger portion of it is cancellous.

2. The bone graft must be *solidly* affixed to the recipient bony area. Grafts that are subject to motion at their point of contact with recipient area bone seem to fare worse than ones which are solidly wired in place. Split ribs in the infraorbital area do better if wired to the infraorbital rim, compared to those which are just laid in place; nasal bone grafts which allow some wiggle are often the ones which will have to be redone. There is some experimental evidence that split ribs do better if a layer of periosteum is left on the outer surface (but then the donor area will not do so well), and the cancellous surface placed against abraded donor bone, than if any other combination is used.

3. There should be coverage of bone grafts by periosteum if possible, and then cover by adequate amounts of soft tissue, not under great tension. If bone grafts are placed free in soft tissue, almost complete resorption can be anticipated. Considerable resorption also occurs if bone grafts are subject to pressure from tight, inadequate soft tissue cover.

4. The size and number of foreign bodies present should be minimized. It may take more skill in carpentry and ingenuity to obtain solid fixation without the use of screws, mesh trays, and cumbersome orthopedic plates, but these types of hardware interfere with vascular contact with the graft,

provide a nidus for infection, and are against basic principles. Solid fixation can generally be obtained with a few properly placed wires, interlocking "autoretentive" bone fixation, and occasionally a small Kirschner wire. If extrinsic support and fixation is required, it is better to use a few percutaneous screws in normal bone on either side of the bone graft, and then bridge across externally with acrylic.

5. Finally, in human beings there seems to be a "critical mass" of bone graft, even fresh, autogenous, cancellous, that can be expected to survive under the best of circumstances. A bone graft can exceed one cm. on two dimensions, but not three. If larger amounts of bone than this are required, surgery must be staged.

The difficulty obtaining adequate amounts of donor bone, and the pain and deformity often associated with taking bone in the past, have led to many efforts over the years to find an acceptable bone substitute: the evolution has been from ivory to Kiel bone to bank bone among biological materials, and from acrylic to silastic to proplast among synthetic materials. Certainly, there have been reported successes using all of these substances, but the failure rate is still high compared to fresh, autogenous bone, and the patient continues to be at risk from infection and rejection long after the procedure, at a time when the autogenous bone would have been incorporated into the skeleton and have the same defense mechanisms as normal bone.

Until the basic transplantation barriers are eliminated, as they eventually will be, efforts should certainly continue in developing and perfecting ways of taking autogenous bone, with as little difficulty, pain and deformity as possible.