New workhorse flaps in hand reconstruction

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Abstract With the passage of time, certain hand surgery procedures are anecdotally dubbed “workhorse” techniques. These are procedures that are extremely reliable and have repeatedly demonstrated good results. However, with time, paradigms undergo shifts, and this is as true for hand surgery as any other field. In this article, we will describe the use of three new “workhorse” flaps that we have found to have reliable results in complex hand reconstruction: the pedicled radial forearm fascia flap for dorsal hand reconstruction, the free anterolateral thigh flap for mangled hand reconstruction, and the medial femoral condyle vascularized bone graft for scaphoid fracture nonunion reconstruction.

Keywords Flap · Radial forearm · Anterolateral thigh · Femoral condyle

Introduction

Hand surgery and microsurgery are innovative fields, and many pedicled and free flaps are described each year. As surgeons perform more detailed anatomic dissections, new flaps for composite tissue transfer have become possible. One of the few drawbacks of this explosion in new flaps is that there can be variable outcomes depending on the patient population, the indications, and the surgeon’s technical ability. Most hand and microsurgeons have tried flaps described in the literature that fall short in terms of reliability and ease of dissection.

The term “workhorse flap” is commonly used in hand surgery and microsurgery. The primary definition of workhorse is “a horse used chiefly for labor as distinguished from driving, riding, or racing”; however, its secondary definition is more relevant: “something that is markedly useful, durable, or dependable” [17]. Similarly, a workhorse flap can be defined as one that has dependable anatomy, ease of harvest and inset, multiple applications, and multiple users.

Current workhorse flaps include the radial forearm flap, the latissimus dorsi flap, and the rectus abdominus flap. In each of these reconstructive options, the anatomy has been well-described and tested, and the average hand and microsurgeon would know how to harvest it. Surgeons are familiar with the likely result of such operations. However, even these current workhorse flaps may have shortcomings. In this review, three common hand problems are highlighted: (1) dorsal hand wound, (2) extensive mutilating hand injury, and (3) scaphoid nonunion. For each problem, a *new* workhorse flap is proposed that may limit some of these shortcomings. The goal is to describe the anatomic basis, indications, technique, and pitfalls for the three flaps that can be added to the reconstructive surgeon’s palette.

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A dorsal hand wound is a common injury because of the thin pliable nature of the skin. Trauma to this skin will result in exposed extensor tendons and metacarpal bones. The current accepted treatment is a reverse flow radial artery pedicled forearm flap. However, shortcomings of this include poor skin graft take on the donor site and noticeable donor scar. In addition, the replacement of thin dorsal skin by thick volar forearm skin leads to a bulky “biscuit-like” result [18]. An alternative new workhorse flap for this clinical problem would be the radial forearm fascia-only flap.

Extensive mutilating injuries to the hand and arm are a considerable reconstructive challenge for the surgeon and patient. Large areas require soft tissue reconstruction. One current workhorse flap is the latissimus dorsi free flap [22]. While this is an extremely reliable and well-used flap, there are limitations due to positioning of the patient (in lateral decubitus position), loss of functional muscle, and the need for extensive skin grafting. Furthermore, it may be difficult to perform secondary tendon reconstruction under the transferred muscle. In the past 10 years, there has been great interest in the anterolateral thigh flap as an alternative because of the large amounts of skin that can be harvested. Here, it is proposed as a new workhorse flap for the hand and upper extremity.

A third common hand problem is scaphoid nonunion. The failure of a scaphoid fracture to properly unite will likely result in scaphoid collapse and further degenerative arthritis [19]. In cases of avascular necrosis, most commonly of the proximal pole, introduction of new vascularized bone has been advocated. The current workhorse flap for vascularized bone grafting of the scaphoid has been the 1,2 intercompartmental supraretinacular artery flap from the distal radius. The limitations of this bone flap include poor quality of distal radius bone, variable vascularity, and difficulty in incorporating it into rigid fixation. Also, prior surgery on the distal radius or through the soft tissue in the area may preclude its availability. Recently, Bishop and others have begun to report on the results of the medial femoral condyle flap as an alternative bone flap that would deliver denser bone in greater quantity. While it is still too early, this may become another new workhorse flap in hand surgery.

Radial Forearm Fascia Flap

History

The reverse radial forearm flap has enjoyed a prominent place in hand soft tissue reconstruction for well over two decades. The first description of any type of radial forearm flap was in 1981, in which it was used as a free tissue transfer [32]. The following year, the first experience with the flap as a reversed pedicled flap was published [16]. Both

of these articles were in the Chinese literature, hence the colloquialism “Chinese flap” that occasionally serves as its alias. Finally, in 1985, another Chinese group published a small series in which the radial forearm flap was used with fascia only in a group of burn patients [13]. While not a new flap, the radial forearm fascia flap is versatile and is well-suited for hand soft tissue reconstruction.

Anatomy

The limited anatomic research that has been performed on the radial forearm flap would seem to suggest that perfusion of the fascia itself is meager. Saint-Cyr and colleagues recently published an analysis of the vascular anatomy of the flap which demonstrated that the substantial perforators went to the dermis of the forearm [23]. However, we know from experience that, while not typically robust, the perfusion of the flap is adequate at least for a skin graft applied directly to the flap.

The radial forearm fascia flap solves two problems that are inherent to the radial forearm fasciocutaneous flap: the poor appearance of the donor site and flap bulkiness at the recipient site. Rather than an unsightly skin graft on the volar forearm, the radial forearm fascia flap is harvested through a linear forearm skin incision. Once placed on the recipient site, the fascia flap is covered with a skin graft, leading to a much better contour on the hand. No matter how slender the patient, the fasciocutaneous version of the flap has a layer of subcutaneous fat that often needs to be debulked in later procedures.

Indications

The radial forearm fascia flap is indicated for any dorsal hand wound and just about any thumb wound (Fig. 1). It can be difficult to make the flap reach the fingertips, and its applicability in palmar digit coverage is limited. For dorsal hand wounds involving musculoskeletal injuries, it is reasonable to use the flap for immediate coverage. Specifically, fracture fixation and extensor tendon repair or reconstruction can be performed, and the flap used to cover the dorsal hand at the same time. Good extensor tendon gliding can be obtained under the flap.

Technique

The techniques for flap elevation are similar to that of the fasciocutaneous flap. An Allen test is performed to assure that the digits will remain perfused by the ulnar artery. Tourniquet control is recommended during flap dissection. A linear incision is made over the course of the radial artery. Skin flaps are carefully elevated from the fascia. The fascia itself is then incised after measuring the defect on the hand.

Fig. 1 Severe dorsal hand injury that includes extensor indicis proprius, extensor digitorum communis (index), extensor carpi radialis longus and brevis, and skin loss. The patient will require extensor tendon grafting prior to soft tissue coverage

Dissection of the deep surface of the flap and the pedicle is performed as with any other radial forearm flap (Fig. 2). The proximal radial artery is left intact but clamped, and the tourniquet is released. At this point, one can assure that both the digits and the flap perfuse through retrograde flow. Once done, the proximal radial artery is then divided and the flap transferred. The linear donor site incision is closed. Once the flap is inset with absorbable suture, a skin graft is placed directly on it. A moderately thick skin graft is used (0.012–0.015 in.), and small stab incisions (rather than meshing, which gives a pebbly appearance) are done (Fig. 3). A large bulky splint is then applied.

Complications

As with any reconstruction, there are pitfalls. When dissecting under the deep surface of the flap, it is very easy to become confused and dissect between pedicle and flap. For this reason, the surgeon must hug the radial border of the flexor carpi radialis muscle and the ulnar border of the brachioradialis muscle during dissection. The flap also appears to have a

Fig. 2 Dissected radial forearm fascia flap prior to release of tourniquet

slightly higher rate of marginal necrosis when compared to the fasciocutaneous version [6]. However, this necrosis is typically minor and heals well with wound care (Fig. 4).

Therapy

Injuries to the dorsal hand (a situation in which the radial forearm flap is commonly used) tend to cause damage to

Fig. 3 Inset radial forearm fascia flap with overlying split thickness skin graft

several structures, including bone, tendon, vascular, and loss of skin coverage. Rehabilitation focuses on restoring tendon excursion and joint motion, while protecting injured structures, and flap continuity. Surgeons should ensure that repaired tendons are strong enough to withstand early protected motion and that there is no tension at the vascular anastomosis site. Approximation of the tendon ends, without gapping and without excessive shortening, is the goal as excessive shortening during surgical repair can result in a loss of flexion, especially at the metacarpophalangeal (MP) joints [2].

The hand and wrist are immobilized for several days following surgery to promote good vascularity of the flap. The postoperative splint positions the MP joints in approximately 30–45° of flexion, with the interphalangeal joints extended, and the wrist in ~30° of extension. In the presence of a dorsal hand flap, care is taken not to place excessive pressure over the vascular anastomosis site when applying

Fig. 4 Healed radial forearm fascia flap demonstrating good contour of the hand

the dressing. At 4–7 days post surgery, early controlled motion may be started as appropriate for the zone of

extensor tendon injury and with protection of any fracture sites. The splinting in these protocols may be discontinued and full active motion initiated at 5–6 weeks post repair, depending on the progress of structure healing.

Significant edema often follows dorsal hand injuries, and the presence of dorsal hand flaps may prevent the early implementation of effective edema control measures. Gentle compression often is initiated within a few days of surgery, and proximal limb edema mobilization techniques may also be helpful in gaining control of edema.

Anterolateral Thigh Free Flap

History

The vascular anatomy of the skin of the thigh and particularly that of the anterolateral thigh flap was first described by Song in 1983. In his dissections, he identified three flaps from the thigh: the lateral thigh flap, the medial thigh flap, and the posterior thigh flap and stated that the “lateral thigh flap” was based on intermuscular perforators [27]. Further experience with this flap showed it not to be entirely reliable on the septocutaneous perforators, and the vascular anatomy of this flap was further elucidated by Xu et al. in 1988, who noted that the perforators to the skin in this area may come through the muscle [30]. Pribaz et al. later suggested that the flap should always be taken with a cuff of vastus lateralis muscle to ensure its viability [21]. As the anatomy of this flap has become better understood, it has become widely utilized in head and neck reconstruction and reconstruction of the extremities [1, 8, 12].

Anatomy

The skin of the anterolateral surface of the thigh is supplied primarily by perforators coming from the descending branch of the lateral femoral circumflex artery and vein as they course between the rectus femoris and vastus lateralis muscles. The lateral femoral circumflex artery is a branch of the profunda femoris artery and gives rise to the ascending branch (which supplies the tensor fascia lata muscle) and the descending branch. There is a transverse branch, but it is often quite small and is absent in some people. The descending branch is a moderately large vessel (2–3 mm) that runs between the vastus lateralis and rectus femoris. It may run deeper to the rectus femoris muscle or within the vastus lateralis. This artery proceeds down the lateral thigh and anastomoses with the superior lateral genicular artery from the popliteal artery at the level of the knee. If this vessel is large enough, it may allow the use of the anterolateral thigh flap as a distally pedicled flap for coverage of the knee. In a 2002 study, Wei and colleagues performed 672 anterolateral

thigh flaps and found six that had no skin perforators (either in the septum or through the muscle), for a rate of only 0.9%. They also noted that 87% of skin perforators were musculocutaneous and only 13% septocutaneous [29].

Indications

The anterolateral thigh flap can be utilized for soft tissue coverage of any large wound of the forearm and/or hand (Fig. 5). It has the distinct advantage that the patient does not have to be turned laterally, as opposed to flaps from the thoracodorsal arterial system (latissimus and/or parascapular). Smaller flaps can be utilized for hand coverage, and flaps large enough to cover nearly the entire volar or dorsal surface of the forearm can be taken. The descending branch, which supplies the flap, can be utilized as a “flow-through” vessel in cases of concomitant vascular injury to the forearm, and fascia lata can be harvested for tendon/ligament reconstruction (i.e., the triceps tendon). If there is a significant deep defect, a portion of the vastus lateralis can be harvested to fill the void. In all, this flap offers great advantages in reconstruction of soft tissue defects of the hand and arm.

Technique

While the descending branch of the lateral femoral circumflex artery is always present, the location of the perforators can be variable. As noted however, most of this course through the vastus lateralis muscle. Generally, the long axis of the flap is located by drawing a straight line from the anterior–superior iliac spine (ASIS) to the lateral border of the patella (LP). This gives a central axis that is usually over the lateral border of the rectus femoris muscle (Fig. 6). The midpoint of this line is marked, and most of the perforators will be located a few centimeters lateral to this line near the midpoint. Many surgeons prefer to locate perforators using a hand-held pencil Doppler. Yu has done an extensive study of the anatomy of the perforators of this flap and has come up with an “A, B, C” system to locate the perforators. He has

Fig. 5 View of patient's forearm and hand after severe electrical injury and loss of volar structures. Plan is for coverage and tendon rods, followed by innervated gracilis transfer

Fig. 6 Outline of anterolateral thigh flap marked on thigh

found that the “B” perforator is generally located 1.5 cm lateral to the midpoint of the line from the ASIS to LP. The “A” and “C” perforators are then usually found 5 cm proximal and distal to the “B” perforator along the same line lateral to the central axis [15, 33]. Flaps elevated using either method should contain adequate perforators.

The dissection is begun medially over the rectus femoris muscle. The flap is elevated in a subfascial plane until the septum is encountered. The dissection can proceed down into the septum at this point so that any septal perforators and the descending branch can be identified. If septal perforators are found, then the lateral flap border can be incised and the dissection taken into the septum. If not, then the lateral incision is made and very careful dissection is performed to identify the location of the perforators as they pierce the muscle fascia. A cuff of muscle can be harvested with the flap or the perforator(s) dissected from the muscle. This intramuscular dissection can be quite tedious, but the main branches of the perforators can usually be identified coming from the descending branch, and this can guide the layer and direction of the dissection. Once the perforators are dissected, the descending branch is divided distally and carefully dissected up to the branching of the ascending branch. If more pedicle length is needed, the vessels can be harvested up to the profunda femoris artery. Some surgeons will perform radical thinning of this flap to avoid bulk [1] (Figs. 7 and 8). The donor site can often be closed primarily, but larger flaps will require a skin graft over the muscle.

Complications

Donor site morbidity from the harvest of the anterolateral thigh flap is low, and in a study of 220 patients undergoing flap transfer, Hanasono and colleagues found low rates of local and wound healing problems [9]. Eighty-four percent of patients noted numbness in the distribution of the lateral femoral cutaneous nerve, and despite 37% of patients having a significant amount of the vastus lateralis muscle

Fig. 7 Flap in place on hand after excision of scar and placement of silicone tendon rods. Note bolster over full-thickness skin graft on thenar area

harvested, all patients returned to the preoperative level of activity [9].

Therapy

The early phase of rehabilitation focuses on recovery of motion and hand function. It is imperative to initiate motion as early as possible, potentially within a few days after surgery. Early motion techniques can be customized in a manner that addresses joints or digits that can be moved, while stabilizing others. The protocols for mobilization vary widely, and careful consideration must be given to each of the injured structures before implementing motion. The literature includes descriptions of early protected motion for replants, early controlled active motion for extensor repairs, synergistic motion for flexor repairs, and early protected passive motion [11, 20, 26]. The goals of early motion are to promote tendon excursion, reduce tendon adhesions, prevent joint stiffness, and decrease edema in a controlled fashion.

A properly designed splint can also positively influence the recovery of functional hand use. During the protective phase of the injury, the splint should position the hand in as much of an intrinsic plus position as the injured structures allow, keeping in mind that when there are injured structures on the dorsal hand, the MP joints should not be fully flexed in the splint. When an injury involves both the dorsal and volar surfaces of the hand, the splint will need to maintain a balance between the injured flexors and extensors. Two

Fig. 8 Flap at 4 months prior to transfer of innervated gracilis

additional priorities for splint design are to maintain the first web space and to prevent the development of PIP flexion contractures.

Throughout the intermediate phase, range of motion exercises are progressed as the patient's healing allows, incorporating more components of the various motion protocols. The last phase of rehabilitation focuses on regaining functional use, strengthening, and perhaps work conditioning. Active and passive range of motion exercises may be more aggressive, and corrective splinting may be implemented. The patient should be educated regarding any work modifications that may be needed, such as to compensate for sensory loss.

Medial Femoral Condyle Flap for Scaphoid Nonunion

History

It had been widely assumed by many that the use of pedicled bone grafts from the radius, whether dorsal or radial, would solve the problem of scaphoid avascular necrosis once and for all. The most popular of these was the 1,2 intercompartmental supraretinacular artery graft (1,2 ICSRA). Many authors reported union rates above 90% following the seminal articles on this graft of Zaidenberg and Sheetz [25, 34]. As experience grew, however, it became clear that the rate of failure may be significant [3, 28]. When the Mayo Clinic group analyzed their long-term results of 50 1,2 ICSRA graft cases recently, they found that 34 healed with an average healing time of 15.6 weeks, with complications including graft extrusion and failure of fixation [5]. Analysis of their results demonstrated that higher rates of failure resulted from known risk factors that might have been better taken into account. Factors associated with failure in this study included older age, avascular necrosis, preoperative humpback deformity, failure to use a scaphoid screw, tobacco use and, surprisingly, female gender.

The medial femoral condyle has been described as a valuable source of vascularized bone grafts by several authors. Grafts from the medial femoral condyle (MFC) were initially described by Hertel and Masquelet as pedicled periosteal and osteoperiosteal grafts based on branches of the descending genicular artery [10]. Sakai et al. subsequently described free vascularized thin, corticoperiosteal flaps based on the articular branch of the descending genicular artery and vein or the superomedial genicular vessels that were used in the treatment of persistent nonunions of the humerus, ulna, and metacarpals [24]. Since that time, MFC grafts have been used in the successful treatment of nonunions of the clavicle, tibia, humerus, mandible, and scaphoid [4, 7].

Anatomy

Extra-articular Blood Supply

The medial femoral condyle has a dual blood supply, from the descending genicular as well as the medial superior genicular vessels (Fig. 9). It was originally described as a corticoperiosteal flap, suitable to envelop small tubular bones although frequently applied like a living 'patch' to recalcitrant nonunions of larger bones, as mentioned previously. The dominance of the two systems varies, although the descending genicular, a branch of the superficial femoral artery is typically longer, larger, and easier to identify.

The descending genicular branches from the superficial femoral vessels proximal to the adductor hiatus at a mean of 13.7 cm proximal to the medial joint line. It has a mean diameter of 2.1 mm, which is sufficient for vascular anastomosis. It further divides into a saphenous branch, one or more muscular branches and the osteoarticular branch used in the free flap. The descending genicular branch is present in 89% of specimens [31]. When the descending genicular is absent or of small caliber, the medial superior genicular is of excellent size and suitable as the graft pedicle.

The saphenous branch was detected in 79% of the specimens branching off of a common trunk with the osteoarticular branch or directly off the descending genicular branch an average of 11.7 cm from the knee joint with an average internal diameter of 0.97 mm [31]. It traveled with the saphenous nerve deep to the sartorius to supply skin and subcutaneous tissues. Inclusion of the saphenous branch allows an osteocutaneous flap to be raised, often for monitoring purposes. The superomedial genicular vessel is identified at the metaphyseal–diaphyseal junction, emerging from the posterior border of the condyle to join the descending genicular artery in forming a nearly circular pattern of blood vessels lying on the face of the medial femoral condyle.

Fig. 9 Vascular anatomy of the medial femoral condyle flap (copyright Mayo Foundation, with permission)

Intraosseous Vascular Anatomy

An average of 30 (range 20 to 51) perforators to the medial femoral condyle were detected in the study of Yamamoto et al. [31]. The vessels run roughly perpendicular to the cortex extending an average depth of 13 mm (range 9.4 to 18.3 mm). Because of the large number of perforators supplying bone in the inferior distal quadrant of the face of the medial femoral condyle, this remains the preferred location for graft elevation (Fig. 10).

Indications

At the present time, we believe the primary indication for the 1,2 ICSRA graft is proximal pole nonunion with avascular necrosis (AVN), so long as no fragmentation or carpal collapse is present. Fragmented proximal poles and wrists with SLAC arthritis should be salvaged by another method. The presence of humpback deformity in a scaphoid with proximal pole avascularity or failed previous surgical treatment requires correction of both problems. Presently, we believe that free vascularized bone grafts from the medial femoral condyle provide a superior option for these patients, although the use of an arteriovenous bundle implanted in the proximal pole with a conventional graft has also been reported to be highly successful [7, 16].

Technique

Grafting of the scaphoid is performed by first correcting the lunate extension. The wrist is flexed under fluoroscopic control until the lunate is in a neutral position. A radiolunate pin maintains this position during fixation. The nonunion site is taken down. The edges are “freshened” with a sagittal

Fig. 10 Quadrants of perforators in the medial femoral condyle flap. The greatest density of perforators is in the distal posterior quadrant (bordered by lines A, C, and D) (copyright Mayo Foundation, with permission)

saw, and the joint surfaces inspected for arthritis in the scaphotrapeziotrapezoid joint. The proximal pole should not be fragmented. If it is, the procedure is abandoned and a salvage procedure, discussed as an option with the patient prior to surgery, is performed. The scaphoid will generally hinge open with the radiolunate pinning and removal of fibrous scar. The needed graft, generally somewhat larger than immediately apparent, is measured and conveyed to the surgical team harvesting the medial femoral condyle.

The medial femoral condyle is harvested once the hand team has determined that the proximal pole is avascular, requires a wedge graft to restore length, and can likely be salvaged (without fragmentation or associated arthritis). The ipsilateral knee is used as the donor site. The knee is flexed and supported by a sand bag, with the surgeon standing on the opposite side of the operating table. Use of the ipsilateral leg also allows the use of an ambulatory aid postoperatively (if needed) in the unaffected opposite hand. A pneumatic tourniquet is used on the leg, but without Esmarch bandage exsanguination (to facilitate visualization of the small vessels). An incision paralleling the posterior border of the vastus medialis is made, extending some 15 cm from the joint line proximally. It should be anterior to the saphenous branch of the descending genicular artery, which is identifiable by preoperative Doppler if a skin paddle is to be included. The fascia of the vastus medialis is incised and the muscle lifted from its compartment to visualize the osteoarticular branch of the descending genicular artery on the compartment floor. It is followed proximally to its origin from the superficial femoral vessels and distally to the medial femoral condyle. The medial superior genicular vessel will be observed at this location by gentle retraction of the adductor muscles posteriorly and inspection of the medial posterior aspect of the condyle. A decision is made regarding which pedicle is to be used, based primarily upon vessel caliber. The medial superior vessel can be followed with meticulous dissection to its popliteal origin, dividing several small muscular and articular branches as necessary. The subsequent dissection on the face of the medial femoral condyle is performed without exposure of the knee joint. Care is taken to spare the medial collateral ligament origin during graft harvest. The genicular vessels form a circle of blood supply at this point, by dividing into an ascending branch running along the patellofemoral joint proximally, and a longitudinal, posterior branch which skirts the origin of the medial collateral ligament to run distally to the reflection of the femoral–tibial joint capsule, curving anteriorly to complete the circular pattern. Visible nutrient vessels penetrating the cortex in the posterior/inferior quadrant are identified, and a vascularized graft to be harvested based upon the size required to correct the DISI deformity and humpback of the wrist is outlined. The graft is generally 1.0 to 1.5 cm in length and 1.0 cm wide (Fig. 11). The proximal/

Fig. 11 Medial femoral condyle flap following osteotomy

distal length corresponds to the gap present in the scaphoid waist, with an axis that includes the longitudinally oriented posterior branch of the genicular system. The more proximal vessels lying on the surface of the bone are lifted with meticulous dissection under loupe magnification to complete the dissection. Once the bone cuts are made, elevation is performed carefully to avoid fracturing the graft. The dissection is entirely extra-articular.

The wedge of graft is placed in the scaphoid gap and secured with a scaphoid screw (Fig. 12). Vascular connections are end-to-side to the radial artery and end-to-end to a venae comitans. The donor site is closed, generally with placement of a bone substitute in the femoral defect. Full weight bearing is allowed postoperatively, although patients generally experience some pain with flexion/extension motion of the quadriceps over the surgical site for a period of 2–6 weeks. This generally does not restrict ambulation.

Results

A retrospective review of patients with humpback deformity and avascular necrosis from the Mayo Clinic and the Landeskrankenhaus Klagenfurt (Klagenfurt, Austria) was conducted [14]. There were 22 nonunions, 10 of which were treated with distal radial pedicle vascularized graft, and 12 with a free vascularized medial femoral condyle. Patient demographics were similar between the groups, and the duration of follow-up averaged 12 months. Union was determined with the use of plain radiographs and computed tomography. Four of 10 nonunions treated with the 1,2 ICSRA pedicled radius graft healed at a mean of 19 weeks, and all 12 nonunions treated with the medial femoral condyle graft healed at a mean of 13 weeks. This rate of union was significantly higher ($p=0.005$), and the median time to healing significantly shorter ($p<0.001$) for the medial femoral condyle grafts.

Complications

The use of the medial femoral condyle bone graft for scaphoid nonunion is a time-intensive procedure and requires microsurgical expertise. Donor site pain is universal, primarily occurring with knee flexion and extension, resolving in 4–7 weeks. No major complications related to the knee joint or femur have been encountered, such as deep infection, instability, or fracture. Obtaining union in scaphoids with humpback deformity, carpal collapse, and proximal pole AVN is a daunting task, especially in multiply operated wrists. Despite the challenges, the use of the medial femoral condyle has provided a means to obtain union with remarkably few complications.

Therapy

Therapy following scaphoid nonunion surgery chiefly aims to improve wrist range of motion. The wrist will have undergone at least several weeks of cast immobilization. Cast removal will be dictated by radiographic evidence of union. Upon discontinuation of the cast, range of motion therapy is begun, with emphasis on wrist flexion, extension, and radial/ulnar deviation. Following motion improvement, strengthening exercises are initiated.

Fig. 12 Radiograph demonstrating inset and fixation of medial femoral condyle bone graft

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