Reconstructing Weight-Bearing Surfaces: Digital Pad Transposition

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ABSTRACT: The paw pads of dogs and cats are specialized skin structures that provide cushioned, durable, weight-bearing surfaces. Otherwise normal limbs may be rendered useless when pad tissue is lost because of trauma or tumor resection. This article reviews previously described reconstructive techniques involving the movement of pad tissue into weight-bearing defects. In addition, a case series of single-stage digital pad transfer to replace all or part of metacarpal or metatarsal defects is reported. This technique was predictably successful with minimal complications in conjunction with complete tumor resection, although results in two cases of severe paw trauma were less favorable.

The paw pads of dogs and cats are specialized skin structures that provide cushioning, abrasion resistance, and traction. Loss or injury of pad tissue, despite an otherwise normal limb, can result in complete loss of limb function. This article reviews the considerations and options for paw reconstruction and 10 cases in which digital pad transposition was used to treat tumor excision or traumatic pad loss. Little information has been available regarding the long-term outcome associated with this technique. Our hypothesis was that results regarding local disease elimination, time to healing, and limb function restoration would be satisfactory in patients treated with digital pad transposition for either neoplasia or trauma.

The amount of pad tissue needed for acceptable limb function is unknown but likely depends on the weight and lifestyle of the patient. The forelimb has digital pads, a metacarpal pad, and a small non-weight-bearing carpal pad, whereas the hindlimb has digital pads and a metatarsal pad. A recent study involving greyhounds and Labrador retrievers on a pressure-sensitive walkway supported the long-held belief that the third and fourth digital pads, along with the metacarpal and metatarsal pads, are the major load bearers. It is also believed that preservation of the metacarpal and metatarsal pads greatly increases the likelihood of maintaining limb function. It has been reported that cats can bear weight adequately on an unpadded, full-thickness skin surface when confined to a carpeted house. However, in general, any viable pad tissue should be conserved when paw salvage is attempted in dogs or cats.

The decision to salvage a paw through reconstructive techniques must include evaluation of the entire patient and an understanding of abnormal forces that may result in flap or graft failure. Large patients, particularly those burdened with orthopedic or neurologic diseases in other limbs, should be strongly considered for paw salvage because limb amputation may result in poor overall ability to ambulate. Loss of pad tissue typically results from trauma (e.g., vehicular accident, bandage ischemia, frostbite, leg trap) or tumor excision. However, abnormal limb carriage due to
neurologic or orthopedic disease can also result in paw injury by increasing loads and shear forces on the tissues.\textsuperscript{4,5} Attempts to treat such wounds without addressing the underlying cause of gait abnormality are prone to failure.

**OPTIONS FOR RECONSTRUCTION**

A variety of techniques involving the transfer of durable pad tissue into areas of pad loss or weight bearing for paw salvage have been experimentally and clinically tested\textsuperscript{2,3,6–22} (Figures 1 to 4). Pad tissue can be obtained either remotely (via segmental pad grafts or microneurovascular anastomosis of a distant pad) or locally (via a flap of an adjacent pad).\textsuperscript{2,3,6–22} Pad tissue is typically obtained locally to decrease the technical demand and increase the likelihood of flap survival.

When pad tissue is unavailable adjacent to a weight-bearing defect, techniques such as segmental pad grafting or microneurovascular pad anastomosis should be considered to obtain it from afar.\textsuperscript{2,6–13} Experiments have shown that segmental pad grafts should be rectangular and placed around the wound edge. This blocks the rapid centripetal growth of thin, delicate epithelium from surrounding skin while allowing tough, keratinized epithelium from the pad grafts to grow and coalesce over the weight-bearing surface.\textsuperscript{9–11} Used in this fashion, segmental pad grafting was also shown to be effective in one trauma case report.\textsuperscript{12} A creative use of segmental pad grafting was illustrated in another report\textsuperscript{13} in which traumatically severed pads were first grafted to the cutaneous trunci muscle and then transferred back to the paw via a direct flap technique.

Another option for challenging paw salvage situations is microneurovascular pad anastomosis. This technique is technically difficult and requires microsurgical instrumentation. Flaps including the fifth digital pad of the hindlimb and the carpal pad have been successfully anastomosed into metacarpal defects.\textsuperscript{14–16}

Depending on the joint level of injury, any of the paw pads (carpal, metacarpal, metatarsal, or digital) can be transferred as local flaps to provide a suitable weight-bearing surface.\textsuperscript{2,3,6–8,11,17–22} Single-pedicle and bipedicile advancement flaps incorporating the carpal pad were described in treating a small dog and a cat that had undergone carpometacarpal amputations\textsuperscript{17,18} (Figure 1). Metacarpal pad advancement was successfully used to salvage a dog’s limb after all digits had been amputated at the metacarpophalangeal level\textsuperscript{2,19} (Figure 2).
Transposition of one or more digital pads is typically used to replace metacarpal or metatarsal pad loss\(^2,3,6-8,11,18-22\) (Figures 3 and 4). Its use has been reported in paw reconstruction of one dog with severe forelimb trauma,\(^20\) one cat with a tumor in a non-weight-bearing area of the paw,\(^21\) and four dogs with metacarpal or metatarsal pad neoplasia (three melanomas and one fibrosarcoma).\(^22\) The surgery-related outcome for most of these patients was generally good except for the fibrosarcoma patient, which underwent limb amputation as a result of incomplete tumor excision. Overall, previous reports of this technique have included few patients and limited information regarding complications and long-term follow-up. A series of 10 cases presented in the next section provides more detailed information regarding the outcome for this technique in terms of early postoperative complications, local disease elimination, time to healing, and time to limb function restoration.

**CASE SERIES**

**Case Presentations**

To obtain detailed information regarding the outcome associated with digital pad transposition, medical records from January 1993 to June 2005 at The Ohio State University Veterinary Teaching Hospital were reviewed to identify patients that underwent the procedure. Outcome information beyond that found in the records was obtained through owner interviews via telephone or electronic mail when possible. Patients included in the study underwent digital pad transposition as reconstructive treatment of a neoplastic or traumatic condition adjacent to the digital pad (typically a metacarpal or metatarsal pad lesion).

General and operative information that was collected included species, breed, age, weight, diagnosis, lesion site, concurrent orthopedic or neurologic disease, percentage of metacarpal or metatarsal pad excised, number of pads transposed, number of digits remaining after surgery, length of surgery, and number of days to discharge.

Follow-up criteria included length of follow-up, which was continued as long as possible until the patient died or the limb was amputated; presence and type of early (within 1 month of surgery) wound-related complications; whether local disease (tumor or nonhealing wound) was cured; length of time to com-
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Breed</th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Diagnosis</th>
<th>Lesion Site</th>
<th>Concurrent Orthopedic or Neurologic Disease</th>
<th>Metacarpal or Metatarsal Pad Lost or Excised (%)</th>
<th>Pad(s) Transposed</th>
<th>Digits Remaining After Surgery</th>
<th>Surgery Time (Min)</th>
<th>Days to Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Labrador retriever</td>
<td>6</td>
<td>43</td>
<td>Nonhealing wound</td>
<td>MT pad and digits</td>
<td>Bilateral hip OA</td>
<td>100</td>
<td>Third, fourth, and fifth (two gone)</td>
<td>0</td>
<td>90</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Labrador retriever</td>
<td>2</td>
<td>35</td>
<td>Nonhealing wound</td>
<td>MC pad (no third, fourth, or fifth digits)</td>
<td>None</td>
<td>33</td>
<td>Second (only digit remaining)</td>
<td>0</td>
<td>110</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Labrador mix</td>
<td>10</td>
<td>33</td>
<td>Hemangiosarcoma</td>
<td>MC pad</td>
<td>Intervertebral disk disease</td>
<td>100</td>
<td>Fifth</td>
<td>3</td>
<td>75</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>Miniature schnauzer</td>
<td>11</td>
<td>15</td>
<td>Melanoma</td>
<td>MC pad</td>
<td>None</td>
<td>33</td>
<td>Fourth</td>
<td>3</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Bouvier de Flandres</td>
<td>9</td>
<td>32</td>
<td>Melanoma</td>
<td>MC pad</td>
<td>None</td>
<td>50</td>
<td>Second and fifth</td>
<td>2</td>
<td>110</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Greyhound</td>
<td>7</td>
<td>38</td>
<td>Plasma cell tumor</td>
<td>MT pad</td>
<td>None</td>
<td>33</td>
<td>Fifth</td>
<td>3</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Mixed</td>
<td>8</td>
<td>21</td>
<td>Histiocytoma</td>
<td>Metacarpus (nonpad)</td>
<td>None</td>
<td>0</td>
<td>Fifth</td>
<td>3</td>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Labrador mix</td>
<td>11</td>
<td>45</td>
<td>Fibroma</td>
<td>MT pad</td>
<td>Bilateral hip and hock OA</td>
<td>100</td>
<td>Second</td>
<td>3</td>
<td>75</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Rottweiler</td>
<td>6</td>
<td>44</td>
<td>Melanoma</td>
<td>MC pad</td>
<td>Hip, stifle, and shoulder OA</td>
<td>33</td>
<td>Second</td>
<td>3</td>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Domestic shorthaired</td>
<td>12</td>
<td>3</td>
<td>Basal cell tumor</td>
<td>MC pad</td>
<td>None</td>
<td>100</td>
<td>Second</td>
<td>3</td>
<td>40</td>
<td>4</td>
</tr>
</tbody>
</table>

*MC* = metacarpal; *MT* = metatarsal; *OA* = osteoarthritis.
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Complete healing of the wound with no further ulceration or drainage; and length of time to resolution of obvious lameness. For comparison, follow-up data were compiled for patients treated separately for neoplastic and traumatic diseases.

A general description of the procedure for patients in the series follows: Anesthesia was provided by an injectable induction agent followed by a maintenance inhalant. Affected limbs, including the interdigital spaces, were clipped and prepared for aseptic surgery. In most cases, tourniquets were applied to improve hemostasis. All patients underwent a single-stage digital pad transposition procedure as previously described.2,3,6–8,11,18–22 First, a palmar or plantar incision was made between the lesion (wound or excised tumor) and the pad(s) to be transposed. A circumferential incision was then made around the nailbed to allow the third phalanx to be disarticulated and removed. The first and second phalanges were then disarticulated and removed via the ventral incision, taking great care to preserve the neurovascular supply of the soft tissues. Digital pads were then approximated into the defect with interrupted, absorbable, subcutaneous sutures followed by interrupted, nonabsorbable skin sutures. A protective bandage (with or without a splint) was placed postoperatively and maintained until wound healing was deemed adequate.

Table 2. Follow-up of Digital Pad Transpositions Performed at The Ohio State University

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Months of Follow-up</th>
<th>Early Complications</th>
<th>Local Disease Elimination</th>
<th>Months to Complete Healing</th>
<th>Months to Consistent Weight Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44 (died from lymphoma)</td>
<td>Severe drainage and gapping</td>
<td>No (ulceration and drainage)</td>
<td>Never</td>
<td>&lt;2</td>
</tr>
<tr>
<td>2</td>
<td>13 (last follow-up)</td>
<td>Tissue necrosis, drainage, gapping</td>
<td>No (ulceration and drainage)</td>
<td>Never</td>
<td>Never</td>
</tr>
<tr>
<td>3</td>
<td>7 (died from metastatic hemangiosarcoma)</td>
<td>Mild gapping</td>
<td>Yes</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>4</td>
<td>7 (amputation and recurrence)</td>
<td>Mild drainage</td>
<td>No (tumor recurrence)</td>
<td>&lt;1</td>
<td>Never</td>
</tr>
<tr>
<td>5</td>
<td>7 (died from metastatic melanoma)</td>
<td>Mild gapping</td>
<td>Yes</td>
<td>&lt;2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>6</td>
<td>2 (last follow-up)</td>
<td>None noted</td>
<td>Yes</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>7</td>
<td>28 (lost contact)</td>
<td>Mild drainage</td>
<td>Yes</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>8</td>
<td>5 (went blind and died)</td>
<td>None noted</td>
<td>Yes</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>9</td>
<td>1 (lost contact)</td>
<td>Mild gapping</td>
<td>Yes</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>10</td>
<td>24 (died from renal failure)</td>
<td>None noted</td>
<td>Yes</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Results

Signalment, operative, and outcome data are summarized in Tables 1 through 3. Ten patients (i.e., one domestic shorthaired cat and nine dogs) that underwent digital pad transposition were identified. Labrador retrievers (including Labrador mixes) were the most common breed (four patients) that underwent the procedure. There was one each of the other breeds, including miniature schnauzer, Bouvier de Flandres, greyhound, mixed breed, and rottweiler. The average patient age was 8 years (range: 2 to 12 years), and the average weight was 68.2 lb (31 kg; range: 6.6 to 99 lb [3 to 45 kg]).

Seven patients were treated for neoplasia of the metacarpal or metatarsal pad, including three melanomas and one each of hemangiosarcoma, plasma cell tumor, fibroma, and basal cell tumor. One patient was treated for histiocytoma of the medial metacarpal skin, and two were treated for nonhealing wounds associated with previous trauma in the area of the metacarpal or metatarsal pads.

Three patients had significant concurrent orthopedic disease, including bilateral hip osteoarthritis in a patient treated for a metatarsal pad lesion; bilateral hip and hock osteoarthritis in a patient treated for a metatarsal pad lesion; and bilateral hip, left shoulder, and left stifle
Table 3. Digital Pad Transposition as Treatment of Trauma Versus Neoplasia

<table>
<thead>
<tr>
<th>Comparison Criteria</th>
<th>Trauma</th>
<th>Neoplasia</th>
<th>All Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Mean weight (kg)</td>
<td>39</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>Mean age (yr)</td>
<td>4</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Mean metacarpal or metatarsal pad lost or excised (%)</td>
<td>67</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>Mean number of digits remaining</td>
<td>0</td>
<td>2.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Mean days to discharge</td>
<td>16</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Mean surgery time (min)</td>
<td>100</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td>Mean months of follow-up</td>
<td>29</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Local disease elimination</td>
<td>0% (0 of 2)</td>
<td>88% (7 of 8)</td>
<td>70% (7 of 10)</td>
</tr>
<tr>
<td>Complete healing within 1 mo</td>
<td>0% (0 of 2)</td>
<td>75% (6 of 8)</td>
<td>60% (6 of 10)</td>
</tr>
<tr>
<td>Complete healing within 2 mo</td>
<td>0% (0 of 2)</td>
<td>100% (8 of 8)</td>
<td>80% (8 of 10)</td>
</tr>
<tr>
<td>Consistent weight bearing within 1 mo</td>
<td>0% (0 of 2)</td>
<td>75% (6 of 8)</td>
<td>60% (6 of 10)</td>
</tr>
<tr>
<td>Consistent weight bearing within 2 mo</td>
<td>50% (1 of 2)</td>
<td>88% (7 of 8)</td>
<td>80% (8 of 10)</td>
</tr>
</tbody>
</table>

osteoaarthritis in a patient treated for a right metacarpal pad lesion. Chronic intervertebral disk disease with mild paraparesis was present in one patient treated for a metacarpal pad lesion.

Four patients had complete (100%) loss of the metacarpal or metatarsal pad, one lost 50%, four lost 33%, and one lost none. Three digital pads (third, fourth, and fifth) were transposed in one patient, two digital pads (second and fifth) were transposed in another patient (Figure 5), and one digital pad (second in four, fifth in three, and fourth in one) was transposed in the remaining eight patients. After surgery, most (seven) patients had three digits, one patient had two, and two patients (the trauma patients) had none. Surgery required a mean of 66 minutes (range: 25 to 110 minutes), and the mean postoperative hospital time was 6 days (range: 1 to 16 days).

The mean length of follow-up was 14 months (range: 1 to 44 months). Early complications included mild incisional gapping, mild to severe wound drainage, and tissue necrosis in one trauma case, which required further debridement. All early complications resolved without further surgery except in the two trauma cases. Over the follow-up period, local disease was eliminated in 70% of patients. Healing was complete within 1 month in 60% of cases and within 2 months in 80% of cases. The two trauma cases never completely healed because of recurrent ulceration and drainage. Consistent weight bearing was achieved within 1 month in 60% of cases and within 2 months in 80% of cases. Two patients (a trauma patient with low-grade, recurrent ulceration and a patient with an incompletely excised melanoma that required limb amputation) never regained consistent limb function (each experienced periods of non-weight-bearing lameness).

In the eight cases of digital pad transposition performed in conjunction with tumor excision, the results were good. Local disease was eliminated in 88% of cases, most wounds healed within 1 (75%) or 2 (100%) months, and most limbs were consistently weight bearing within 1 (75%) or 2 (88%) months. However, case number nine had only 1 month of follow-up, and case number seven involved transposition to a defect in a non-weight-bearing site (no metacarpal pad was excised).

The two trauma patients had poorer results, including longer hospital stays after surgery (16 days compared with 4 days for patients with neoplasia) and incomplete resolution of ulceration and drainage. Only one of the two patients regained consistent weight bearing in the limb despite failure to achieve complete healing. The trauma patients likely had poorer outcomes because of two major reasons: First, neither...
Figure 5. Transposition of the second and fifth digital pads to repair a metacarpal pad defect following melanoma removal (case number five).

Metacarpal pad with tumor removed and second and fifth digits filleted.

Second and fifth digital pads transposed.

Two weeks after surgery, small unhealed areas are visible proximally.

Four weeks after surgery, healing is complete.
Key Points

- One to four digital pads may be transposed into surgically or traumatologically created defects of the metacarpal or metatarsal pads.
- Salvaging an injured paw is particularly important in large patients or those with orthopedic or neurologic disease in other limbs.
- Any of the paw pads of cats or dogs can be incorporated into flaps or grafts to salvage a weight-bearing surface.

Based on this review of 10 digital pad transposition cases, most patients undergoing the technique can be expected to completely heal and regain limb function within 1 to 2 months, although patients with extensive preexistent trauma may not fare as well as those with localized disease, such as a tumor. Early complications typically are minor and resolve without further surgical treatment. When clinicians design a paw reconstruction, digital pad transposition should be considered first for defects affecting the metacarpal or metatarsal region that would benefit from additional pad tissue.

REFERENCES


ARTICLE #2 CE TEST

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I. The major weight-bearing pads of the forelimb are digital pads
   a. III and IV.
   b. II and III.
   c. III and IV and the metacarpal pad.
   d. II, III, IV, and V.
2. Which pads may be incorporated into a flap to provide weight-bearing tissue?
   a. digital pads II, III, IV, and V   c. the metacarpal pad
   b. the carpal pad   d. all of the above

3. Regarding free pad grafts, which configuration has been recommended?
   a. rectangular grafts randomly dispersed over the defect
   b. rectangular grafts placed around the defect
   c. small circular grafts placed around the defect
   d. small circular grafts randomly dispersed over the defect

4. Which has(have) reportedly been transferred to a weight-bearing defect via microneurovascular anastomosis?
   a. the carpal pad
   b. the metatarsal pad
   c. digital pad V of the hindlimb
   d. a and c

5. Based on the case series in this article, which statement regarding digital pad transposition following tumor excision is incorrect?
   a. Minor complications such as incisional gapping typically resolve without surgical intervention.
   b. In most cases, consistent weight bearing returns within 1 month.
   c. Amputation of more than one digit results in poor limb function.
   d. Most incisions heal completely within 2 months.

6. Which statement regarding digital pad transposition is incorrect?
   a. Patients with concurrent orthopedic or neurologic disease are poor candidates because of increased risk for complications.
   b. A bandage should be placed for several weeks after surgery to provide protection and structural support during the healing process.
   c. Long-term complications include recurrent ulceration and drainage.
   d. Digital pads may provide an acceptable weight-bearing surface following excision of the entire metacarpal or metatarsal pad.

7. Factors that may negatively impact the outcome of patients undergoing digital pad transposition include
   a. incomplete excision of diseased tissue.
   b. loss of all digits on the paw.
   c. deep infection.
   d. all of the above

8. Which statement regarding the need to preserve pad tissue to ensure adequate limb function is incorrect?
   a. Any viable pad tissue should be conserved when paw salvage is attempted in both dogs and cats.
   b. Preservation of the metacarpal or metatarsal pad greatly increases the likelihood of maintaining limb function.
   c. Cats and small dogs can achieve adequate limb function with just an epithelialized distal paw surface.
   d. An unpadded, full-thickness skin surface over the distal paw is satisfactory for adequate weight bearing in cats confined to carpeted houses.

9. In this and previous reports of digital pad transposition, the most common pad tumor requiring pad reconstruction is
   a. melanoma.
   b. plasmacytoma.
   c. fibrosarcoma.
   d. basal cell tumor.

10. The most common short-term complications following digital pad transposition in this case series include
    a. infection and gapping.
    b. self-trauma and hemorrhage.
    c. gapping and drainage.
    d. pad necrosis and hemorrhage.