Biologic resurfacing of the ankle and first metatarsophalangeal joint: case studies with a 2-year follow-up.

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Biologic Resurfacing of the Ankle and First Metatarsophalangeal Joint: Case Studies with a 2-Year Follow-Up

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KEYWORDS

- Biologic resurfacing • Acellular regenerative tissue scaffold
- Ankle arthritis • First metatarsophalangeal joint arthritis
- Arthrodiastasis

CUTIS ARTHROPLASTY: A HISTORICAL PERSPECTIVE

Since the nineteenth century, arthroplasty has been a favored solution for patients with problem joints; however, the nature of the interposing material has often perplexed surgeons. In the past, rather than look within the body itself for a viable membrane, researchers sought and produced artificial materials—chromicized pig bladder by Baer[1] in 1918, cellophane by McKeever[2] in 1943, and nylon by Burman[3] in 1943. From 1920 to 1940, fascia lata became the most commonly used material. Fascia lata was preferred because of its acceptability to its host, but it was not without drawbacks: limited supply, lack of pliability, and susceptibility to tearing.[4] The cutis, or dermal graft, seemed to offer all of the benefits of fascia lata with none of the disadvantages; thus in the 1950s cutis began its reign as the interposing membrane of choice.

In 1956, Kettunen[5] studied the autogenous whole-thickness skin graft used as interposing material in hip-joint arthroplasties performed on 6 adult cats. The hip joint was opened with a lateral incision, and the interarticular cartilage was removed from the acetabulum. The skin graft was then placed into the joint—with the epidermal side

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against the surface of the acetabulum—and was attached by sutures. The leg was immobilized for 2 weeks, after which the cat was encouraged to move freely. On examination, the acetabulum revealed that the transplanted skin graft retained its vitality and developed new tendonlike connective tissue, acting as an organic layer between the joint surfaces.

A 1958 study on the use of cutis as an interposing membrane in knee arthroplasty on 4 patients had similar successful results. Realizing that the most satisfactory material is the deepest layer of the derma that contains a minimum amount of fat, Brown and colleagues[4] discovered that the easiest way to obtain this cutis was to use a dermatome. The graft was inserted into the joint, with the fatty tissue forming the new joint surface and the superficial layer adjacent to the bone. Using the ''pull-out wire'' technique, the graft was sutured at corners so that it was draped over bone surfaces. Wires were then tied under moderate tension over buttons on the skin surface. After all wires were inserted, excess graft was removed. A 3-week immobilization period was required to allow the graft to ''take,'' after which physical therapy was progressively administered. All 4 arthroplasties were rated successful; the range of active motion varied from 60° to 80°, and extension of 180° was achieved in all cases.

Kelley and Gross[6] used a comparable technique with a hip-joint arthroplasty in 1958. A split-thickness graft was removed from the lower abdomen with a dermatome and left attached on one of its lateral borders. A dermal graft with a small amount of fat was then removed, and the split-thickness graft was sutured back to cover the abdomen. A Smith-Peterson incision was made, exposing the left hip anteriorly and superiorly, and the entire capsule was removed. The remnants of the capsule were excised, and the head of the femur was dislocated and trimmed to cancellous bleeding bone. The dermal graft was fitted over this bone and held by a circumferential purse-string suture. The head of the femur was then reduced to its original position. Although the patient was allowed to move his knee, ankle, and toes 24 hours after surgery, the hip was immobilized for approximately 1 month. A small infected area along the incision developed after 3 weeks; it was superficial and did not penetrate the fascia. The surgery was deemed successful, with a leg flexion of 90°, normal external rotation of 70°, normal internal rotation of 50°, and no pain in the hip joint.

From 1969 to 1971, Bailey[7] performed dermal arthroplasties on 30 hands severely crippled by rheumatoid arthritis. Dermis was cut from the submammary region where it is thickest, and an incision was made 3 mm radial to and parallel with the extensor tendon over the metacarpophalangeal joint. Dermis was cut into a 1- by 2-cm strip, and inserted into the artificial joint cavity as a double layer with the hinge ventral and the subepithelial layer of the dermis toward the bone ends. The graft was held into position by 3 fine nylon stitches through the periosteal cuff on the metacarpal neck and the base of the phalanx. The hood was closed with radial overlap, and the extensor indicis proprius was rerouted through the thumb web. All patients reported an absence of pain, and all but one felt they had better hand function. All patients with the exception of one made a large gain in joint range. One poor result with active flexion from 45° to 70° at all metacarpophalangeal joints followed a breakdown of a transverse wound, which occurred after 3 weeks. Two cases had a mild recurrence of proximal phalangeal subluxation at 1 and 2.5 years, respectively.

Froimson and colleagues[8] performed dermal arthroplasty of the elbow joint on 5 patients in 1976. A dermatome was used to remove a split-thickness skin graph, and the cutis graft was applied to the distal end of the humerus with the superficial side against the bone. The graft was sutured to the bone through 2 drill holes. The seams on either side of the graft were closed, trimming excess cutis to achieve a snug fit. The elbow was then reduced, and a compression dressing was applied.

A posterior plaster splint was used to immobilize the elbow in 90° flexion for 2 weeks; after which gentle exercises commenced (between the periods of exercise, the splint was reapplied). In all patients, a satisfactory excursion of flexion and extension was achieved, and pronation and supination were satisfactory.

Uuspää[9] achieved similar results when he performed 51 elbow arthroplasties between 1978 and 1984. Flexion contracture was diminished, and range of flexion and range of rotation were improved. Sixteen patients reported no pain, whereas others reported pain at times. Thirteen patients had ulnar nerve symptoms before arthroplasty, and only 2 of these had symptoms after surgery. In all, 8 patients had ulnar nerve symptoms after arthroplasty. In 5 of these, elbow joints had been operated on before the arthroplasty. With no elbow operations before arthroplasty, the risk of ulnar symptoms was 10%; with previous operations the risk was 24%. Bone resorption of a variable degree was noted in osteoporotic joints. Thirty-nine patients were satisfied with the result of the surgery; 13 were not. Sixteen considered the results "good," 32 "satisfactory," and 3 "bad." Forty-four patients said they would have the operation again.

These studies illustrate that cutis has proved to be a successful autogenous interposing membrane in arthroplasties. Cutis is strong, pliable, and well tolerated by the host, and has exhibited few negative results. However, the popularity of cutis seems to have declined since the advent of biologic allograft scaffolds.

Burkhead and colleagues[10,11] described the resurfacing of the glenohumeral joint with an acellular regenerative tissue scaffold. In 2008, Berlet and colleagues[12] detailed the interpositional arthroplasty of the first metatarsophalangeal (MTP) joint in 9 patients with a 12-month follow-up. Increased function and a reduction in pain were attributed to the scaffold's ability to maintain the inherent nature of the joint and the resurfacing of the first metatarsal-sesamoid articulation. Also in 2008, Lee described the resurfacing of the tibio-talar joint with the use of external fixation and an acellular regenerative tissue (ART) scaffold. At a minimum of 8 months, 18 ankles exhibited increased function and decreased pain.[13]

The purpose of this article is to describe additional cases in which the ankle and first MTP joint underwent biologic resurfacing, with a 2-year postoperative follow-up.

ACELLULAR HUMAN DERMAL SCAFFOLD

The ART scaffold (Graftjacket, Wright Medical Technology, Arlington, TN) is a type of acellular human dermal scaffold that can be used to treat tendon and ligament injuries, as well as full-thickness skin wounds. ART is an allogeneic permanent dermal equivalent derived from human cadaveric tissue, and is processed in a way that minimizes the destruction of the original human dermis.[14] This process preserves the extracellular matrix that contains elastin, proteoglycans, laminin, tenacin, and collagen types I, III, IV, and VIII; it also preserves the vascular channels of the cadaveric dermis (**Fig. 1**).[15] However, the main objective of the processing technique is to remove all immunogenic components and preserve the extracellular scaffold; this allows for rapid revascularization and cellular repopulation, and maintains tensile strength.

In the operative setting, the surgeon will notice that the scaffold contains 2 sides: the *active side* and the *basement membrane surface*. The active side—the side that will be applied to the augmented tissue—is called the *reticular surface*. The reticular surface is the intact collagen network that will serve as the scaffold for revascularization and cellular repopulation. The reticular surface incorporates into, and is gradually

Fig. 1. Electron scanning microscopy image of the acellular regenerative tissue (ART) scaffold and its intact vascular channel. (*Reprinted courtesy of* Wright Medical Technology, Arlington, TN; with permission.)

reorganized by, the host tissue. The other side of the scaffold, the basement membrane surface, is the anatomic equivalent of the epidermal-dermal junction, and will resorb as the reticular surface becomes populated by host cells (**Fig. 2**).

The load-failure strength of acellular human dermis scaffold was assessed by Barber and colleagues[16] in 2006. Compared with other commercially available allografts and xenografts,[16] the acellular human dermis (ie, ART) was found to have superior tensile load strength and suture retention. This benefit was attributed to the preservation of the human extracellular matrix during processing.[16,17]

The acellular human dermis scaffold minimizes host immune response while providing enough strength to withstand the shear forces of the foot and ankle joints.[10–13] These characteristics make the acellular human dermis scaffold an effective choice for biologic resurfacing.

DISTRACTION ARTHROPLASTY WITH TALAR RESURFACING

A 56-year-old man presents with an extremely painful arthritic ankle and a history of right distal tibia-fibula fracture 33 years before presentation (**Fig. 3**). Opposed to ankle fusion and unsure about total ankle arthroplasty due to "limited data," the patient consents to distraction arthroplasty with talar resurfacing.

An external fixator device is applied to the ankle and leg for distraction of the tibiotalar joint. The authors prefer a strong monolateral device to better access the anterior

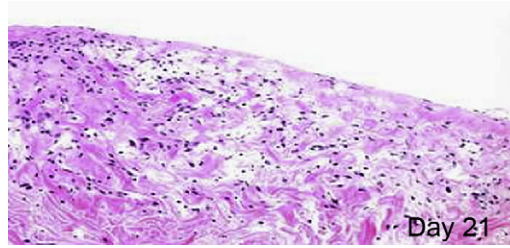

Fig. 2. Histologic slide of nude rat Achilles tendon model 21 days after implantation. Slide demonstrates tenocyte proliferation across the collagen scaffold.

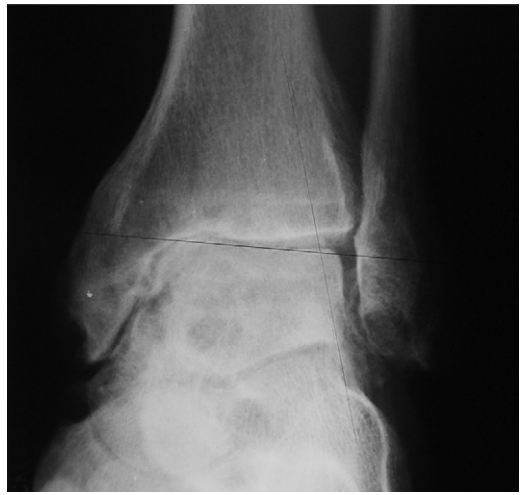

Fig. 3. Preoperative radiograph of severe tibio-talar joint arthritis before biologic resurfacing.

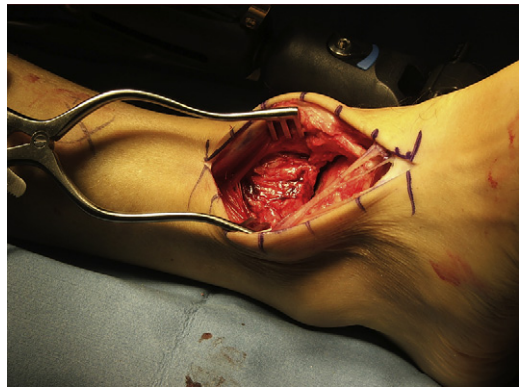

Fig. 4. Anterior ankle exposure after the joint distraction has occurred.

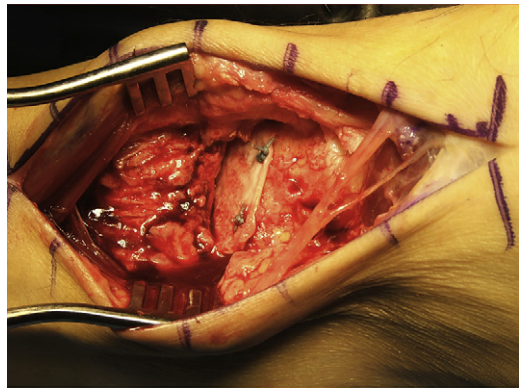

Fig. 5. The ART scaffold was affixed to the talar dome using suture anchors.

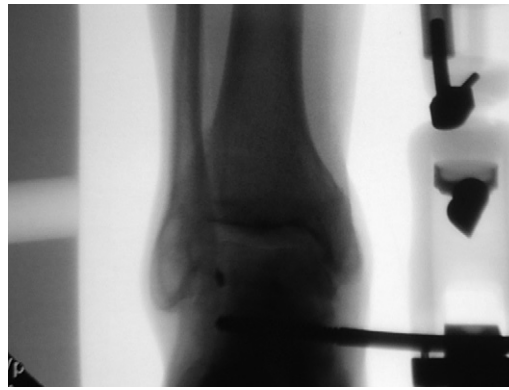

Fig. 6. Immediate postoperative view of the ankle after biologic resurfacing.

aspect of the ankle during the resurfacing approach. Using the fixator, the tibio-talar joint is distracted approximately 1 cm.

A standard anterior approach is used to access the tibio-talar joint. Attention initially is directed to the superficial peroneal nerve deep to the skin. Blunt dissection is carried to the deep tissue, where the neurovascular bundle is visualized and protected (**Fig. 4**). Once seen, attention is directed to the anterior lip of the tibia and extra-articular structures. A complete cheilectomy of the ankle is performed. While performing the joint debridement, the acellular human dermal bioscaffold is soaking in a warm bath of sterile saline. This material is properly hydrated when the paper attached to the scaffold is easily removed.

Once the extra-articular joint structures are debrided, the articular surface of the talar dome is prepared. The entire dorsal aspect of the talar dome is debrided to bleeding subchondral bone, and the acellular human dermal bioscaffold is cut to match the size of the dome. Using an anterior-to-posterior pattern of suture anchors, this material is affixed to the talar dome with the reticular surface facing toward the exposed subchondral bone (**Fig. 5**). It is important to ensure that the bioscaffold is affixed smoothly to the talar dome, as any folds or creases may disrupt the incorporation of the scaffold (**Fig. 6**).

Postoperatively the patient is encouraged to engage in as much weight bearing as possible. Van Roermund and colleagues[18] hypothesized that weight bearing during distraction allows for changes in intra-articular fluid pressure and an increase in synovial fluid production. This activity, coupled with a decrease in shear force across the joint, allows for reparative activity to occur in osteoarthritic cartilage.

Table 1
Pain scale

Pain Scale (0–10)	Preop.	6 months	1 year	2 years
First step out of bed	9	4	3	0
Pain when standing	8	3	0	0
Pain when walking	9	4	2	0
Pain at the end of the day	9	5	3	1

Pain scale: 0 is no pain, 10 equals worst pain possible.

Table 2
Function scale

Function Scale (0–10)	Preop.	6 months	1 year	2 years
When climbing stairs	9	6	2	0
When descending stairs	9	5	3	1
When standing tiptoe	9	6	3	1
When running	10	10	10	10

Function scale: 0 is no difficulty, 10 equals unable to perform.

The fixator is removed at 3 months, and the patient is placed in a rigorous physical therapy program to address functional and mechanical instability, strength, and range of motion. The data given in **Tables 1–3** describe pain, function, and assistant device at 6 months, 1 year, and 2 years postoperatively.

FIRST METATARSAL HEAD BIOLOGIC RESURFACING WITH HEMI-ARTHROPLASTY

A 52-year-old woman with prior first MTP joint hemi-arthroplasty presents with joint pain, limited range of motion, and jamming. Radiographs demonstrate a hemi-implant in poor position with a significant decrease in first MTP joint space. This patient consents to biologic resurfacing of the first metatarsal, with a goal of decreasing pain, increasing range of motion, addressing the degeneration of the first metatarsal head, and using the acellular human dermal bioscaffold (Graftjacket, Wright Medical Technology, Arlington, TN) as a separating medium between the first metatarsal-sesamoid complex.

A linear incision is created over the course of the first MTP joint. To expose the first metatarsal head, dissection is carried to the level of the joint. The metatarsal head is debrided, removing all extra-articular spurs and releasing the sesamoid-first metatarsal complex. Using a cup-and-cone reaming system, the first metatarsal head is shaped using the conical reamer (**Fig. 7**). Reaming occurs to the level of subchondral, bleeding bone. All articular cartilage is removed. The base of the proximal phalanx is prepared for hemi-arthroplasty with a cup reamer and sagittal saw (**Fig. 8**). During the debridement of the first MTP joint, the bioscaffold is soaked in a warm bath of sterile saline.

Using a 2.0 drill bit, 2 vertical trephine holes are drilled into the metaphyseal region of the first metatarsal (**Fig. 9**). Using a strong, nonabsorbable suture, the human dermal bioscaffold is tagged, and then passed through each of the trephine holes with a tendon passer (**Fig. 10**). The bioscaffold is wrapped around the metatarsal head in a ''hoodlike'' fashion. The nonabsorbable suture is then sewn around the metatarsal neck using an ''under-and-over'' technique (**Fig. 11**). The excess

Table 3
Assistant device

Assistant Device	Preop.	6 months	1 year	2 years
Use indoors	7	4	0	0
Use outdoors	8	5	0	0

Assistant Device Scale: 0 is never use, 10 is use all of the time.

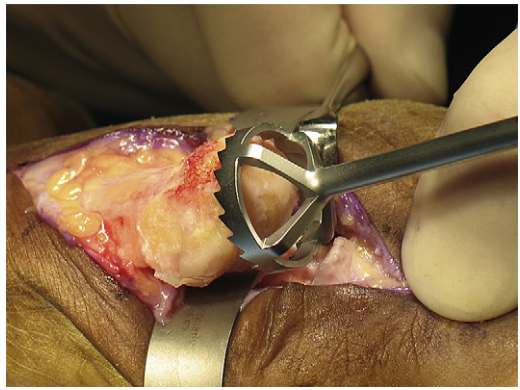

Fig. 7. Preparation of the first metatarsal head using conical reamer.

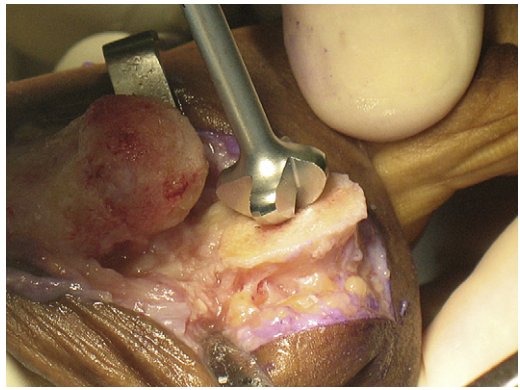

Fig. 8. Preparation of the base of the proximal phalanx for hemiarthroplasty.

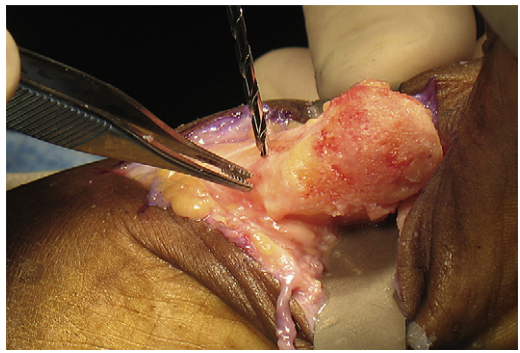

Fig. 9. Drilling of the vertical trephine holes for scaffold attachment.

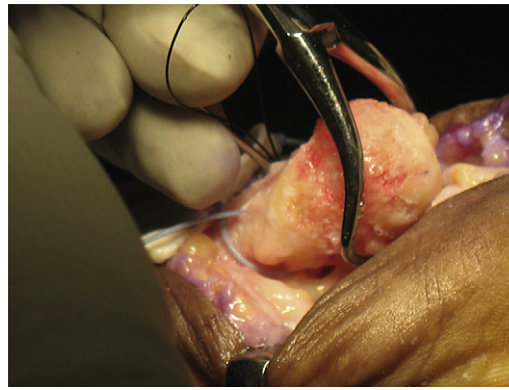

Fig. 10. Passing of the suture through the trephine holes. This action allows for proper placement of the scaffold on the metatarsal head.

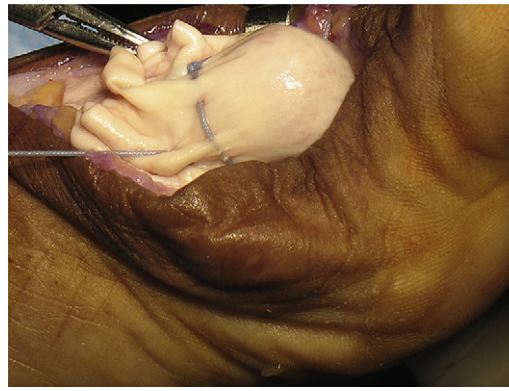

Fig. 11. Suturing of the scaffold using an "over and under" technique.

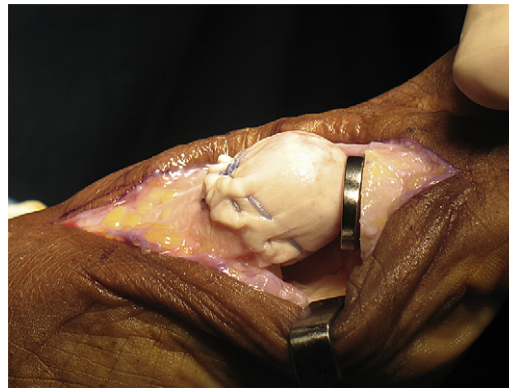

Fig. 12. Final resurfacing of the metatarsal head and its articulation of the hemi-implant.

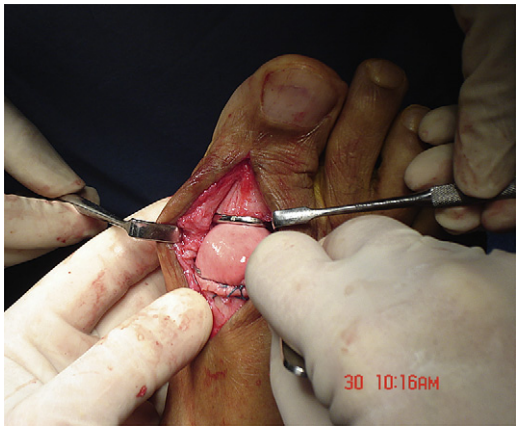

Fig. 13. Intraoperative view of the first metatarsal head resurfacing.

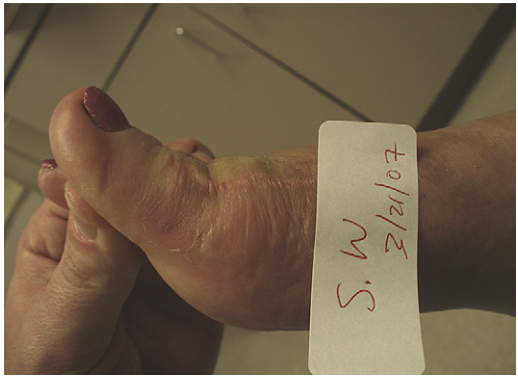

Fig. 14. Great to dorsiflexion 6 months after first metatarsal head resurfacing.

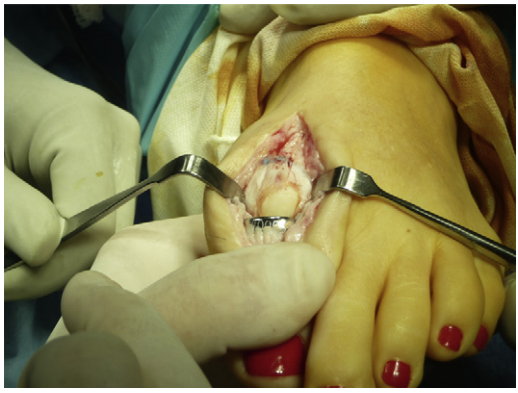

Fig. 15. Intraoperative views of the first metatarsal head previously resurfaced.

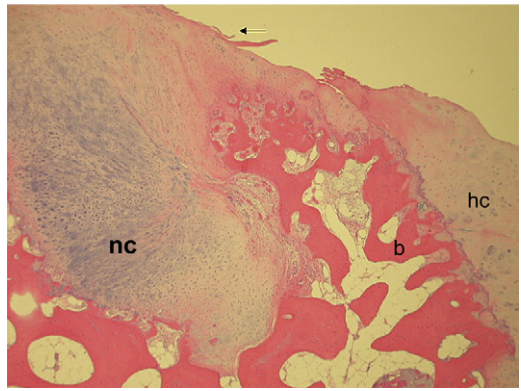

Fig. 16. Host cartilage (hc) is present above the subchondral bone (b). The cartilage surface is irregular and adjacent, and there is loss of articular cartilage (*arrow*). Neocartilage (nc) is present (hematoxylin-eosin, original magnification ×10).

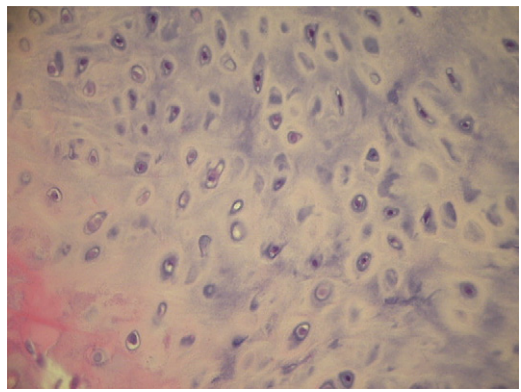

Fig. 17. Higher magnification of neocartilage reveals mature, differentiated chondrocytes with dense proteoglycan deposition (hematoxylin-eosin, original magnification ×40).

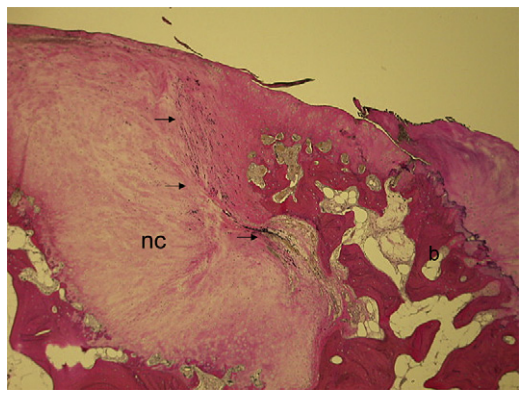

Fig. 18. The arrows indicate ART scaffold with neocartilage beneath the scaffold (nc). Subchondral bone (b) is adjacent to the newly formed cartilage.

bioscaffold is removed, and the hemi-implant is placed in the base of the proximal phalanx (**Figs. 12** and **13**).

During postoperative examination the patient was found to have less pain and more function (**Fig. 14**). Eighteen months postoperatively, the patient presented with tenderness to the first interspace, and biopsy of the previously resurfaced metatarsal head was performed. Visual inspection demonstrated an articular surface with smooth, shiny, ''hyaline-like'' appearance (**Fig. 15**). Histologic analysis showed a significant layer of neocartilage adjacent to the subchondral bone (**Fig. 16**). Higher magnification of the neocartilage revealed mature, differentiated chondrocytes throughout the matrix of the acellular human dermal bioscaffold (**Figs. 17** and **18**). These findings confirm that the bioscaffold is able to accept host chondrocytes and form a joint surface that will act and function in a way similar to that of articular cartilage.

SUMMARY

The goal of biologic resurfacing is to provide a smooth joint surface with a low coefficient of friction, which allows the joint to function with near-normal biomechanics, as well as provide intermittent pressure, to the subchondral and cancellous bone. This unique combination often results in the formation of a ''neocartilage-like'' structure that can reduce pain and restore biomechanics.

Due to its potential for regenerative healing, high tensile strength, and easy handling characteristics, acellular human dermal bioscaffold seems to be an excellent tissue for resurfacing. Although there has yet to be significant level 1 evidence that supports biologic resurfacing, the authors believe that as fixation techniques and technologies evolve, biologics will dominate the management of osteoarthritis.

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