ENCLAVEMENT: INDICATIONS AND TECHNIQUES

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HISTORY

Bernard Regnauld of Nantes, France developed an osteocartilaginous graft procedure for the treatment of hallux valgus which would avoid the pitfalls associated with the Keller type resection arthroplasties of the phalangeal base. He dates the procedure to 1968. (Table 1)

Regnauld described this procedure for hallux valgus in his 1968 publication, *The Foot*. Regnauld advocates avoidance of first metatarsal osteotomy due to potential shortening and reduction of load transfer as well as the "extended period of plaster immobilization" required for metatarsal osteotomy.

The Europeans (French, Italians) seem to shy away from extensive use of osteotomies and internal fixation for hallus valgus. The enclavement procedure seems to be a product of this philosophy and Regnauld's desire to reduce to length of the great toe.

In the 1980s, there was an exchange of ideas between surgeons such as Regnauld, Valenti and Viladot and the American Podiatry community. Several American surgeons (Kashuk, Pittsburg Podiatry Hospital, Shelton and Clark, Weil) have utilized this procedure and some have continued to recommend it. During this transition, not only was the osteocartilaginous graft utilized for hallux valgus but also hallux limitus and hallus valgus rigidus.

The author has had experience with the procedure since 1968 when a patient with senile hallux valgus refused an implant procedure. The enclavement was performed as an alternative and due to the excellent result further usage was encouraged.

Table 1

Regnauld Bunionectomy:
Osteochondral graft of the proximal phalangeal base

Capsule tendon balancing with relocation of the MPJ sesamoids

Goals:
Restoration of metatarsophalangeal joint & metatarso-sesamoidal joint function

Limit postoperative rehabilitation & morbidity

Objectives: Joint Decompression through shortening of the phalanx; Reduction of the 1st MPJ deformity is greatly enhanced through this joint relaxation, be it in the transverse (hallux abductus) or sagittal plane (hallux flexus).

Indications: Hallux Valgus; Hallux Valgus Rigidus; Hallux Rigidus (Drago et. al.; Stages I, II or III)

Goals: Reduction of Deformity; Restoration/Maintenance of 1st MPJ Motion; Early Rehabilitation

Requirements: Joint Decompression through linear reduction of the proximal phalanx; Cheilectomy (clean-up all adjacent joint margins) Rigid Internal Fixation (Herbert Bone Screw); Early Mobilization

Joint Decompression

This group of phalangeal osteotomies approaches the problem of hallux valgus and hallux rigidus from the concept of joint decompression.

Long-standing hallux valgus often presents with significant soft tissue contractures in and around the 1st MPJ. Joint decompression procedures allow for reduction of significant proportions of transverse of frontal plane deformity. Use of the procedure in senile hallux valgus and hallux valgus rigidus illustrated its potential and usefulness. Radiographically, surgeons like to quantitate deformity and devise a surgical plan on the basis of osseous relationships, eg radiographic angles, such as PASA or IM angle. Joint decompression procedures more or less allow for important reductions of what has been called positional or soft tissue components of deformity. Joint relaxation plays an important role in reduction of deformity. This is most clearly evident in cases of severe deformity and the rigid foot type.

Hallux rigidus often illustrates a hallux equinus, metatarsus primus elevatus, and restricted joint motion. One may argue that the metatarsus elevatus is the primary problem or that it is a secondary phenomenon of the hallux equinus. Certainly, hallux rigidus is a varied deformity and in some cases features a very prominent metatarsus primus electus, or it may be present to milder degrees, or be completely absent. By achieving relaxation of the first metatarsophalangeal joint, any secondary elevation of the first metatarsal as a result of hallux equinus should reduce. This is true whether the relaxation is accomplished on the phalangeal or metatarsal side of the joint.

A recent addition in the surgical treatment of hallux rigidus is the enclavement procedure initially described by Regnauld. This phalangeal osteotomy shortens the osseous segment distal to the first metatarsophalangeal joint. As such, this procedure becomes a decompression osteotomy and is useful in cases of hallux limitus/rigidus with a long proximal phalanx and/or a short metatarsal.

Regnauld's Osteocartilaginous Graft

Regnauld actually described three variants of the enclavement concept, the Hat-shaped graft, Cork-shaped graft, and Inverted graft . All three begin with osteotomy within the midsubstance of the proximal phalanx. The basal portion is extirpated and remodeled, then reinserted as an osteocartilaginous graft. The process of bone removal is probably an important determinant in accomplishing joint decompression or relaxation. To maintain this relaxation, the amount of bone reinserted must be less than that removed.

Regnauld utilizes three configurations of the graft dependent upon the presenting deformity and quality of the bone. The Europeans have utilized this procedure as their predominant procedure for hallux valgus repair. Valenti boasts of over 3,000 procedures while Regnauld also admits to a significant number.

The HAT GRAFT

The hat-shaped graft mirrors the basic shape of the hemi-implant. (Fig. 1) The base is excised, remodeled and reinserted into an excavated medullary canal. A cheilectomy is performed on the entire circumference of the base while distally it is fashioned with a central stem. Regnauld utilized the hat graft in situations of hallux valgus and hallux rigidus wherein the quality of the bone stock is essentially normal.

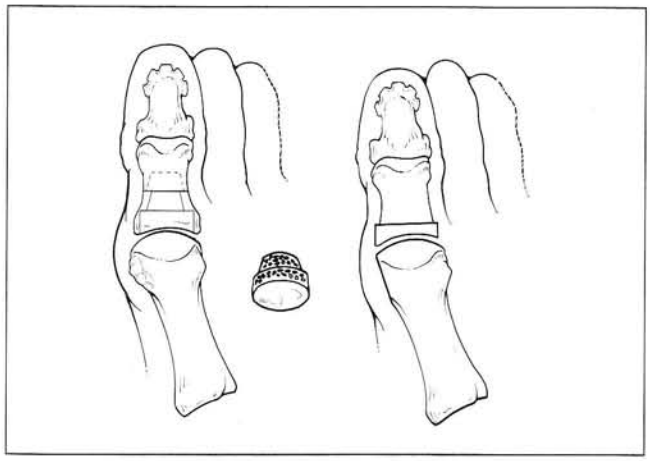

Fig. 1. The Hat-Shaped Graft

The CORK GRAFT

The cork-shaped graft again utilized a peripheral cheilectomy of the base but of greater severity than the hat graft. (Fig. 2) Only a central area of healthy articular cartilage is retained while the remainder of the distal portion is tapered to be reinserted into the excavated shaft. Regnauld recommends the cork graft when the bone quality is poor, for example in senile hallus valgus.

The INVERTED GRAFT

A so called inverted-shaped graft involves an almost tongue-in-groove osteotomy of the phalanx with the distal portion inserted into a recess hallowed out in the base. (Fig. 3) There is no description of peripheral remodeling of the base. Regnauld essentially discards this variation. He sites stability of the graft as being least satisfactory compared to the prior variations.

All three of these osteocartilaginous grafts are variants of the Keller procedure with reinsertion of the resected base without the benefit of internal fixation. Kashuk has described an "in-situ" technique similar to the inverted procedure but maintaining the plantar attachments to the phalangeal base. This helps avoid the complications of avascular necrosis and hallucal instability.

The Burutaran or STEP DOWN

Reese has also described a phalangeal osteotomy for linear shortening; Regnauld identifies this osteotomy as the Burutaran technique for hallux valgus. This is somewhat analogous to the "in-situ" procedures and the potential for joint relaxation is questioned. This osteotomy allows for rigid internal fixation with dual screws placed transversely across the phalangeal diaphysis. (Fig. 4)

The therapeutic nature of these autografts is that of a decompression osteotomy with relaxation of the joint space. In order to accomplish this, the soft tissue attachments to the basal fragment must be completely dissected free. One of the most valuable aspects of the Regnauld procedure is the exposure it affords to the metatarsal upon removal of the phalangeal base from the wound. Cheilectomy of both the metatarsal head and the phalanx, subchondral drilling and/or abrasion chondroplasty are easily accomplished. Access to the sesamoids including potential sesamoidectomy is allowed from an intracapsular approach.

Primary joint reconstruction via cheilectomy and enclavement osteotomy is still a relatively new technique and long term results are yet to be appreciated. These techniques are complicated and fraught with potential complications. Due to removal and reinsertion of the phalangeal base, many of the negative aspects of resection arthroplasty are encountered such as disruption

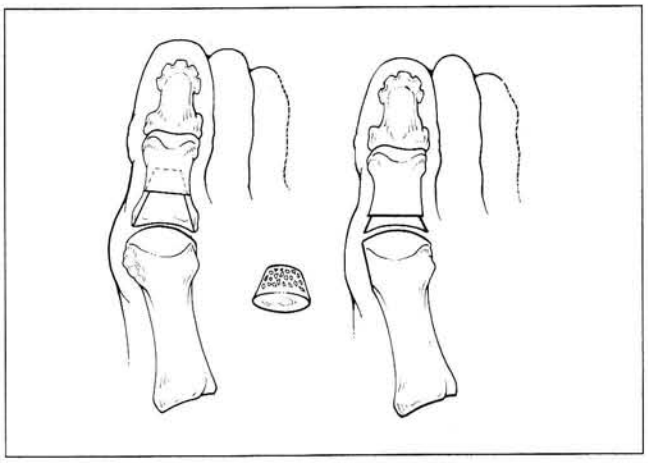

Fig. 2. The Cork-Shaped Graft

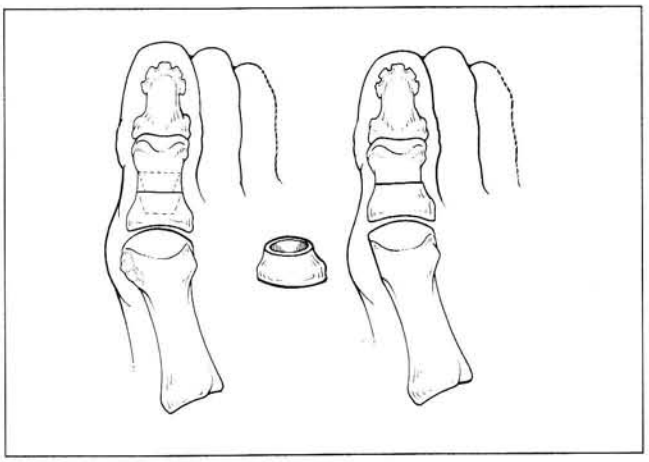

Fig. 3. The Inverted Graft

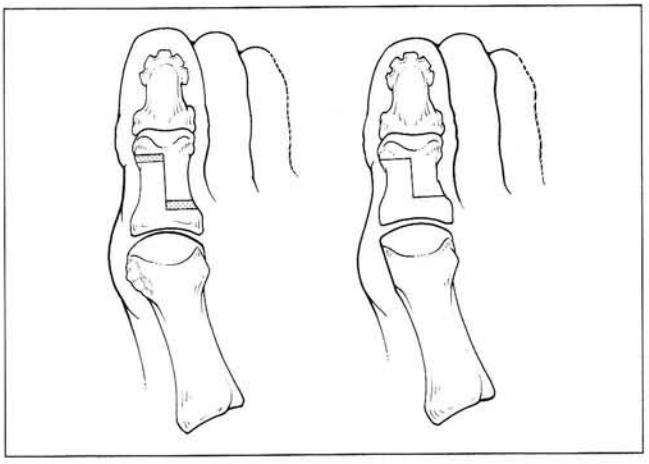

Fig. 4. The Burutaran or Step-Down

of the glenosesamoidal joint and its distal attachments. The surgeon must address this problem to avoid a potential hallux malleus deformity. Various techniques include: tethering of the long flexor tendon to the phalangeal base, tethering of the

plantar aponeurotic medial and lateral heads of the short flexor to the base, or simply anastomotic suture between the long and short flexor. Any of these variations are useful adjuncts to improve hallucal purchase, avoid sesamoidal retraction, and improve joint stability.

In addition, the demands of re-incorporation of the auto-implant must be considered. This re-incorporation process may be staged into four distinct phases according to Judet, Lexer, Axhausen, Vigliani, and Valenti. These phases include: avascular necrosis of the autograft; revascularization and creeping substitution; periosteal new bone formation; reconstitution and consolidation.

Avascular necrosis probably occurs in a large number of non-fixated procedures. Primary vascular bone union implies an early restoration of the osseous blood supply. Rigid internal fixation is an aid to this revascularization process. A technique utilizing the Herbert bone screw has been developed that achieves rigid internal fixation, allows for the immediate restoration of motion, achieves primary bone union, and allows very rapid rehabilitation and weightbearing.

SURGICAL TECHNIQUE

The operation may be performed through either a dorsal or medial incisional approach and this is more a preference of the surgeon rather than any requirement of the enclavement procedure. Joint exposure is similar to that of an implant procedure with subperiosteal dissection of the base of the proximal phalanx and distal first metatarsal. Phalangeal dissection should be limited to only the portion to be resected as with a Keller-type procedure. The proximal third of the proximal phalanx is resected utilizing a power saw. Prior to removal of the phalangeal base, a 0.045 inch Kirschner wire is placed directly from dorsal to plantar just distal enough to avoid damaging or placing the wire through the articular surface. Remember, the phalangeal articular surface is concave. This wire provides a reference point so that articular congruency will be maintained, and remains until the base is reinserted later in the procedure. The basal fragment is then extirpated from the wound with some care so as to minimize damage to its structure.

Following its removal from the wound, the resected portion of the proximal phalanx is wrapped in a damp sponge for later use. The surgeon may now address the arthrosis of the first metatarsal. Usually, some additional dissection is required to fully free all soft tissue attachments to the distal third of the metatarsal. This is performed so that a peripheral cheilectomy may be adequately performed. This should also accomplish a sesamoidolysis and allow inspection of all surfaces of the metatarsal head and its sesamoids. Cheilectomy or removal of peripheral lipping of the sesamoids is possible, as well as complete removal of a sesamoid if deemed necessary is quite possible from an intracapsular approach.

Subchondral drilling, or abrasion chondroplasty of chondromalacia or erosions is recommended and may be easily performed. Up to 50% of the articular surface of the metatarsal head or phalangeal base has been abraded. Generally, this intraoperative abrasion chondroplasty should be followed by postoperative use of CPM for several weeks.

With the phalangeal base removed from the wound, tethering of the flexor tendons to each other may be accomplished to aid in hallucal purchase and help avoid interphalangeal joint instability postoperatively. A few cases of mild malleus was identified and this is now a routine maneuver to avoid the complication.

The excised portion of the phalanx is now remodeled. All soft tissue attachments to the base should be removed. Usually this is begun with a rongeur and then decortification of the periphery of the base is performed with a rotary drill and round bur (5 mm). Next, the periarticular lipping or osteophytosis that may be present is resected and remodeled.

A 0.028-inch. Kirschner wire is used to perforate the entire osseous circumference of the phalangeal base. This is performed to aid in revascularization and avoidance of avascular necrosis.

The stem of the graft is then fashioned. Osteotomies to a depth of 3- to 4-mm are made along the cut surface. Using the reference Kirschner wire as a guide, the medial and lateral osteotomies are cut parallel followed by the dorsal and plantar ones perpendicular to those. (Fig. 5) The medial osteotomy is cut first just inside the

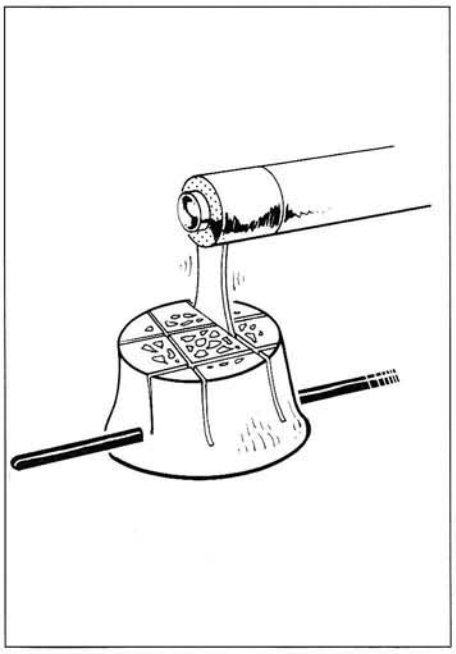

Fig. 5. The medial and lateral osteotomies are cut parallel, followed by the dorsal and plantar osteotomies cut perpendicular. The Kirschner wire is used as a guide.

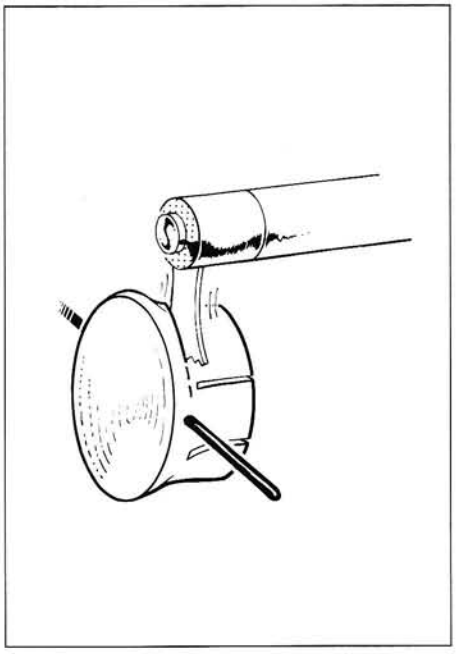

Fig. 6. Four osteotomies are cut from the medial, plantar, lateral and dorsal cortical margins perpendicular to and into the first set of osteotomies.

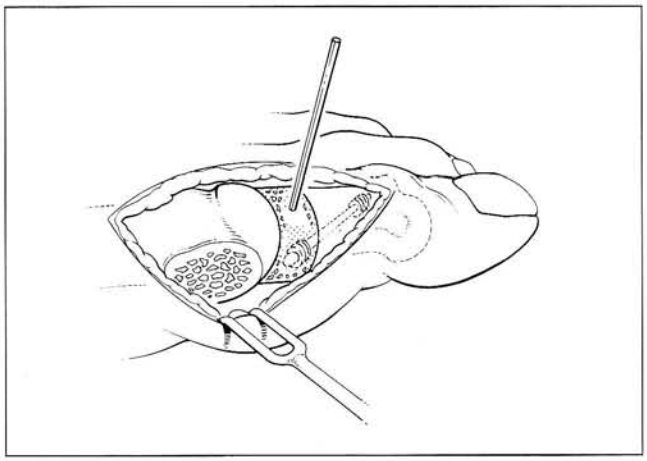

Fig. 7. A 0.045-inch Kirschner wire is used for preliminary fixation.

medial cortical margin so as to avoid a large medial overhang after the reinsertion of the graft.

Next four osteotomies are cut from the medial, plantar, lateral and dorsal cortical margins perpendicular to and into the first set of osteotomies. (Fig. 6) This is best accomplished with an oscillating saw and a micro teeth blade. The rongeur is then used to pry the osseous fragments from the base. Care should be taken to preserve the centrally fashioned stem and an assistant is recommended to hold the phalangeal base while the surgeon cuts the osteotomies. The Kirschner wire reference pin is also useful as an ancillary point to hold the graft while working on it.

Once the surgeon is satisfied with the configuration of the graft, it may be prepared for reinsertion. Drill holes are made along the entire periphery of the phalangeal base/graft. These holes are similar to those placed in any bone graft to encourage revascularization. The author's preference is to use the same 0.028 in. Kirschner wire and drill 25 to 35 holes. Care must be taken to avoid drilling into the articular surface due to the concave geometry of the articular surface.

A very shallow hole is made in the distal portion of the phalangeal shaft to accommodate the stem just fashioned. This hole should be just slightly smaller in dimension so that the stem fits tightly. The wound is copiously irrigated and the graft is reinserted using the reference wire as a guide to its placement.

A 0.045 in. Kirschner wire is often used for preliminary fixation while definitive fixation with a Herbert Screw is performed. (Fig. 7) The Herbert bone screw is inserted from the planar medial aspect of the base into the distal lateral aspect of the phalanx.

FIXATION SEQUENCE

Pilot Hole An AO-type triple drill guide must be used as a guide to drill the 2.0 mm pilot or core diameter hole. The drill has a pointed edge that allows placement of the drill hole right on the edge of the osseous/articular surface. The hole is in a slight plantar-medial to dorsal-lateral direction.

Drill With Stop The 2.0-mm hole in the base in enlarged with the 2.4-mm Herbert drill with stop (a hand instrument).

Depth Measurement A small fragment depth gauge can then be used to measure the correct length screw necessary. Note, no countersinking is performed.

Tap The entire depth of the pilot hole is tapped with the 3.0 Herbert tap equivalent to the thread of the leading 3.0 mm thread of the Herbert screw.

Screw Insertion The screw is inserted using some axial pressure as the screw advances completely within the substance of bone. A 28- or 30-mm screw is most commonly used so that the leading thread may just perforate the opposite cortex for solid purchase of bone. (Fig. 8)

The Kirschner wire reference pin may then be removed and any overhang of the base to the shaft can then be remodeled. Irrigation is again performed followed by capsular and skin closure per surgeon's preference. Immediate weightbearing in a surgical shoe is allowed and the procedure may be performed bilaterally on an outpatient basis. Immediate range of motion is encouraged as this is a joint salvage procedure in a patient usually with evidence of joint disease. Continuous passive motion machines have also been prescribed in the younger patients where restoration of function, and attaining an adequate range of motion is particularly important.

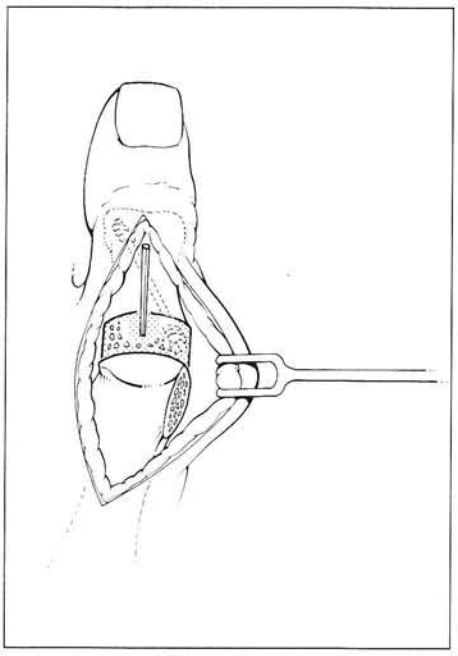

Fig. 8. A 28 or 30-mm screw is most commonly used so that the leading thread may just perforate the opposite cortex.

POSTOPERATIVE CARE

A Darco or Reese type surgical shoe is utilized postoperatively for 3-4 weeks. Thereafter, a gym shoe or soft leather shoe is allowed. Immediate range of motion is possible due to the stability imparted by the internal fixation. Complete bony union within 3 months is the rule.

This procedure also does not address metatarsus primus elevatus or a long first metatarsal as observed in many cases of hallux rigidus. Careful preoperative assessment is mandatory for successful results. The author's experience with this procedure has been very gratifying particularly in cases of stage II rigidus or hallux valgus rigidus with a long proximal phalanx and short first metatarsal.