INTRODUCTION

Hand reconstruction using pedicled abdominal flaps has been a well-established procedure for many years.1-4 However, this method of reconstruction has several disadvantages, including delayed hand therapy leading to stiffness. Hence, free flaps have become the method of choice in the coverage of large complex hand defects. However, pedicled abdominal flaps for hand coverage are still being used in the current era of microsurgery. The indications for their use have been recently reviewed by Al-Qattan and Al-Qattan.5

One of the major disadvantages of pedicled abdominal flap reconstruction is stiffness of the uninjured digits. Literature is lacking regarding the feasibility, safety, and benefit of implementing immediate postoperative physiotherapy of the attached hand (before flap division).

For over 15 years, the senior author (MMA) has been designing and in-setting pedicled abdominal flaps used for hand reconstruction in adults so that physiotherapy of the attached hand was feasible. This method was applied in cases of coverage of a single anatomical area such as the coverage of a distal digital defect, a proximal digital defect, a dorsal hand defect, or a palmar hand defect.

The aim of this article is to retrospectively review 70 cases of pedicled abdominal flaps used for hand reconstruction in adults in whom physiotherapy of the attached hand was implemented. The review aims to investigate the rate of flap dehiscence, infection, hematoma, and flap edge necrosis in our cases, and to establish that physiotherapy of the attached hand is not associated with an increased risk of complications. The review also aims to establish the effectiveness of physiotherapy of the attached hand in reducing the risk of stiffness by documenting the range of motion of the uninjured digits immediately after flap division and at final follow-up.

Results: There were no cases of flap dehiscence, infection, or hematoma. Six cases had minor partial flap edge necrosis that was treated conservatively and allowed to heal by secondary intention. In 62 patients, the range of motion of the uninjured digits was 90%-100% of the normal range of motion at day 1 post-flap division, and all of these patients recovered a full range of motion (in the uninjured digits) within 2 weeks of follow-up. Eight patients were reluctant to do the exercises as instructed because of low pain threshold; 4 of these 8 patients had residual stiffness at the final follow-up.

Conclusion: The implementation of active exercises of the attached hand is feasible in selected cases and it helps minimize the risk of stiffness of the hand.

(Plast Reconstr Surg Glob Open 2021;9:e3474; doi: 10.1097/GOX.0000000000003474; Published online 24 March 2021.)

Disclosure: The authors have no financial interest to declare in relation to the content of this article. The work was funded by the College of Medicine Research Centre, Deanship of Scientific Research, King Saud University, Riyadh, Saudi Arabia.
edge necrosis in our cases to establish that physiotherapy of the attached hand is not associated with increased risk of complications. The review also aims to establish the effectiveness of physiotherapy of the attached hand in reducing the risk of stiffness by documenting the range of motion of the uninjured digits immediately after flap division and at final follow-up.

METHODS

This is a retrospective review of 70 adult patients with complex skin defects of the hand treated by the senior author over the last 15 years. All patients underwent reconstruction using pedicled abdominal flaps with implementation of immediate postoperative physiotherapy of the attached hand.

Designing and In-setting of the Flap to Allow Physiotherapy of the Attached Hand

For distal digital (tip) defects (usually done for thumb avulsion amputations), a tubed flap is used and the pedicle is made long enough to allow active flexion and extension exercises of the fingers, as shown in Figure 1.

For proximal finger defects, the flap pedicle is also made long enough to allow physiotherapy of the remaining fingers, as shown in Figure 2.

![Fig. 1. An example of a Tubed Flap for thumb tip coverage. A, The flap pedicle is long enough to allow exercises of the attached hand. B, Active finger flexion with the hand still attached. C–D, Full range of motion 2 days post-flap division.](image-url)
For dorsal hand defects, flap in-setting is done so that the ulnar border of the hand is lying on the abdomen, as shown in Figure 3.

For volar (palm) defects, the flap is designed and inset so that the hand is resting on the abdomen, with gauze at the metacarpophalangeal joints of the fingers to maintain the hand in the safe/functional position between exercises, as shown in Figure 4. For physiotherapy, the gauze is removed, and active exercises of the digits are done.

Parameters Studied

Demographic data were documented regarding gender, age, the etiology of the hand defect, the site of hand defect (a digital tip defect, a proximal digital defect, a dorsal hand defect, or a palm defect), and follow-up time.

Complications (flap dehiscence, infection, hematoma, and flap edge necrosis) were documented.

Finally, a range of motion of the uninjured digits was documented as percentage of normal range of motion (compared with the digits of the contralateral uninjured hand) both at day 1 post-flap division and at final follow-up.

RESULTS

Of the 70 patients, there were 63 men and 7 women. The mean age was 36 years (range, 20–56 years). There were 60 patients with traumatic hand defects and 10 patients with oncologic hand defects. The sites of hand defects were 20 digital tip defects, 16 proximal digital defects, 30 dorsal hand defects, and 4 palm defects. The mean follow-up of the patients was 8 months (range, 6–10 months).

There were no cases of flap dehiscence, infection, or hematoma. Six cases had minor partial flap edge necrosis that was treated conservatively and allowed to heal by secondary intention.

In 62 patients, the range of motion of the uninjured digits was 90%–100% of the normal range of motion at day 1 post-flap division; all these patients recovered a full range of motion (in the uninjured digits) within 2 weeks of follow-up (Figs. 1–3). Eight patients were reluctant to do the exercises as instructed because of low pain threshold. In these 8 cases, the range of motion of the uninjured digits at day 1 after flap division was below 60% of the normal range of motion, mainly because of stiffness of the metacarpophalangeal joints (MPJ) in extension. The differences in range of motion at day 1 post-flap division in patients who underwent physiotherapy of the attached hand versus patients who did not undergo physiotherapy were highly significant (Table 1). These patients were referred to the physiotherapy department for postoperative exercises. At final follow-up, 4 of the 8 patients recovered a full range of motion of the uninjured digits (Fig. 4), and the remaining 4 patients had residual stiffness at the final follow-up. This stiffness was noted at the MPJ in all 4 patients (mean range of motion at the MPJ was 0–70 degrees in 2 patients and 0–60 degrees in 2 patients). The fact that all cases of residual stiffness were seen in patients who did not undergo physiotherapy of the attached hand was also highly significant (Table 2).

Note should be given that we did not provide a range of motion data for the injured digits because motion in these digits is greatly affected by the degree of injury. For example, the patient shown in Figure 4 had soft tissue stiffness.
sarcoma of the thenar area, which required resection of the thenar muscles, the flexor pollicis longus tendon, both volar neurovascular bundles of the thumb, and the radial side of the palmar arch (the thumb was viable through the princeps pollicis artery). Reconstruction was done by opponensplasty, flexor digitorum superficialis tendon transfer to the distal end of the flexor pollicis longus, and nerve grafts (Figs. 5–6). The patient also had postoperative radiotherapy. In this case, a poor range of motion of the thumb (the injured digit) is expected regardless of the rehabilitation program.

**DISCUSSION**

Our article mainly aims to introduce the concept of implementation of physiotherapy of the attached hand in pedicled abdominal flap reconstruction. It is important to note that this is not feasible in all cases. The method is difficult to apply in cases with multiple digital defects and those with large combined defects involving more than 1 anatomical area. It is also difficult to apply if the abdominal flap is based on the paraumbilical perforators because of limitations of the pedicle length. Our series included only patients with complex skin defects in 1 anatomical area.

*Fig. 3.* An example of a dorsal hand defect covered with an abdominal flap. A, Flap in-setting is done so that the ulnar border of the hand is lying on the abdomen, allowing active digital extension. B, Active digital flexion is also feasible. C, Digital extension at day 1 post-flap division. D, Digital flexion at day 1 post-flap division.
area, and did not include cases covered with flaps based on the paraumbilical perforators.

We have given an overall outline of the site of hand defect and flap design. However, flap design may be modified according to the size of the defect, the vascular pedicle of the flap, and patient comfort.6,7 Physiotherapy was done daily and is supervised by the physiotherapist. The first therapy session (at the first postoperative day) was attended by the surgeon to give instructions to obtain safe exercises of the uninjured digits and to maintain the fingers in the safe position (MPJ flexion and interphalangeal joint extension).

Several authors have stressed technical tips to ensure a successful reconstruction of hand defects with pedicled abdominal flaps.4,8 These tips include adequate debridement, respect of the vascular territory of the flap, minor thinning of the flap at the margins, tubing of the flap if possible, and the use of mattress sutures or simple sutures.

Fig. 4. An example of a defect of the palm. This patient was reluctant to do physiotherapy while the hand was attached to the abdomen. She required prolonged physiotherapy following flap division, but she eventually recovered a full range of motion of the uninjured fingers at 4 months after flap division. A, Demonstration of flap in-setting. B, The hand is resting on the abdomen, with gauze at the metacarpophalangeal joints of the fingers to maintain the hand in the safe/functional position (between physiotherapy sessions). C, Full finger extension at 4 months. D, Full finger flexion at 4 months.
We applied these principles in our cases and prefer to use 3/0 polypropylene interrupted mattress sutures. Another important principle is the method of limb immobilization and maintenance of hand position after surgery to avoid kinking of the pedicle. In our cases, we made the flap pedicle long enough to allow physiotherapy, but not too long to reduce the risk of kinking of the pedicle. Previously reported methods of immobilization usually include a combination of Velcro straps and adhesive tape. We prefer a combination of an arm sling and adhesive tape, as shown in Figure 5. We divide our flaps at 18–20 days. However, techniques allowing early flap division have been described using gradual or intermittent clamping of the pedicle.

Complications of abdominal flaps in hand reconstruction are well described in the literature and range from 5% to 40%. Complications are known to be more frequently observed in elderly patients, patients with diabetics, smokers, and in the presence of infection. Furthermore, in severe hand trauma, there is a more pronounced hand edema and a higher risk of stiffness. The low rate of complications in our series is probably partly related to several favorable conditions. Most of our patients were relatively young industrial workers with no major comorbidities. Hand infection at the time of reconstruction was not present in any of our cases. Our series included only traumatic or oncologic hand defects in our anatomical area, and hence, generalized hand edema was

Table 1. Comparison of Range of Motion at Day 1 Post-flap Division in Patients Who Underwent Physiotherapy of the Attached Hand before Flap Division and in Patients Who Were Reluctant to Do the Exercises

|                                          | Patients who Underwent Physiotherapy of the Attached Hand | Patients who Were Reluctant to Do the Exercises |
|------------------------------------------|----------------------------------------------------------|-------------------------------------------------|
| Excellent range of motion at day 1 post-flap division (90%–100% of the normal range of motion) | 62                                                       | 0                                               |
| Poor range of motion at day 1 post-flap division (<60% of the normal range of motion) | 0                                                        | 8                                               |

*P* is highly significant (*P* < 0.00001) by the Fisher Exact test.

Table 2. Comparison of Residual Stiffness at Final Follow-up in Patients Who Underwent Physiotherapy of the Attached Hand before Flap Division and in Patients Who Were Reluctant to Do the Exercises

|                                          | Patients Who Underwent Physiotherapy of the Attached Hand | Patients Who Were Reluctant to Do the Exercises |
|------------------------------------------|----------------------------------------------------------|-------------------------------------------------|
| No residual stiffness at the final follow-up | 62                                                       | 4                                               |
| No residual stiffness at the final follow-up | 0                                                        | 4                                               |

*P* is highly significant (*P* = 0.0001) by the Fisher Exact test.

Fig. 5. A demonstration of our method of immobilization.

Fig. 6. Intraoperative view showing the extensive resection and reconstruction of sarcoma of the thenar area (see text for details).
not pronounced. Regardless of these favorable conditions in our series, we believe that the implementation of exercises of the attached hand was an important factor in reducing the risk of stiffness.

Stiffness of the fingers post-abdominal flap coverage is known to occur mostly at the metacarpophalangeal joints of the fingers. In most previously reported series, the hand is kept flat on the abdomen. The extended interphalangeal joints keep their collateral ligaments stretched, and hence stiffness of these joints has not been a problem. In contrast, the extended metacarpophalangeal joints develop contractures and shortening of the collateral ligaments. Acharya et al recommended immobilization of the metacarpophalangeal joints in flexion using K-wires, while the hand is attached to the abdomen, and they found a lower rate of stiffness in these patients compared with those who had no K-wires. Others have tried to divide the abdominal flap early (by gradual or intermittent clamping of the pedicle) to allow early hand physiotherapy. We believe that the implementation of active exercises of the attached hand is more attractive and a simpler option to minimize the risk of stiffness of the hand reconstructed with pedicled abdominal flaps.

**CONCLUSION**

In selected cases of pedicled abdominal flap reconstruction, the implementation of active exercises of the attached hand is feasible, safe, and helps minimize the risk of stiffness of the hand.

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