Suture-Button Device Stabilization Following Ring Finger Ray Amputation: A Comparative Cadaver Study

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Abstract

Background: The purpose of this study was to determine whether placing the suture-button device between the long and small finger metacarpals following ring finger ray amputation may better close the intermetacarpal gap and allow early range of motion without increasing the risk of malrotation than soft tissue repair alone. **Methods:** We performed ray amputation of the ring finger of 14 cadaver specimens by performing an osteotomy of the base of the ring finger metacarpal and then excising the remainder of the digit. We first performed a soft tissue repair of the transverse metacarpal ligaments and then cycled the fingers in simulated active flexion and extension on a custom computer-controlled device to re-create 6 weeks of range of motion. We then placed a suture-button device across the long and small finger metacarpals and tested the specimens again, thereby using each hand as an internal control. **Results:** The distance between the ring and small finger metacarpals was reduced following suture-button device placement compared with the initial control; this spacing was maintained following complete cycling of the fingers. The angle between the metacarpals was divergent following soft tissue repair, and then became slightly convergent after insertion of the suture-button device. None of the hands developed clinically relevant scissoring of the digits before or after application of the suture-button device. **Conclusions:** The suture-button device provides stable fixation to withstand early range of motion following ring finger ray amputation and significantly closes the gap and angle between the adjacent metacarpals without causing scissoring.

Keywords: TightRope, suture-button device, ray amputation, amputation

Ray amputation of the ring finger is indicated in select cases of trauma, infection, tumor, vascular dysfunction, recurrent Dupuytren contracture, proximal interphalangeal joint dysfunction, and congenital abnormalities of the hand.^{1,11} Although ray amputations are associated with decreased grip strength, the cosmetic appearance of the hand is often preferable to other amputation levels of the finger.^{1,8}

Multiple techniques exist for performing a ray amputation of the ring finger, from osseous transposition of the small finger metacarpal to the ring finger metacarpal base to soft tissue repair alone. The classic Bunnell procedure involves disarticulating the ring finger metacarpal at its carpometacarpal (CMC) joint and repairing the deep transverse metacarpal ligament between the remaining long and small finger metacarpal heads.¹³ The base of the small finger metacarpal then slides radially upon its articulation with the hamate.⁸

We prefer a variation of this procedure, which involves an osteotomy through the base of the ring finger metacarpal, keeping its CMC joint intact. We then repair the deep

transverse metacarpal ligament to close the gap between the adjacent digits. The remaining base of the ring finger metacarpal maintains the anatomic relationship of the CMC joints. The deep transverse metacarpal ligament repair controls the rotation and relationship of the adjacent metacarpals, but it can become lax while the adjacent soft tissues heal, necessitating immobilization for several weeks after surgery.¹⁵

The suture-button device (Mini TightRope, Arthrex; Naples, Florida) has been successful in similar cases requiring additional stability while awaiting soft tissue healing, such as in cases of trapeziectomy, longitudinal forearm instability, reconstruction of cleft foot, and hallux varus

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deformity.^{4,6,12,16} The purpose of our study was to investigate whether the suture-button device could provide sufficient stabilization to allow early range of motion following ring finger ray amputation, reliably close and maintain the intermetacarpal gap, and not produce scissoring of the adjacent digits.

Materials and Methods

Fourteen fresh-frozen adult cadaver arms were obtained through our institutional protocol. The average specimen age was 71.6 years (range: 47-93). Eleven arms were male and 3 were female. Before preparation and testing, we warmed each specimen to room temperature.

We first performed a ring finger ray amputation consistent with our current intraoperative technique. We performed an osteotomy of the ring finger metacarpal base at the junction of the diaphysis and metaphysis of the metacarpal. The extensor and flexor tendons, digital nerves, and arteries were excised, and the ray was removed in its entirety. Care was taken to maintain the deep transverse metacarpal ligaments' attachment to the long and small finger metacarpals. The deep transverse metacarpal ligaments to the long and small finger were sutured together with 3-0 Ethibond using figure-of-8 stitches. The repair was performed such that the space between the adjacent digits was closed down while maintaining physiologic rotation of the digits in flexion and extension of the digits.

Each arm was transected at the level of the distal third of the forearm. Threaded Steinmann pins were placed intramedullary from the ulna and radius across the wrist to mount the hand to a stationary jig. We sutured the flexor digitorum profundus tendons and extensor digitorum tendons to a force transducer at the level of the distal forearm. We mounted the force transducer to a computer-controlled jig that allowed for controlled simulated active flexion and extension of the remaining digits as described in prior studies.¹⁴ We cycled the fingers in flexion and extension for 2000 total cycles to simulate the initial 6 weeks of postoperative range of motion at which point early soft tissue healing would be expected to have occurred. Finger abduction and intrinsic muscle activity were not included in our model as we deemed its effect to be negligible. At the 5, 100, 500, 1000, 1500, and 2000 cycle points, the hand was examined in flexion and extension radiographically and clinically. We measured the distance between the metacarpal heads and the angle between the metacarpal shafts on fluoroscopic images at each cycle point (Insight; Hologic, Inc; Bedford, Massachusetts; Figure 1). We also examined clinical photographs taken at each cycle point for evidence of scissoring of the digits, as defined by overlap of the digits.

A 1-cm incision was then made over the ulnar aspect of the small finger metacarpal neck, and dissection was carried down to the metacarpal. The previous soft tissue repair was

Figure 1. Each fluoroscopic image was used to measure the angle between the metacarpals (red lines) and distance between the metacarpal heads (black line).

confirmed as still intact after the initial testing. This repair was left intact to simulate expected clinical use of the suture-button device as an adjunct to intermetacarpal ligament repair. The guidewire for the suture-button system was drilled from ulnar to radial in the distal third of the small and then long finger metacarpals, just proximal to the collateral recess (Figure 2). The suture-button device consists of two #2 FiberWire strands between 2 oblong stainless steel buttons that provide cortical fixation. We passed the suture-button device from ulnar to radial, and the strands were tied in maximal tension over the button on the radial aspect of the long finger metacarpal. This was all completed through the dorsal incision utilized for removing the ring finger ray. The base of the ring finger metacarpal acted as a hard stop during tightening of the sutures; that is, the suture-button device sutures were tightened until the remaining ring finger metacarpal base prevented any further tightening. No additional interpositional block was used during tensioning of the suture-button device.

Each specimen was then cycled again in flexion and extension using the same protocol as described above. Measurements were compared via paired *t* tests for each specimen between the soft tissue and suture-button device repairs, thereby using each specimen as its own internal control.

Figure 2. (a) Guide wire device passed from ulnar to radial across the distal small and long finger metacarpals followed by (b) suture-button device. No overdrilling is required. (c) Final placement of the suture-button device on fluoroscopy.

Results

Each specimen had decreased distance between the metacarpal heads in extension and in flexion following placement of the suture-button device compared with the soft tissue-alone repair (Figures 3a and 3b). This difference was statistically significant at each cycle point ($P < .05$). The baseline distance between metacarpal heads was maintained across 2000 cycles for both soft tissue-alone repair and with supplemental suture-button device fixation.

Initially, the long and small finger metacarpals diverged after soft tissue repair alone, and then slightly converged after suture-button device placement (Figures 4a and 4b). The difference in angles between the metacarpals between soft tissue repair and suture-button device placement was statistically significant at each cycle point ($P < .05$).

Upon clinical inspection, none of the specimens demonstrated scissoring with soft tissue-alone repair or with suture-button device placement. There were 2 specimens that demonstrated slight digital overlap that did not limit the range of motion and was thought to be clinically insignificant, being very similar to the degree often seen intraoperatively between the ring and small fingers (Figure 5). For these 2 specimens, the slight digital overlap was present with both soft tissue-alone repair and suture-button device fixation. Upon clinical inspection, an improvement in the cosmetic appearance of the hand was noted following placement of the suture-button device as compared with soft tissue repair alone (Figures 6a and 6b). This improvement was observed anecdotally, and a cosmetic rating system was not utilized as part of the study.

Figure 3. Average distance in millimeters between the long and small finger metacarpals in (a) flexion and (b) extension following soft tissue-alone repair and suture-button device fixation at each cycle point for all specimens. Error bars illustrate 95% confidence intervals for all specimens.

Figure 4. Average angle between long and small finger metacarpals at each cycle point in (a) flexion and (b) extension for soft tissue repair and suture-button device fixation. Note. Positive values denote divergence; negative values denote convergence. Error bars illustrate 95% confidence intervals for all specimens.

Figure 5. Image of hand following ring finger ray amputation with slight digital overlap between the long and small fingers.

Figure 6. (a) Example of specimen with fingers in flexion following soft tissue repair and (b) specimen with fingers in flexion following suture-button device placement.

Discussion

Suture-button device fixation following ray amputation of the ring finger may offer several benefits. For ray amputations in cases of trauma or malignancy, the transverse metacarpal ligament may be absent or deficient. In these situations, the suture-button device could serve in the place of the transverse metacarpal ligament repair, although we do not know whether the suture-button device alone without biological supplementation would be sufficient long term. The currently available literature on suture-button device fixation following trapeziectomy indicates that the fixation benefits of the device are maintained in the short-term period.^{10,12,19} Even if the transverse metacarpal ligament is not deficient, the added strength of the FiberWire construct can allow early range of motion.^{18,19} One report of suture-button fixation used following a long finger ray amputation was recently published, with successful results utilizing a similar intraoperative technique and allowing early motion following surgery.⁹ Recent clinical studies of the device in other reconstructions have also been encouraging.^{12,19}

We found that the suture-button device more reliably closed the gap between the remaining long and small fingers, both radiographically and clinically. It is possible that with different soft tissue suture repair techniques, we could have achieved this same gap closure, but we chose to recreate our current intraoperative technique as best as possible for this study. Indeed, this was part of the impetus for the study. In our clinical experience, we have found it difficult to achieve optimal gap closure without malrotation/scissoring and to optimize cosmetic appearance with soft tissue repair alone. We therefore wanted to investigate whether the suture-button device could allow for more reliable, easier gap closure through tensioning between the buttons without causing clinically significant scissoring. In this study, the

retained ring finger metacarpal base provided a convenient block to overtightening of the suture-button device. The suture-button device is also completely contained within the wound and does not depend upon osseous healing or temporary fixation for stability, another advantage over other techniques for ring finger ray amputation such as osseous transfer or stabilization with Kirschner wires.²⁰

Issues with the utilization of suture-button devices have been reported in the literature for the hand and lower extremity. Metacarpal fractures after trapeziectomy and suture-button suspension with the first-generation device were reported.^{7,12,19} The first generation required overdrilling of the guidewire for the device, resulting in a larger osseous defect and stress riser in the bone. The second generation of suture-button devices utilizes the guidewire for a passing device and does not require overdrilling, thereby making a smaller osseous defect which should decrease the risk of metacarpal fracture. Soft tissue reaction has been reported in association with the suture used in the first-generation device and may be an issue with the second-generation device.¹⁷ Also, the buttons may gradually erode through bone. Other reported issues with the construct include symptomatic prominence of the buttons.⁵ These issues may require secondary surgical treatment. We have experienced a few cases of subsidence of the buttons in our practice following trapeziectomy and suture-button device suspension-plasty, and incidences of erosion of the suture buttons have been reported for the suture-button device in the ankle and clavicle.^{2,3} Certainly another concern with this technique is the cost of the additional suture-button device, although it may be outweighed by a patient's earlier return to activity and work as it has been in other surgeries of the hand.¹⁹

An issue with our study design is that we did not test load-to-failure for the suture-button construct compared with suture-alone repair and therefore cannot comment as to which technique is stronger in the initial postoperative period. We did not think this would be as critical to test because surgeons may allow patients to do early range of motion following ring finger ray amputation but are unlikely to allow full unrestricted weight bearing, lifting, strengthening, or resistance activities. We also could not devise a clinically relevant method to test load-to-failure following the 2 types of repairs that we studied. Another potential criticism with our study design was our choice to first test with the suture repair and then to test the same specimens following reconstruction with the suture-button device repair. We chose this order as the specimens could then serve as their own control and we were not testing to failure. We also thought this would allow a closer approximation of typical clinical use given that surgeons would still likely prefer to have some biological tissue for this repair rather than just the artificial construct as a stand-alone whenever possible.

Future research directions following our study could include clinical trials to examine outcomes after suture-button device fixation. Researchers could also examine the

ideal placement and trajectory of the suture-button device on the metacarpals. We chose to place the device at the distal one-third of the metacarpals to mirror the anatomy of the transverse metacarpal ligaments while remaining free of the collateral ligaments and joint surface.

The suture-button device offers a source of additional fixation following ring finger ray amputation that supplements intermetacarpal fixation, providing better closure of the intermetacarpal gap and angle while still allowing range of motion in the simulated immediate postoperative period. The improved intermetacarpal gap closure following insertion of the suture-button device without increased risk of scissoring, along with maintained construct stability, provides a compelling argument for the adoption of this technique but should be balanced with the possible clinical concerns with its implementation.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Not applicable to this study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The views expressed in this article are those of the author(s) and do not reflect the official policy of the Department of Army, Department of Defense, or U.S. Government.

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