RETTAIN THE ARTICULAR CARTILAGE IN FINGER JOINT AMPUTATIONS

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In amputations of the upper extremity, conservation of length is the rule. However, if amputation is through a joint, excision of the articular cartilage has been advised—ostensibly to allow the soft tissues to gain a firm attachment to the bone and to avoid possible sequestration of the cartilage after degeneration. Some have stated that this same attachment will eventually occur if the cartilage is left in place, but only with a risk of possible chondritis and sequestration. We have felt, from our clinical experience, that leaving as much articular cartilage behind as possible in transarticular amputations is actually the best method. The following experiments were done to test this.

EXPERIMENTAL METHOD

The left forepaws of 8 young cats were amputated. In 4, the disarticulation was between the proximal carpal row and the radius-ulna; in the other 4, the amputation was done at the same level, but the articular cartilage was entirely removed by rongeur from the distal ends of the radius and ulna. One cat from the disarticulation group, and one from the disarticulation plus chondrectomy group, were killed at two, 4, 6, and 8 months. One cat in the disarticulation plus chondrectomy group died within one month, leaving only 7 in the study group. Thus, only the disarticulation animal was available for the 8 months observation.

At operation, the significant bleeders were ligated with 5-0 chromic catgut and the wounds were closed with a continuous suture of 5-0 nylon. A gauze bandage was applied and taped in place. All wounds healed primarily without evidence of complications.

Following sacrifice of the animals at designated times (two, 4, 6, and 8 months), forelegs were disarticulated at the elbow and submitted for radiographic and microscopic study. The skin of the first pair was removed but it was left on the remainder.

Specimens were prepared for microscopic examination by first shaving and then removing the remainder of the hair with a chemical preparatory. The entire foreleg was then:
1. placed in 15% formic acid and carefully agitated until decalcification occurred usually within about two weeks;
2. split into two halves with a razor blade to make a sagittal section;
3. dehydrated with alcohol and placed in xylol;
4. embedded in paraffin;
5. cut with a microtome into about 10 sections (with a sagittal cut orientation);
6. stained with hematoxylin and eosin and mounted between two glass slides.

This method allowed gross and microscopic visualization and comparison. Sections to be representative of each time period were chosen for analysis.

X-RAY FINDINGS

There was slight rounding off of the bones, between killing of the first animals (two months) and the last (8 months). Growth and smoother ends were visible in the disarticulation specimens; the growth plates were absent in the disarticulation plus chondrectomy specimens (Fig. 3).

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t maturation and bones, between the rimals (two months) thths). Growth plates were visible in all the imens; the growth in the disarticulation pecimens (Fig. 1).

Two Months, Disarticulation Only
Remnants of the joint capsule (with villi and synovial cells), and the connective tissue contiguous with the joint capsule, were present. They formed a pannus which, at the point of fusion, appeared to be fibrocartilage sealing the end (Fig. 2).
The articular cartilage had degenerated, with a change in staining reaction peripherally, from the normal basophilic to eosinophilic. The cartilage present showed changes ranging from normal nuclei with abnormal cytoplasm (in the outer two-thirds of the cartilage) to abnormal, pyknotic nuclei (in the proximal one-third, next to the subchondral plate). In the proximal one-third, smearing and several pseudo-tide lines paralleled the articular cartilage; the subchondral bone was indistinct and irregular. (These changes were all consistent with inadequate cartilaginous nutrition—normally supplied by the synovial fluid produced by the joint capsular structures of the opposing joint surfaces.) A few round cells were scattered between the layers of connective tissue, but there was no significant inflammation or fluid accumulation (Fig. 2).

Two Months, Disarticulation plus Chondrectomy
The epiphyses and growth plates had been cut away, along with the joint capsule, leaving a surface of irregular and blunt ends of metaphyseal trabeculae (Fig. 3).
Active remodeling was in progress, with connective tissue encasing the exposed trabeculae and sealing off the marrow spaces. Newly formed fibrocartilage and bone had been laid down on the trabecular and surface ends.
Necrotic bone chips, indicated by absence of osteocytes in the lacunae, were present in the adjacent connective tissue. Necrotic metaphyseal trabecular ends, adjacent to the line of chondrectomy, were present—as occurs with all fractures. There were numerous osteoclasts. (All this was evidence of considerably more remodeling occurring in the disarticulation plus chondrectomy specimen than in the disarticulation specimen.) Numerous round cells were present throughout all layers, but with no collection into focal areas of inflammation (Fig. 3).

Four Months, Disarticulation Only
The fibrous tissue had decreased in amount, and there was a more normal and healthy appearance—including the presence of normal-appearing fat cells in the connective tissue interstices. The remaining cartilage had narrowed, and
cells were now dead distal to the tide line throughout the articular cartilage. The pseudo-tide lines had all disappeared; a single heavy tide line remained. Again, there were a few inflammatory cells, but in a decreased number compared with the previous specimens (Fig. 4, left).

**Four Months, Disarticulation plus Chondrectomy**

There was considerable fibrous tissue over the stump end. A discontinuous bony cortex was now present, with trabecular fusion. Active remodeling with multiple osteoclasts was still in progress;...
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generally, considerable tissue activity
and change were evident. The inflam-
matory response was again present
throughout all layers, probably about
the same as in the disarticulated speci-
men (Fig. 4, right).

Six Months, Disarticulation Only
A fat pad was present over the end of
the stump, within the fibrous tissue. All
cartilage had been replaced except a
small area in the middle portion of the
articular surface and subchondral plate.
In this central area, cartilage was present only proximal to the tide line. A narrow layer of periosteal-like tissue, continuous over the periphery and similar to that developing in the 4-month disarticulation plus chondrectomy specimen, was present. Scattered round cells were present, the only indication of inflammation (Fig. 5, left).

**Six Months, Disarticulation plus Chondrectomy**

A thick fibrous tissue layer was present, with no fat pad. All other features were similar to the specimen at 4 months; continuing remodeling, with several osteoclasts, and a discontinuous bony cortex were present. There was persistent round cell infiltration in all fibrous layers (Fig. 5, right).

**Eight Months, Disarticulation Only**

The articular cartilage had disappeared entirely, with only the bone of the subchondral plate remaining; a periosteal-like tissue was continuous over the surface of the underlying bone. Less, but continuing, remodeling was in progress.

(As noted, there was no “Disarticulation plus Chondrectomy” specimen available at this period.)

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**Fig. 6.** Finger disarticulations in our clinical series of patients. (left) Number disarticulated at each joint. (center) Removal of lateral flare. (right) Removal of palmar bulge.

**Fig. 7.** One of the patients, brought in after traumatic amputations of the ring and long fingers. (left) The long finger amputation was at the distal joint; here, the lateral flare of the distal end of the middle phalanx is being removed with a rongeur. (center, right) Appearance several months later. The articular cartilage was left on the stump of the long finger, but removed from the stump of the ring finger. The patient felt that the long finger stump was quite comfortable. The photographs do not demonstrate any significant difference between the results.
SUMMARY OF THE EXPERIMENTAL FINDINGS

Disarticulation Only

Articular cartilage degeneration was present at two months postoperatively, with fibrous tissue formation distally and new bone proximally. This continued progressively with an end fat pad becoming apparent, but minimal inflammatory response and no sequestration. By 8 months all the articular cartilage had been replaced.

Disarticulation plus Chondrectomy

Remodeling was very active at two months, and was still active at 6 months—with a relatively heavy fibrous tissue cover, an incomplete cortex, numerous osteoclasts, and a pronounced round cell infiltration.

CLINICAL CASES

Twenty male patients, ranging in age from 17 to 63 years, have been treated over the last 5 years by transarticular disarticulation, with preservation of as much articular cartilage as possible. All amputations were traumatic in origin; all but two occurred while the patient was at work. These amputations involved, at one time or another, the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints of all digits—except the M-P joints of the thumb and long fingers (Fig. 6, left). Six patients have had injuries to more than one finger.

Where sufficient local soft tissue covering was available, and the level of the amputation made it appropriate to do so, only the lateral or palmar flare of the phalanx (with its overlying cartilage) was rongeured away (Fig. 6). Enough was removed so that the digit was left without a bulbous tip. (With care, perhaps 60 to 70 per cent of the articular cartilage can be left on the stump.) An operative view of the lateral flare of cartilage being removed, and the end result in the same patient, are shown in Figure 7.

In this series, there was no infection, sequestration, or other form of delayed healing; none required revision. Six other fingers in this series, with conventional amputations, likewise required no revision and healed without complications. But we believe that those with the disarticulated fingers generally had a more flexible and less fixed stump scar, and a more comfortable stump. This impression was confirmed by several patients who had both types of amputations simultaneously. In addition, this method produced less bleeding, the surgery was simplified, and it preserved more length. Therefore, while the appearance of the fingertips postoperatively often showed no significant difference (as in the case depicted) we believe this method to be preferable—for the reasons given above.

SUMMARY

In transarticular amputations of the fingers, it has been customary to surgically remove the articular cartilage. Here we present experimental and clinical evidence to support our view that it is better to leave the articular cartilage on the end of the stump.

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REFERENCES

FINGERTIP INJURIES

LOSS  soft tissue only  NEED  durable sensible cover for bone
      volar pad                support for nail
      bone                    restoration of length
      nail + support for nail satisfactory appearance

REPAIR  open
         graft (thickness, donor site
         flap - same digit (V-Y advancement, volar adv, dorsal, flag)
            - elsewhere (cross finger, thenar)
            - innervated flap

GRAFT DONOR SITES  wrist crease, hypothenar, groin, forearm

CHOICE OF METHOD  age, work requirements, nature of injury, compensation

TIMING  delayed primary repair
        KISS
NAIL INJURIES

Clayburgh: "significant trauma [to the germinal matrix] obviates repair of the distal portion of the nail bed."

McCash: "The tips of the fingers in man represent the tactile horizon of the body."

"Apart from the value of the nails in relation to the rest of the body, their cosmetic importance remains the chief indication for our efforts as plastic surgeons to find a satisfactory technique to restore them."

1938 Barrett Brown reported replacement of amputated nail matrix and a little bit of tip skin with complete take and normal nail appearance

Buncke: "Measles is one of the few systemic illness which has an arresting effect on nail growth, even more profound than that of death, but not as permanent."

Nail functions

Buncke - instruments for scratching and picking plus lending support and protection to the tactile pad of the fingertip

Zook - protects fingertip; may also play a part in tactile sensation of the tip; adds to delicate and precise touch, skilled hand function and ability to pick up tiny objects

Verdan: "The epidermis under the nail is able to build a corneous substance which is responsible for the extraordinary adherence of the nail to its bed."
(5) Fillet
(6) Muscles
   (a) Brachioradialis
   (b) ECRL
   (c) FCU
   (d) ECU
   (e) Pronator quadratus
   (f) Abductor digiti minimi
(7) Reversed radial forearm
(8) Reversed posterior interosseous artery — PIA

E. Distant flaps
   1. Random
      a. Examples
         (1) Cross arm
         (2) Chest
         (3) Abdominal
   2. Axial
      a. Pedicle
         (1) Groin
      b. Free (by microvascular transfer)
         (1) Examples
            (a) Scapular (cutaneous)
            (b) Lateral arm (fascial)
            (c) Tailored latissimus dorsi (muscular)
            (d) Radial forearm

Fingertip

I. Introduction
   A. Most common hand injury
   B. Most sophisticated organ of touch
   C. Injury may lead to significant disability

II. Anatomy

\begin{center}
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\textbf{Figure 3}
III. Goals of Treatment
A. Adequate sensation
B. Minimal tenderness
C. Satisfactory appearance
D. Full joint motion
E. Maximum length consistent with above goals

IV. Factors in Choice of Treatment
A. Patient
   1. Age
   2. Occupation
   3. Digit involved
   4. Sex

Algorithm for Selection of Treatment of Fingertip Injuries

Figure 4
B. Nature of defect
1. Size and location
2. Mechanism of injury
   a. Sharp
   b. Crush
   c. Avulsion
3. Bone exposure or not
4. Angle of loss

V. Treatment Methods
A. Open—healing by wound contraction and epithelialization
1. Indications and advantages
   a. Children
   b. Adults with defects 1 cm or less
   c. Simple procedure
2. Technique
   a. Thorough cleansing
   b. May need to shorten bone (always equal nail bed)
   c. Dressing change at three to five days
   d. Daily dressing changes until healed
3. Disadvantages
   a. Prolonged healing
   b. Stump tenderness

B. Replacement of amputated part
1. Composite graft
   a. Indications and advantages
      (1) Children
      (2) Distal tissue
      (3) Sharp amputation
      (4) Best appearance when successful
   b. Disadvantages
      (1) Unpredictable
      (2) Recovery delayed by failure
2. Microvascular replantation
   a. Indications and advantages
      (1) Level just distal to DIP joint
      (2) Outpatient procedure
      (3) Best appearance
      (4) Potential for useful sensibility and neuroma prevention
   b. Disadvantages
      (1) More prolonged surgery
      (2) Expense

C. Primary closure with shortening
1. Indications and advantages
   a. Loss of over 50% of the distal phalanx
   b. Irreparable damage to nail matrix
   c. One stage procedure
   d. Early immobilization and desensitization (important in older or stiffer hands)
2. Technique

**Figure 5**

a. Trim bone to achieve tension-free closure
b. **Always** trim nail bed as far proximal as bone
c. Neurectomy
d. Tension-free closure

3. Disadvantages
a. Digital shortening
b. May develop painful neuroma

D. Skin graft
1. Split-thickness graft
   a. Indications and advantages
      (1) No bone exposed, sites with less contact
      (2) Graft shrinkage reduces size of defect
   b. Technique
      (1) Prepare recipient site
      (2) Choice of donor site (side of proximal phalanx or hypothenar eminence)
         (a) Donor site scarring
         (b) Color and texture match
      (3) Attach graft
         (a) Sutures
         (b) Tape strips
c. Disadvantages
   (1) Wound coverage may be
       (a) Unstable
       (b) Dysesthetic
       (c) Unsightly
   (2) Donor site scar may be objectionable
2. Full-thickness skin graft
   a. Indications and advantages
      (1) No bone exposed, sites with more contact
      (2) More durable coverage
      (3) Direct closure of donor site
   b. Disadvantages
      (1) More difficult "take"

E. Local flaps
1. V-Y Advancement
   a. Lateral (Kutler)
   b. Palmar (Atasoy)
   c. Indications and advantages
      (1) Transverse (Atasoy) and dorsal oblique amputations (Kutler)
      (2) Good sensation; minimizes sensitivity
   d. Technique

Figure 6
(1) Single palmar V-Y (Atasoy)
(2) Outline palmar triangular flap
   (a) Width equals width of nail
   (b) Length: apex based at distal interphalangeal joint flexion crease
(3) Loupe magnification
(4) Incise skin and dermis
(5) Divide septae
(6) Separate flap from palmar surface of distal phalanx periosteum and terminal flexor tendon
(7) With small, fine scissors separate the V limbs of the triangle to identify and divide fibrous septae
(8) Differentiate septae from vessels and nerve by examination under loupe magnification
(9) Remember
   (a) Vessels and nerve—elastic
   (b) Fibrous septae—inelastic
(10) Advance and suture flap
(11) Release tourniquet.
(12) Double lateral V-Y (Kutler)

Kutler double lateral V-Y advancements. (A) The advancement flaps are designed over the neurovascular pedicles and carried right down to bone (B). The fibrous septae are divided, permitting mobilization (D) on the neurovascular pedicles alone. The flaps then advance readily to the midline (E).

**Figure 7**

(a) Location of apex—may locate proximal to DIP crease
(b) Anterior incision through skin only
(c) Mobilization—through dorsal incision divide septal connections between flap and periosteum
(13) Through palmar incision as in palmar V-Y advancement, carefully identify and release fibrous septae, preserving more elastic vessels and nerves.
(14) Round off distal contour of amputated bony stump (*not* proximal to nail bed)
(15) Advance radial and ulnar flaps created to meet in midline
(16) Disadvantages
   (a) Technically demanding
   (b) Limited tissue available
2. Palmar advancement flap (Moberg)

![Figure 8A](image)

**Figure 8A**

- **Indications and advantages**
  1. Only for thumb (Macht and Watson, 1980)
  2. May cover up to 1.5 cm palmar defect
  3. Near normal sensibility

- **Technique**
  1. Midlateral incision, dorsal to neurovascular bundles
  2. Careful mobilization of flap based upon neurovascular bundles
  3. Advancement (helped by flexion of interphalangeal joint)

- **Disadvantages**
  1. Flexion contractures
  2. Potential for dorsal tip necrosis if neurovascular bundles injured
F. Regional flaps—adjacent digit or palm

1. Cross finger flap
   a. Indications and advantages
      (1) Covers large defects
      (2) Versatile and reliable
      (3) May be innervated (Hastings)
   b. Technique

   ![Diagram of cross finger flap]

   It can be seen that this approximates the flaps to the defects with full
closure of the bridge segment. (F) This is shown diagrammatically.

**Figure 9**

(1) Prepare recipient area
(2) Design flap from adjacent digit (usually middle phalanx)
(3) Raise flap and suture in place
(4) Split- or full-thickness coverage of donor defect (over graft pedicle)
(5) Release and inset at two to three weeks

C. Disadvantages
(1) Potential for joint stiffness in both digits (possibly more)
(2) Creates defect on normal digit
(3) May be hair-bearing
(4) Scar of secondary defect unacceptable in women
2. Thenar flap

Figure 10

a. Indications and advantages
   (1) Children and young adults (especially women)
   (2) More subcutaneous fat available than cross finger
   (3) Good color and texture match for pulp
   (4) Donor site can be closed primarily, but rarely

b. Technique
   (1) Prepare recipient site
   (2) Design and elevate thenar flap (50% wider than defect to recreate pulp)
   (3) Close donor defect
      (a) Graft
      (b) Suture if in thenar crease
   (4) Suture flap in place
   (5) Detach at two weeks

c. Disadvantages
   (1) Potential for joint stiffness
   (2) Limited size of flap
VII. Summary

A.
1. Open treatment
2. Free graft

B.
1. Cross finger flap
2. Thenar flap
3. Double lateral V-Y
4. Free graft

C.
1. V-Y advancement flap
2. Volar advancement flap
3. Free graft
4. Shorten and close

Figure 11

Nail and Nail Bed Injuries

I. Importance of Nail
   A. Support of pulp
      1. Sensibility
      2. Protection
      3. Fine manipulation
   B. Appearance of finger

II. Types of Injury
   A. Subungual hematoma
   B. Avulsion of nail matrix from nail fold
   C. Nail bed laceration
   D. Loss of nail matrix

III. Principles of Treatment
   A. Remove nail if undermined by large subungual hematoma
   B. Repair nail bed laceration
   C. Replace nail if possible to prevent nail fold and splint
   D. Graft nail bed defects with split-thickness nail bed graft
      1. Adjacent uninjured nail
      2. Toenail
   E. K-wire distal phalanx if unstable

References


