Minimally Invasive Dorsal Cheilectomy of the First Metatarsal: A Cadaveric Study

Kar Hao Teoh, FEBOT, FRCS (T&O)1, Esten Konstad Haanaes, MD2, Saud Alshalawi, MD3, Hiro Tanaka, FRCS (T&O)1, and Kartik Hariharan, FCRS (I), FRCS (T&O)1

Abstract

Background: Minimally invasive dorsal cheilectomy (MIDC) for hallux rigidus is gaining in popularity. The optimal position for the stab incision for MIDC is dorsomedial to allow an ergonomic sweeping movement of the burr, potentially putting the dorsomedial cutaneous nerve (DMCN) to the hallux at risk. We aimed to quantify the risk of using this minimally invasive technique with a cadaveric study.

Methods: A total of 13 fresh-frozen cadaveric specimens amputated below the knee were obtained for this study. After the procedure, the specimens were dissected, and structures were inspected for damage.

Results: The DMCN to the hallux was cut completely in 2 specimens (15%). All the extensor hallucis longus tendons were intact, although in 1 specimen, the tendon showed some fraying on the underside of the tendon. The average distance of the stab incision from the first metatarsophalangeal (MTP) joint was 17.7 (range, 10-23) mm. The relationship of the DMCN to the stab incision was variable. The average distance of the DMCN to the incision was 3.8 (range, 0-7) mm. The danger zone for damaging the DMCN was at one-third the length of the first metatarsal proximal to the first MTP joint.

Conclusion: The DMCN has been well studied by several authors and has a variable course. This nerve was damaged in 15% of our specimens following MIDC.

Clinical Relevance: We believe patients should be made aware of this risk when considering surgery. A carefully made working capsular pocket for the burr and marking this nerve before making the incision if palpable could mitigate this risk.

Keywords: dorsomedial cutaneous nerve, hallux rigidus, minimally invasive, percutaneous, dorsal cheilectomy, cadaveric

Hallux rigidus is a degenerative condition of the first metatarsophalangeal (MTP) joint, usually characterized by a dorsal osteophyte. It typically results in impingement pain and limitation of movement of the first MTP joint. Following failure of conservative treatment, a dorsal cheilectomy can be performed for patients in early stages of hallux rigidus. A cheilectomy can provide relief of their symptoms provided that it mainly consists of impingement pain and stiffness in the absence of mid-range pain and a negative grind test. In Coughlin and Shurnas’s landmark series of 93 feet undergoing cheilectomy with a mean follow-up of 9.6 years, they noted a 92% success rate in terms of pain relief and function. Roukis12 performed a systematic review of isolated cheilectomy of the first MTP joint and concluded that the overall rate for revision surgery was 8.8%.

Minimally invasive forefoot surgery is becoming more popular with advances in technology. Traditionally, a dorsal cheilectomy is performed with an open approach through a dorsomedial or midmedial incision. It is possible to perform minimally invasive dorsal cheilectomy (MIDC) of the first metatarsal with a wedge burr. The proposed benefits of a minimally invasive operative procedure over traditional open surgery are smaller incisions, thus minimizing soft tissue disruption; less operative morbidity; better cosmesis; and a potentially shorter recovery period.

The stab skin incision for MIDC is usually made over the dorsomedial aspect of the first metatarsal with a beaver blade, proximal to the medial eminence. The incision must allow sufficient access to the dorsal osteophyte and avoid the dorsomedial cutaneous nerve (DMCN) to the hallux. It

1Foot and Ankle Unit, Ysbyty Ystrad Fawr, Ystrad Mynach, Hengoed, UK
2St Olav’s Hospital, Trondheim, Norway
3Prince Sultan Military Medical City, Riyadh, Saudi Arabia

Corresponding Author:
Kar Hao Teoh, FEBOT, FRCS (T&O), Ysbyty Ystrad Fawr, Ystrad Mynach, Hengoed CF82 7EP, UK.
Email: karhao@gmail.com
is recommended to mark this nerve before making the incision, if palpable. The DMCN supplies the sensation to the medial side of the hallux. Anatomical studies have shown the risk to this nerve when performing operative incisions around the great toe.\textsuperscript{3,8,13} It is suggested by Solan et al\textsuperscript{13} that a dorsomedial incision is more likely to damage the DMCN, while the midmedial incision was safer in their cadaveric study because it lies midway between the dorsal and planter digital branches.

The DMCN can be difficult to identify in minimally invasive surgery, unlike open surgery. The stab incision for MIDC ideally needs to be dorsomedial to allow an ergonomic sweeping movement of the burr over the dorsal cortex of the first metatarsal to remove the osteophyte and to gain adequate access for the more laterally lying osteophyte. This could potentially put the DMCN at significant risk. There have been no clinical or cadaveric studies to date quantifying the risk to the DMCN and the surrounding structures when a wedge burr was used for MIDC. We aimed to assess this risk by using fresh-frozen cadaveric specimens in a “high-risk” situation in which most of the surgeons were novices to the technique and working out of a safe zone for this technique.

**Materials and Methods**

A total of 13 fresh-frozen cadaveric specimens amputated below the knee were obtained for the present study. This study was performed during a training session conducted by Wright Medical (Memphis, TN). The participants were 11 consultant orthopaedic surgeons and 1 foot and ankle fellow who were inexperienced in minimally invasive (MI) surgery, as well as 1 experienced demonstrator. After a demonstration by an experienced MI surgeon and a practice on sawbones by participants, each surgeon performed a MIDC over the first metatarsal. Fluoroscopic guidance was available throughout the procedure.

Seven right and 6 left feet were dissected after completion of the MI dorsal cheilectomy. Thirteen different surgeons performed the procedure. Eleven of the surgeons were using an MI burr for the first time, one for a second time. The other surgeon was the demonstrator, who was a pioneer of MI foot surgery in Europe. Two surgeons were left-handed and the rest were right-handed.

**Operative Technique**

The stab skin incision was made over the dorsomedial aspect of the first metatarsal with a beaver blade, proximal to the medial eminence. A working pocket for the burr was made using a periosteal elevator to carefully lift the capsule from the metatarsal head. A 3.1-mm wedge burr (Wright Medical) was inserted into the working portal and a dorsal cheilectomy was performed (Figure 1).

![Figure 1. The 3.2-mm wedge burr used in the study.](image)

The burr was set to high torque but low speed, similar to any minimally invasive surgery of the foot. Fluoroscopic guidance was used to ensure an adequate amount of bone was removed.

**Dissection**

After the procedure, the specimens were carefully dissected by the 2 junior authors, and the DMCN to the hallux and the extensor hallucis longus (EHL) were inspected for damage. The same dissection steps were used for each specimen. The dorsum of the foot was exposed using the midmedial incision described by Solan et al.\textsuperscript{13} This incision was made midway between the plantar and dorsal margins of the first metatarsal, and this was extended proximally to identify the main trunk of the superficial peroneal nerve proximally. The nerve was followed distally to its terminal branches. Both junior authors inspected all the specimens for damage independently. Any anatomic variation of the dorsomedial cutaneous nerve to the hallux was noted. The relationship of the nerve to landmarks was measured. All measurements were made to the nearest millimeter with a caliper. We expressed the distance of the incision from the first MTP joint as a ratio of the first metatarsal length to standardize it as the length of the metatarsal was variable.

**Results**

Dissection of the specimens revealed that the dorsomedial cutaneous nerve to the hallux was cut completely in 2 specimens (15%). All the EHL tendons were intact, although in 1 specimen, the tendon showed some fraying on the underside of the tendon, estimated to be 15%.

The average distance of the incision made by the beaver blade was 17.7 (range, 10-23) mm from the first MTP joint. In terms of the relationship of the DMCN to the incision, the DMCN was superior to the incision in 5 specimens and inferior to the incision in 6 specimens where the DMCN was not cut (Figures 2 and 3). The average distance of the dorsomedial cutaneous nerve to the incision was 3.8 (range, 0-7) mm. The average first metatarsal length was 63.4
Teoh et al

(58-72) mm. Table 1 summarizes the findings in the 13 feet. The relationship between the distance of the incision to the DCMN and the ratio of incision from the first MTP joint to length of the first metatarsal is shown in Figure 3. The nerve crossed the EHL tendon proximal to metatarsocuneiform joint at an average of 11.5 (0-21) mm. The gap between the EHL and DMCN at the first MTP joint was 12 (8-16) mm.

Discussion

The course of the DMCN to the hallux has been well studied and described by several authors. The DMCN arises from the medial dorsal cutaneous nerve (MDCN) of the superficial peroneal nerve and has a variable course.1,8 Damage to the DMCN is a commonly reported complication following hallux surgery, with the incidence of nerve damage reportedly as high as 45%.1,5 This can lead to sensory loss to the medial side of the hallux and a painful scar. Formation of a neuroma can be severely disabling for the patient, which can be difficult to treat, and prevention has been advocated as the best option.9

Several authors have studied the position of the DMCN in relation to the EHL tendon, the nailbed, the first MTP joint, and the sentinel vein to reduce the risk of damage to the DMCN.2,6,13 Anatomical structures are not visualized or dissected when performing MI surgery. It might not be possible to use these references unlike in open surgery. A recent cadaveric study looked at increasing the safety of minimally invasive hallux surgery using the clock method with the medial border of the EHL as a reference point corresponding to 0 degrees.7 They found that the DMCN was between 12 o’clock and 2 o’clock, corresponding to 0 and 60 degrees in a right foot, and between 10 o’clock and 12 o’clock, corresponding to 300 and 360 degrees in a left foot. This corresponds to where the dorsomedial stab incision for MIDC will be placed and would not be a particularly useful landmark in our opinion.

Makwana et al6 showed that there is a consistent anatomical relationship between a sentinel superficial vein and the DMCN. This sentinel vein was found to be transversely placed and about 2 cm proximal to the distal margin of the MTP joint. The DMCN lies immediately deep and distal to this sentinel vein. They reported that identifying this vein can be helpful in reducing the risk of nerve damage occurring during surgery. However, it is not possible to identify this vein without operative exploration. A recent study suggested it is possible to use in vivo imaging by a near-infrared vascular imaging system of this sentinel vein prior to incision.10 This is a possibility in MI hallux surgery, but the cost of acquiring this imaging system can be expensive. Another possibility would be to perform MIDC without a tourniquet. If there is obvious venous bleeding with the stab incision, it might alert the surgeon that the incision is close to the DMCN. However, it is not possible to prove this theory in cadaveric studies.

A dorsomedial stab incision allows an ergonomic sweeping movement of the burr. The ideal stab incision for the burr would be midmedial, as per Solan et al,13 to avoid DMCN damage, but it is difficult to access the dorsolateral part of the osteophyte with a midmedial stab incision. This will likely mean an additional dorsolateral incision to access the dorsolateral part of the osteophyte. This incision is not without risk as the dorsolateral digital nerve was found consistently between 10 o’clock and 12 o’clock in a right foot and 12 o’clock and 2 o’clock in a left foot.7

Figure 2. A dissected specimen showing the dorsomedial cutaneous nerve (DMCN) is above the incision (black arrow = working pocket for burr made in capsule from stab incision; white arrow = DMCN).

Figure 3. A dissected specimen showing the dorsomedial cutaneous nerve (DMCN) is below the incision (black arrow = working pocket for burr made in capsule from stab incision; white arrow = DMCN).
One of the most important findings of this study is that the danger zone for damaging the DMCN is at one-third the length of the first metatarsal from the first MTP joint. The DMCN was cut in both specimens at this point (Figure 4). However, we could not prove whether it was cut by the beaver blade or wedge burr. It might be worth marking this point and making the incision more distal or proximal to this point to avoid the DMCN. The DMCN was reasonably close to the stab incision in most cases (range, +6 mm to −7 mm). We recommend that the surgeon should try to palpate the DMCN if possible and mark it prior to making the stab incision (Figure 5). It is imperative to make a good periosseal elevation for the working pocket to prevent damage to the DMCN and EHL.

Table 1. Findings in the 13 Feet Cadaveric Specimens Following Minimally Invasive Dorsal Cheilectomy.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Side</th>
<th>Length of First Metatarsal, mm</th>
<th>Distance of Incision to First MTPJ, mm</th>
<th>Percentage of Incision to First MTPJ to Length of First Metatarsal</th>
<th>Incision in Relationship to DMCN</th>
<th>Distance From Incision to DMCN, mm</th>
<th>DCMN Intact</th>
<th>EHL Intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Right</td>
<td>62</td>
<td>21</td>
<td>33.9</td>
<td>Above</td>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Left</td>
<td>63</td>
<td>22</td>
<td>34.9</td>
<td>Below</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Right</td>
<td>71</td>
<td>23</td>
<td>32.4</td>
<td>NA</td>
<td>2</td>
<td>No</td>
<td>Yes (85%)</td>
</tr>
<tr>
<td>4</td>
<td>Left</td>
<td>63</td>
<td>18</td>
<td>28.6</td>
<td>Above</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Left</td>
<td>65</td>
<td>19</td>
<td>29.2</td>
<td>Above</td>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Right</td>
<td>60</td>
<td>15</td>
<td>25.0</td>
<td>Below</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Left</td>
<td>72</td>
<td>12</td>
<td>16.7</td>
<td>Below</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Right</td>
<td>61</td>
<td>10</td>
<td>16.4</td>
<td>Above</td>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Left</td>
<td>58</td>
<td>18</td>
<td>31.0</td>
<td>NA</td>
<td>2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Right</td>
<td>60</td>
<td>11</td>
<td>18.3</td>
<td>Below</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>Left</td>
<td>59</td>
<td>21</td>
<td>35.6</td>
<td>Below</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Right</td>
<td>70</td>
<td>19</td>
<td>27.1</td>
<td>Above</td>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Right</td>
<td>62</td>
<td>21</td>
<td>33.9</td>
<td>Below</td>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Abbreviations: DMCN, dorsomedial cutaneous nerve; EHL, extensor hallucis longus; MTPJ, metatarsophalangeal joint; NA, not applicable.

**Figure 4.** The relationship between metatarsal length in percentage and distance of dorsomedial cutaneous nerve (DMCN) from incision (mm) (positive indicates DMCN was above incision, negative indicates DMCN was below incision).

**Figure 5.** Clinical picture showing marking of the dorsomedial cutaneous nerve (DMCN) after palpation (dotted line) and incision (the cross).

**Conclusion**

The DMCN has been well studied by several authors and has a variable course. This nerve was cut in 15% of our specimens following MIDC by surgeons with no experience with the MIDC. We believe patients should be made aware of this risk when considering surgery. A carefully made working capsular pocket for the burr and marking this nerve before placing the incision if palpable could mitigate this risk. The danger zone for damaging the DMCN was at one-third the length of the first metatarsal from the first MTP joint.

**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. ICMJE forms for all authors are available online.
**Funding**

The author(s) received no financial support for the research, authorship, and/or publication of this article.

**ORCID iD**

Kar Hao Teoh, FEBOT, FRCS (T&O), https://orcid.org/0000-0002-1538-8760

**References**