CHAPTER **18**

REAPPRAISAL OF THE REGNAULD PROCEDURE FOR HALLUX VALGUS AND HALLUX RIGIDUS

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The Regnauld procedure has been part of this investigator's surgical armamentarium for deformities of the first ray for more than a decade. The Regnauld has been called by various names in an attempt to describe the procedure as performed by various authors. Regnauld himself call this procedure an "autograft" describing the complete removal of the phalangeal base from the foot, followed by remodeling and then its re-insertion. He did not fixate the graft and described avascular necrosis as a consequence of the procedure.[1]

Several American Podiatrists including Gudas, Weil, Shelton and Clarke, Kashuk, Jacobs have utilized this procedure in the 1980s and 1990s following interaction with Regnauld at European and American venues. It was at the Hershey Surgical Seminar of 1990 with a presentation by Bernard Regnauld and particularly following discussions with Valente Valenti also a proponent of this procedure that I chose to investigate its potential usefulness. Somewhere along the way, this procedure was labeled an "enclavement" and I also have utilized this term to describe the Regnauld type "hat-graft" procedure, Figure 1.

Bernard Regnauld, France (1968) developed this osteocartilaginous or "autograft" procedure[1] for the treatment of hallux valgus which would avoid the pitfalls associated with the Keller-Brandes procedure; specifically, loss of toe purchase, hallux instability with development of malleus and poor joint motion. Regnauld describes three variations of this procedure that removes the proximal phalangeal base and then provides for its reinsertion with a variety of reconfigurations.[1] These techniques of remodeling of the proximal phalanx was described as a hat-graft, cork shaped graft and inverted graft. Regnauld did not describe any fixation technique for this procedure other than simple impaction of the remodeled fragments.

Due to reports of bone healing problems and avascular necrosis; I performed the procedure with several modifications from the onset. My experience with the Regnauld procedure began with the "hat-graft". As a type of autogenous bone graft, revascularization and consolidation were a prime consideration. In an effort to improve bone healing and avoid avascular necrosis of the re-implanted base, the "hat-graft" was performed analogous to other bone graft procedures. The phalangeal base was remodeled and fenestrated to enhance revascularization. Multiple small holes along the entire periphery of the phalangeal base were prepared. Consolidation of a bone graft is also aided by rigid internal fixation. Bone healing generally behaves according to the biomechanical environment of the fracture/osteotomy and a stable osteosynthesis was developed.[2]

Experience with resection arthroplasty procedures including the Keller, implants and arthrodesis illustrated the vast potential of procedures that yielded joint relaxation through bone resection to correct very severe deformity.[3] This concept was applied to joint preservation surgery and lead to the development of decompression osteotomy. The Regnauld type procedures are examples of this concept on the phalangeal side of the first MTP joint. The surgeon just had to perform the procedure in a manner to behave or heal like any other type of osteotomy. Kashuk did so by not stripping soft tissue attachments from the phalangeal base.[4,5] His "in-situ" Regnauld does not lead to the vascular demise of bone that complete removal from the wound will yield. However, the consequence of limited soft tissue dissection is loss of joint decompression. My own experience with several hundred procedures in both an "in-situ" fashion as well as complete extripation of the phalangeal base from the wound clearly illustrated the pros and cons.

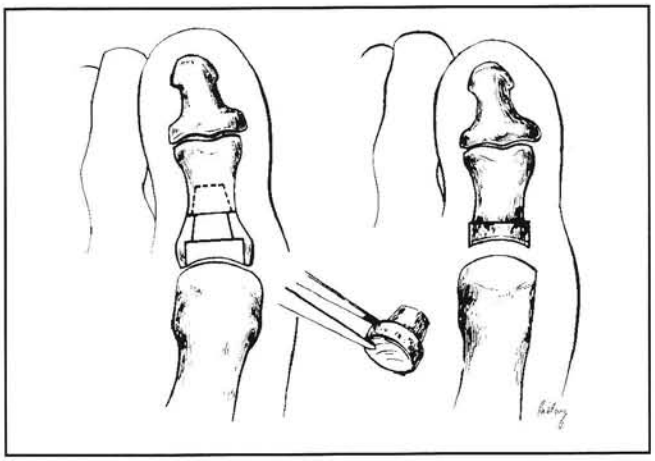


Figure 1.

The following discussion will describe present techniques of the Regnauld procedure. Clearly, both variants of the procedure with complete versus incomplete dissection have their advantages and appropriate patient selection is the proper determinant.

Phalangeal osteotomies of the hallux have traditionally been utilized for the treatment of hallux valgus and hallux valgus interphalangeus with the primary goal of reduction of the abduction of the great toe through a wedge osteotomy.[6,7] Traditionally, surgeons have viewed the hallux osteotomy or Akin type osteotomy as an adjunctive procedure to improve the cosmetic alignment of the great toe. The Regnauld enclavement procedure provides much greater potential but preoperative assessment must identify the problems and the surgeon plan corrective maneuvers.

Long-standing hallux valgus often presents with significant soft tissue contractures in and around the first MTP joint. Joint decompression procedures allow for reduction of significant proportions of transverse or 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, for example radiographic angles, such as the intermetatarsal (IM) or proximal articular set angle (PASA).[8] Determining the corrective potential of joint decompression procedures is more difficult. The bone resection of a decompression osteotomy provides soft tissue and joint relaxation that allows for not only positional or soft tissue components of deformity but also indirect reduction of structural components. Joint relaxation plays an important role in reduction of deformity and improvement of mobility. This is most clearly evident in cases of severe deformity and a 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 in that some cases feature a very prominent metatarsus primus elevatus, or it may be present to milder degrees, or be completely absent. By achieving relaxation of the first metatarsophalangeal joint, any positional or 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 rather 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. The osteotomy is very powerful when combined with complete removal of the base of the proximal phalanx but this requires stripping of all soft tissue attachments to the base of the proximal phalanx.

THE "MODERN REGNAULD"

The Regnauld procedure may be performed through many permutations and the author has now eliminated all the various complexities of the hat graft technique which was the mainstay technique for many years. Simplification with a double transverse osteotomy, Figure 2, in usually a trapezoidal manner is the preferred technique. The surgeon still has the option of complete removal of the proximal phalangeal base or performance as an "in-situ" or cylindrical Akin 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 procedure itself. Joint exposure is similar to that of an implant arthroplasty procedure with subperiosteal dissection of the base of the proximal phalanx and distal first metatarsal. Osteotomy at the level of the proximal metaphysis of the proximal phalanx is preformed usually as a trapezoidal osteotomy with the medial section being wider with an overall shortening of the proximal phalanx proportional to the overall length of the phalanx, great toe and degree of correction required (Figure 3).

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

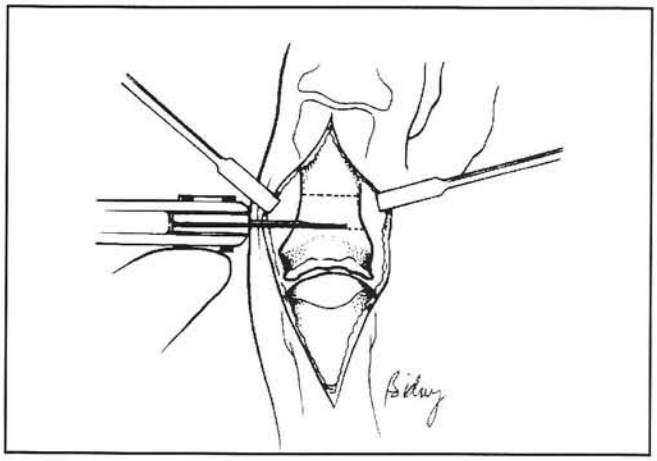
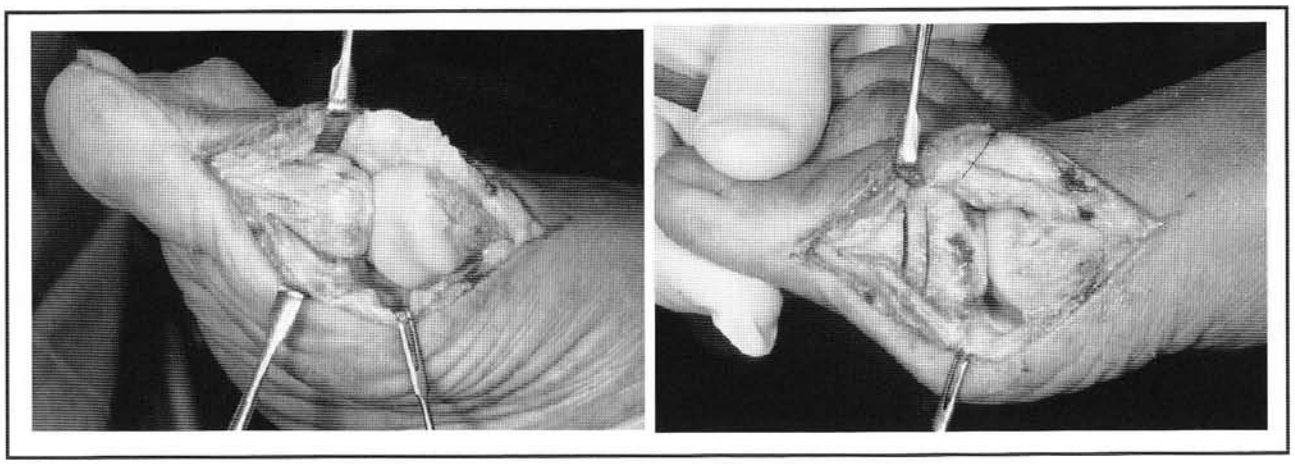


Figure 2.



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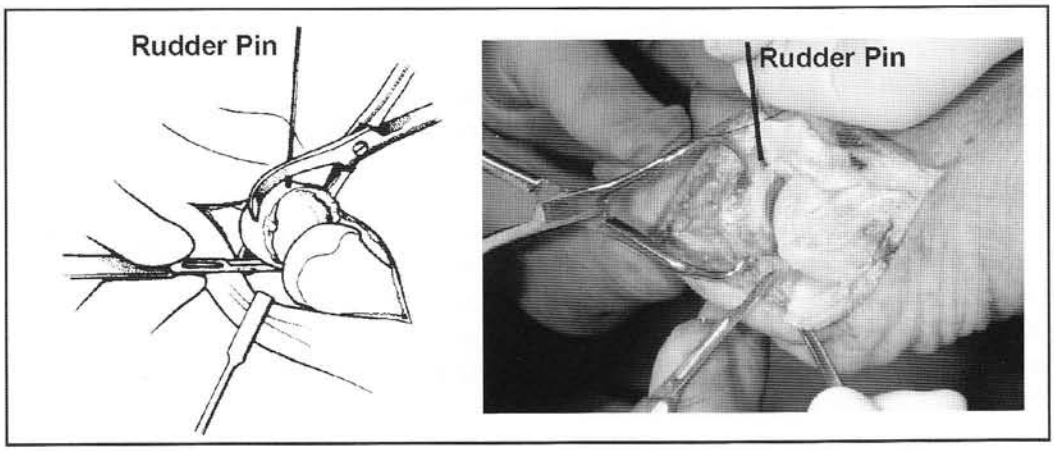

Figure 4.

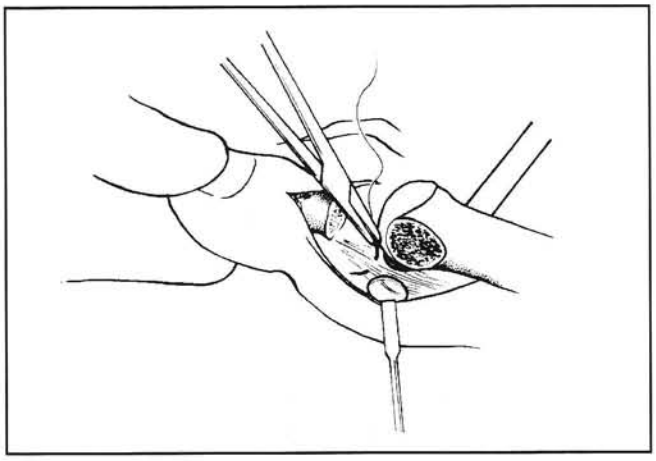

Figure 5.

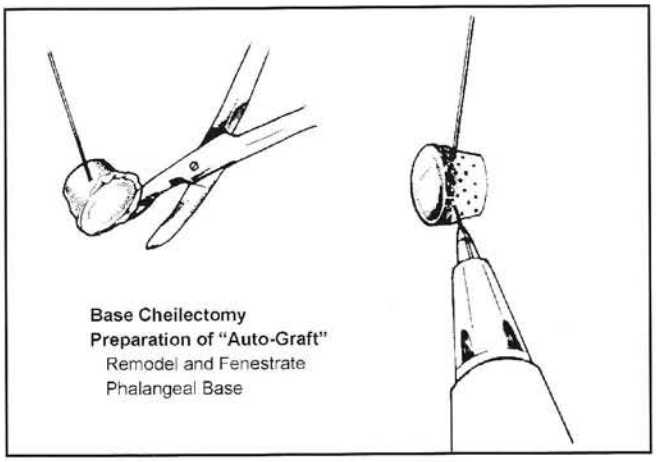

Figure 6.

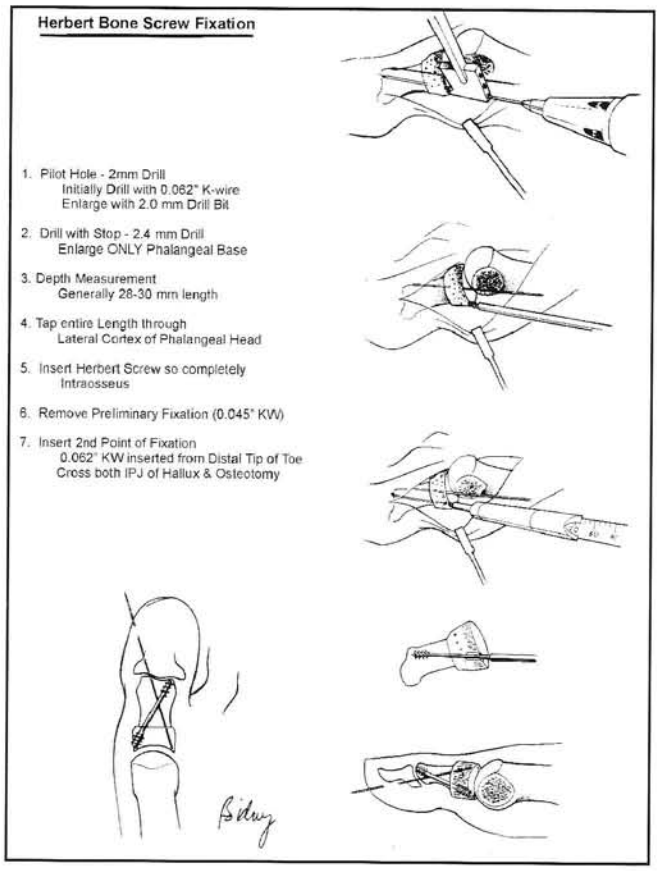

Figure 7.

the wire through the articular surface; remember that the phalangeal articular surface is concave. This wire, the "rudder pin" will remain until the base is reinserted later in the procedure (Figure 4). It provides a reference point so that articular congruency will be maintained as well as providing a point for handling the fragment.

If the surgeon chooses, alternatively the base may be left in place with dissection limited to that necessary for osteotomy and fixation. For full decompression, the basal fragment is then extirpated from the wound with care so as to minimize damage to its structure. The bone may be soft and this often means avoidance of the points of bone forceps to grasp the base during excision. A 6 inch Brown forceps or guarded pressure with an alligator bone forceps is useful.

Following its removal from the wound, the resected portion of proximal phalanx is wrapped in a damp sponge for later use. The surgeon may now address the proliferative bone or arthrosis of the first metatarsal. If the operative pathology is one of hallux valgus, only limited dissection of the first metatarsal is necessary. In cases of severe deformity or first MTP joint arthrosis then additional dissection may be required. This allows adequate exposure for peripheral cheilectomy of the osteophytosis. A sesamoidolysis may be performed with 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 easy from an intracapsular approach with the base removed from the wound.

Alternatively, the base need not be excised but complete subperiosteal dissection along the medial aspect of the base of the proximal phalanx is necessary for both later internal fixation as well as providing some degree of joint relaxation.

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 later interphalangeal joint instability postoperatively (Figure 5). A hallux malleus was identified in some of the early cases postoperatively and this is now a routine maneuver to avoid this complication.

The excised portion of the phalangeal base is remodeled. All soft tissue attachments to the base should be removed. Usually, this is begun with a rongeur followed by decortication of the periphery of the base performed with a rotary drill and side-cutting oval or round bur (5 mm). The hand rongeur is also helpful in resecting the periarticular lipping or osteophytosis that may be present.

Following remodeling, a small kirschner wire is used to perforate the entire remaining cortical surface a few millimeters to aid in revascularization and avoidance of avascular necrosis (Figure 6). These holes are similar to those placed in any bone graft to encourage revascularization. A 0.028 inch kirschner wire is utilized to drill 25 to 35 holes around the entire osseous circumference of the phalangeal base. Here, care must be taken to avoid drilling into the articular surface due to the concave geometry of the articular surface.

The wound is copiously irrigated and the graft is reinserted using the "rudder pin" as a reference or guide to its placement to re-establish a congruous first MTP joint. A 0.045 in. kirschner wire placed from the medial surface of the re-inserted base into the lateral cortex of the phalanx is used for preliminary fixation. Definitive fixation is performed with insertion of a Herbert or Bold screw.

Fixation with the Herbert bone screw will be described as this has been the most common form of fixation performed, Figure 7. Fixation with a Herbert bone screw inserted from the plantar medial aspect of the base into the distal lateral aspect of the phalanx has been very effective. Alternatively, the Bold Screw has been used

as the screws are similar but the latter is cannulated with a simplified insertion technique. Other fixation alternatives have been utilized over the years but generally the Herbert (Zimmer, Warsaw, IN) or Bold (Wright Medical Technology Group, Arlington TN) screws have yielded rigid fixation with no extra-osseous prominence.

PILOT HOLE

An AO type triple drill guide is useful as a guide to drill the 2.0 mm pilot or core diameter hole. The drill guide has a pointed edge that allows placement of the drill hole on the edge of the osseous/articular surface along the plantar medial aspect of the base of the proximal phalanx. The hole is drilled from plantar medial to dorsal lateral and distal direction. Actually, the preferred technique is to form the initial screw hole with a 0.062" kirschner wire as this is stiff and can be maneuvered more easily then a drill bit. Subsequently, this is enlarged it with a 2.0 mm drill by hand.

DRILL WITH STOP*

The 2.0 mm hole in the base is enlarged with the 2.4 mm Herbert drill with stop; this a hand instrument that allows for this overdrill only a short segment of the phalangeal base. This accommodates the larger diameter of the trailing thread of the Herbert bone screw.

DEPTH MEASUREMENT

A small fragment depth gauge can then be used to measure the correct length screw necessary. Alternatively, a 0.045in kirschner wire is inserted by hand and then clamped with a hemostat. The length of wire inserted is then compared to a ruler. This has shown to be a reliable and accurate technique. The exact length screw to that measured may be inserted, generally a 28 or 30 mm screw. Note no countersinking is performed.

TAP*

The entire depth of the pilot hole is tapped with the 3.0 mm Herbert tap equivalent to the thread of the leading 3.0 mm thread of the Herbert screw. It is important to cut the thread through the entire portion of phalanx to avoid later difficulties with screw insertion.

SCREW INSERTION*

The appropriate length screw is inserted using some axial pressure as the screw advances until it lies 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.

FINAL PREPARATION AND SECONDARY STABILIZATION

The kirschner wire used as preliminary fixation as well as the "rudder pin" may then be removed and any overhang between the base and the shaft can then be remodeled. A second point of fixation has been found useful both for increasing the rigidity of the screw fixation as well as for stabilization of the hallucal interphalangeal joint. A 0.062 in kirschner wire is driven from the tip of the toe in a proximal manner crossing the IP joint as well as the osteotomy.

Irrigation is again performed followed by capsular and skin closure per surgeon's preference. Immediate weight bearing in a surgical shoe is allowed and the procedure may be performed bilaterally on an out-patient basis. Immediate range of motion is encouraged as this is a joint salvage procedure in a patient usually with evidence of joint disease or preoperative limitation of joint movement.

POSTOPERATIVE CARE

Generally, a Darco (Darco International, Huntington, WV) 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. When the base is completely excised, my preference is to continue to splint the hallux for a period of time usually with a bunion splint for 6 weeks. Very predictable bone healing can be expected with the technique described with almost complete absence of avascular necrosis. 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. Our experience with this procedure has been very gratifying

particularly in cases of stage II and stage III hallux rigidus or hallux valgus rigidus with a long proximal phalanx and short first metatarsal. The procedure is useful in obese patients wherein first metatarsal osteotomy is difficult to protect. It may also be useful in hallux varus with the bone resection then wider on the lateral side much like a "Reverse Akin."

AUTHOR'S EXPERIENCE

The Regnauld procedure has been performed for the past 14 years and has shown to be a quite valuable surgical alternative. The author has performed over 300 procedures most for hallux rigidus or hallux valgus rigidus with the majority being performed as the described "autograft" technique versus "in-situ". In cases of limited joint disease, the base need not be excised; and certainly this may be preferred as bone healing would be expected to be more predictable as would hallucal stability. The procedure can be useful also as an adjunctive role for the management of hallux valgus particularly in cases of a rigid foot type. Several cases will be described in the illustrations.

CASE 1.

Figure 8. Radiographs of 43-year-old obese white female who presented with a stiff and painful great toe. She had prior bunionectomy with basal osteotomy by an orthopedist. A "autograft" was performed with cheilectomy and excision of the fibular sesamoid. A congruous and painfree joint was re-established as well as excellent correction of the recurrent hallux valgus deformity. Note osteotomy consolidation without resorption or callus.

Figure 8.

CASE 2.

Figure 9. Radiographs of 31-year-old female who presented with a stiff and painful great toe one year post-operative cheilectomy. An enclavement was performed incorporating significant linear shortening of the proximal phalanx. This allowed widening of the joint space and re-establishment of a painfree range of motion.

Figure 9.

CASE 3.

Figure 10. This 69-year-old female presented with a symptomatic hallux valgus deformity. Preoperative radiographs (A) show a low IM angle with mild osteopenia without degenerative changes. She underwent Regnauld procedure as an "in-situ" type osteotomy fixated with an oblique bone pin®4 and an axial 0.062in kirschner wire. Postoperative radiographs at 2 weeks (B), 6 weeks (C) and 6 months (D) show bone consolidation without resorption and gradual resorption of the bone pin.

Figure 10.

CASE 4.

Figure 11. Radiographs of 60-year-old female presented with an extremely painful first MTP joint. Preoperative radiographs (A) reveal severe hallux valgus with extensive degenerative arthrosis. A "autograft" was performed with cheilectomy and excision of the fibular sesamoid. She had an extremely nice result with correction of deformity and a painfree joint with little postoperative disability.

Figure 11.

SUMMARY

Primary joint reconstruction via cheilectomy and Regnauld type "autograft" is an extremely useful technique although not fully appreciated but for a limited number of surgeons. Due to the removal and reinsertion of the phalangeal base, several of the negative aspects of resection arthroplasty are encountered such as disruption 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, re-insertion 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. The author also feels that the kirschner wire used as a second point of fixation aids IPJ stability as it is placed across the IPJ as well as the osteotomy and imparts residual stiffness to the hallucal IPJ.

In addition, the demands of bone healing must be considered. Avascular necrosis probably occurs in a good 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 and later the Bold screw achieves rigid internal fixation and allows for reincorporation of the "autograft" with primary bone healing in a good proportion of the cases. This technique allows for immediate joint movement with rapid rehabilitation and weight bearing.

The Regnauld enclavement is a versatile procedure for primary joint reconstruction for a variety of pathologies of the first MTP joint. Phalangeal osteotomies of the hallux have traditionally been utilized for the treatment of hallux valgus and hallux valgus interphalangeus.[6] Due to the decompressive nature of the Regnauld, its utilization in hallux rigidus and limitus has been popular.

The Regnauld procedure is a joint preservation type of reconstruction versus the joint destructive nature of a resection arthroplasty such as a Keller.[9-11] As such, younger more active patients are candidates for this type of reconstruction. The therapeutic nature of the Regnauld enclavement procedure is one of a decompression osteotomy with joint relaxation. Some degree of decompression does occur with linear shortening of the proximal phalanx but in order to accomplish maximal relaxation, 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. Medial bunion resection or cheilectomy of both the metatarsal head and the phalanx are easily accomplished. Access to the sesamoids including potential sesamoidectomy is also allowed from an intracapsular approach.

Hallux limitus, hallux rigidus and hallux valgus rigidus are variations of first MTP joint osteoarthrosis combined with (hallux valgus rigidus) or without (hallux limitus and rigidus) abduction of the great toe. These deformities generally involve a stiff and painful first MTP joint. Reduction of the first MTP joint deformity is greatly enhanced through the joint relaxation inherent to this procedure. The most striking examples of joint relaxation accomplished through bone resection are with variations of the Keller resection arthroplasty or first MTP joint fusion.

This procedure may be applied to a variety of clinical pathology of the first MTP joint. The objectives of the Regnauld procedure are reduction of deformity, be abduction of the great toe, valgus rotation, restoration of normal sagittal plane position of the great toe at the first MTP joint and non-painful movement of the great toe joint. This is accomplished through 1) joint decompression through shortening of the phalanx and soft tissue release from the base of the proximal phalanx, 2) cheilectomy (clean-up all adjacent joint margins), 3) rigid internal fixation (Herbert or Bold screw), and 4) early mobilization.

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