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UEMURA T., et al. (2019). Nerve capping technique with nerve conduit for treating painful digital neuroma: A case report. *Journal of Orthopaedic Science*. 27, 284-287. doi:10.1016/j.jos.2019.02.012

Nerve capping technique with nerve conduit for treating painful digital neuroma: a case report

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Key words: nerve conduit; neuroma; digital nerve; capping; pain

Abstract

Amputation neuromas of the digital nerves cause intolerable pain and the treatment remains challenging. Recently, a nerve capping treatment for painful neuroma using nerve conduits has been introduced in basic research, analyzing the role of several pain-related factors. Here, we report the first clinical case of a 41-year-old female with a painful digital neuroma treated successfully by the nerve capping technique using a collagen nerve conduit. Intraoperatively, the digital nerve was amputated and formed neuroma with scarring adhesion, but the distal nerve stump was absent. After removal of the neuroma, the nerve stump was pulled to the proximal end of the nerve conduit while the distal end of the nerve conduit remained open. After the 16-month follow-up, the scores of the pain Visual Analogue Scale and the patient-reported outcomes were significantly improved. The nerve capping technique with nerve conduit after neurectomy could successfully be applied clinically for pain relief caused by digital neuromas.

Introduction

Amputation neuromas of the digital nerves can cause intolerable severe pain and seriously affect the patient's daily life. Although various surgical treatments for painful neuromas of the digital nerves have been reported, none of them has been established as the gold standard treatment(1). Resection of the neuroma in the upper and lower extremity and implantation of the nerve stump into the muscle or the bone is widely used to treat painful neuromas with 82% to 90% successful pain relief but its effectiveness for treating digital neuromas is limited, with only 14 % success rate in one series(2-5). Capping the transected nerve with an autologous vein or covering it with a vascularized flap such as the reverse vascular pedicle digital island flap are other useful procedures with 70% to 87% successful pain relief, but the venous lumen can easily be collapsed in the vein capping and vascularized flap is technically difficult with the risk of donor-site morbidity(6-9).

Recently, bioabsorbable artificial nerve conduits are widely used for the treatment of posttraumatic peripheral nerve defects as an alternative to autologous nerve graft repair(10). In basic research, some nerve conduits have been applied as a capping

device for the treatment of painful neuromas. Capping the nerve stump with a nerve conduit in addition to resection of the neuroma successfully prevented the re-occurrence of neuromas and suppressed neuropathic pain(11-14). However, few studies have reported the clinical application of nerve conduits as nerve capping devices for the treatment of neuromas, and those involved only cases in the foot and the ankle in English literature(15). Here, we report the first clinical case of a painful digital neuroma treated successfully by the nerve capping technique with a nerve conduit.

Report of the case

A 41-year-old female, who regularly carried heavy loads, had undergone excision of a recurrent fibroma in the right middle finger. Since the operation, she had suffered from intolerable pain and tingling sensation with touching on the middle finger pulp (Figure 1). The pain Visual Analogue Scale (VAS) was 62 mm on the pulp of the middle finger at rest and 100 mm at tenderness on pressure of the distal interphalangeal joint. X-ray showed no bone atrophies, but both magnetic resonance imaging and ultrasonography images showed neuroma of the radial digital nerve at the distal interphalangeal joint of

the middle finger. Based on these findings, the patient was diagnosed with symptomatic painful neuroma of the digital nerve due to digital nerve amputation associated with excision of a soft tissue tumor in the middle finger.

One year after the operation, neurolysis of the digital nerve was performed under a microscope using the Brunner incision. Intraoperatively, the digital nerve was ruptured and lacerated completely at the distal part of the distal interphalangeal joint (Figure 2). Subsequently, the nerve stump formed a slightly bulb-like neuroma with severe adhesion to surrounding tissues. The distal nerve stump was absent. Hence, the neuroma was removed by neurectomy at the proximal site of the neuroma, and the transected nerve stump was capped with a collagen nerve conduit (RENERVE (NIPRO, Osaka, Japan))(16). Histologically, the random axon sprouting was found in the slightly bulb-like neuroma. The nerve conduit as long as possible was desirable, because nerve fibers grew out across the nerve conduit and new neuroma might reform outside the nerve conduit if the nerve conduit was too short. After removal of the neuroma, the remaining distances between the nerve stump and the distal end of the finger were about 14mm. The nerve conduit was 16 mm long to prevent dislocation of the nerve stump

and was 2 mm in diameter which was wider than the digital nerve with a diameter of 1.5 mm. The nerve stump was pulled into the proximal end of the nerve conduit by a length of 2 mm and sutured together with 8-0 nylon suture on the lumen wall. The distal end of the nerve conduit remained open with stay sutures to the surrounding tissue. Thus, capping of the nerve was secured with less tension during finger movement.

The middle finger was immobilized in a splint for 3 weeks. Afterwards, a range of motion exercises were started. The nerve conduit was gradually absorbed without new neuroma until 6 months after implantation as assessed via ultrasonography (Figure 3). After the 16-months follow-up, pain VAS was reduced to 10 mm at rest and 32 mm at tenderness on pressure of the distal interphalangeal joint. The tingling sensation with touching on the middle finger pulp also was relieved with the full range of motion of the finger. The quick Disabilities of the Arm, Shoulder and Hand (DASH) Scores improved from 43 preoperatively to 20 postoperatively and Hand 20 scores from 48 to 17. The patient was able to hold a pencil and carry loads easily.

Discussion

The treatment of neuroma remains challenging, although numerous surgical procedures have been described for the management of neuroma-induced neuropathic pain(1, 17). The established strategy for treatment of painful neuromas is shortening of the nerve and capping or covering the nerve stump(7, 12). It is necessary to cover the nerve stump after removal of the original neuroma to protect the nerve stump from scarring or external stimuli and prevent the formation of a new neuroma(18). Recently, bioabsorbable nerve conduits have been demonstrated to protect the transected nerve stump from surrounding scar or irritation by blocking external axonal fibers from scarring and adhesion and reducing inflammation in a rat sciatic nerve adhesion model(19). The postoperative DASH patient-reported outcome in the present case was equivalent to the results of neuroma excision and transposition into muscle or bone in the previous report that the postoperative mean DASH scores were 22.4 in 11 patients treated with neuroma excision and transposition into muscle or bone but 32.0 in 17 patients treated with simple excision(20).

Many authors have reported the successful application of nerve conduits for the clinical treatment of painful neuromas, but most of the nerve conduits were used in the

nerve gaps caused by the removal of the neuromas as interposition grafting between the proximal and distal ends of the nerves(21, 22). To our knowledge, there has been just one report about applying the nerve capping technique of only the proximal nerve stump using nerve conduits after neurectomy of neuromas(15). Gould et al reported on 69 painful neuromas of the foot and ankle in 50 patients that were successfully treated by simple excision of the neuroma and capping of the proximal nerve stump with collagen conduits(15). There have been no reports about digital neuromas treated by the nerve capping technique with nerve conduits.

In 2017, NEUROCAP (POLYGANICS, Groningen, Netherlands) has become commercially available as a peripheral nerve capping device targeted for the surgical treatment of neuromas in Europe and the United States. NEUROCAP is a bioabsorbable tubular device with one open end and one closed end, which is composed of an existing nerve conduit product, NEUROLAC (POLYGANICS, Groningen, Netherlands)(23). Although the clinical results of NEUROCAP have not been published yet, the STOP Neuroma Trial, a global multicenter post-marketing trial, investigating the long-term efficacy and results of NEUROCAP in upper and lower limb-end neuroma has just been

progressed.

In 1977, Swanson et al published a nerve capping technique with silicone tubes for the treatment of amputation neuromas both in animal and clinical studies involving 56 peripheral nerves in the upper and lower extremities(24). Okuda et al revealed the therapeutic effect and the detailed pain relief mechanism of a silicone tube covering the proximal nerve stump after neurectomy of the neuromas in rats with regard to the expression of nerve growth factor and TrkA(13). However, today, silicone capping is rarely performed due to poor results, as the caps become dislodged and nerve fibers grow out through the loose proximal opening(6, 25). Silicone is also a foreign material that will not dissolve in the body. On the other hand, the nerve conduit used in the present case was very soft, biocompatible and bioabsorbable and had different size variations to cap the nerve stump appropriately without dislodgement of the capping. With the development of bioabsorbable nerve conduits for peripheral nerve repair, more researchers have investigated the effectiveness and the pain-relief mechanism of the nerve capping technique with nerve conduits in the treatment of neuromas in animal models, regardless of the material type of nerve conduits(11-14, 26). The studies

demonstrated that several pain-related factors such as c-fos, substance P, sigma-1 receptor, and alpha-smooth muscle actin in the local nerve or the spinal cord were notably suppressed by nerve capping with a nerve conduit(14, 26, 27).

The nerve conduit used in the present case consisted of collagen and was absorbed completely until 6 months after implantation(16). Further considerations will be needed to evaluate the long-term therapeutic effect of nerve capping with a nerve conduit. Nevertheless, the nerve capping technique with a nerve conduit after neurectomy could successfully be used in clinics to relieve pain caused by digital neuromas.

Source of support

None.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgments

None.

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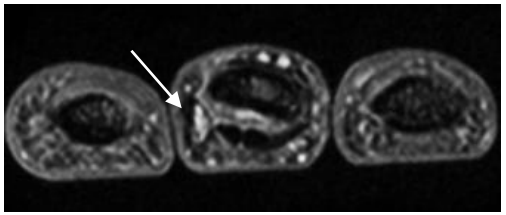
Figure captions

Figure 1. A. Preoperative gross appearance of the right middle finger. B. The high-intensity area as detected by magnetic resonance imaging showed neuroma of the digital nerve (arrow). C. Hypo-echoic areas in ultrasonography images showing neuroma of the radial digital nerve (asterisk).

Figure 1

A

B



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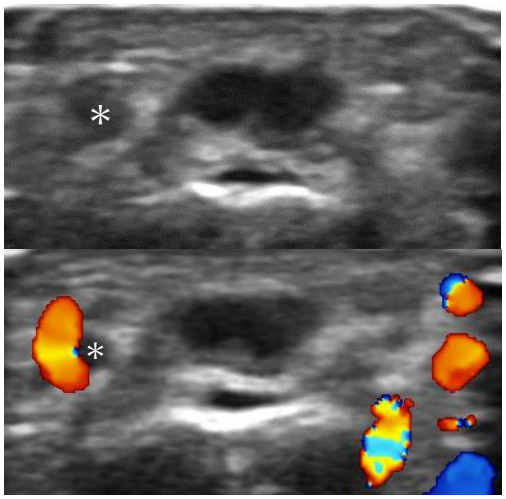
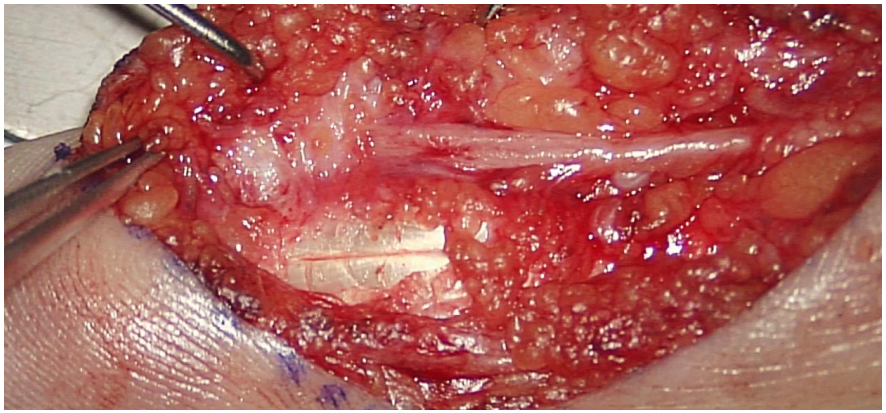


Figure 2. A. The amputated and lacerated digital nerve. B. The neurolyzed digital nerve with the slightly bulb-like neuroma (black arrowhead). C. Hematoxylin and eosin staining of the resected neuroma. D. The nerve conduit capping the transected nerve stump.

Figure 2

A



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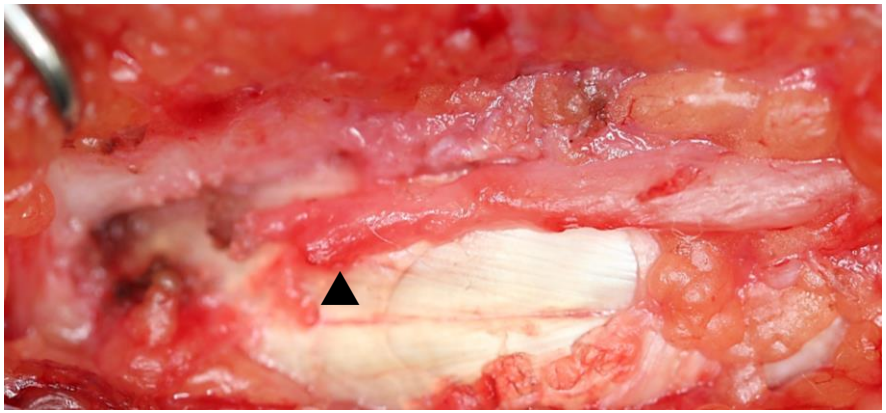

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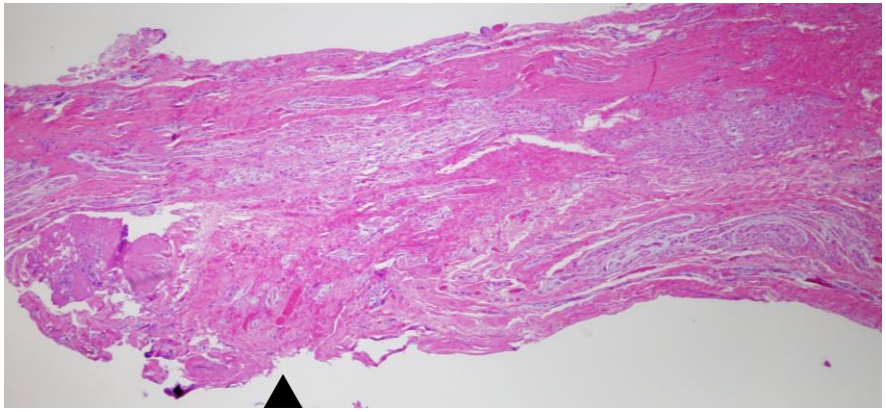

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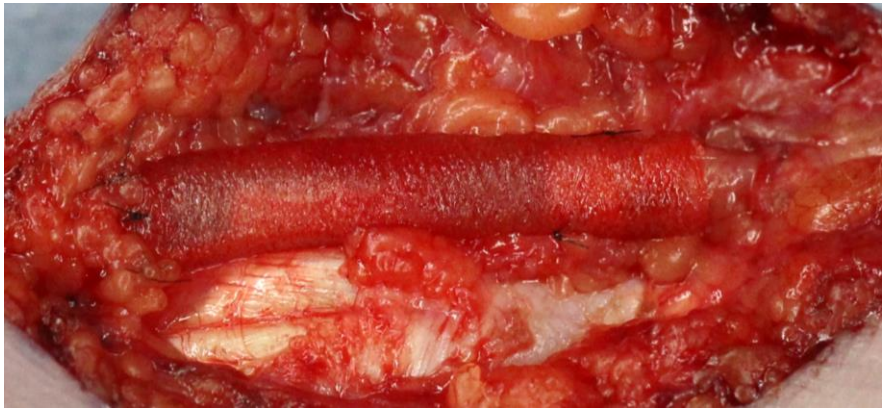
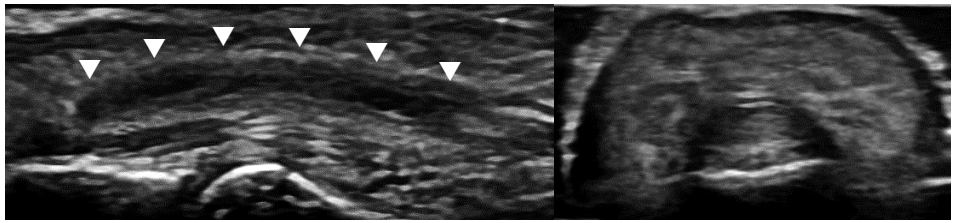


Figure. 3. Postoperative ultrasonography images of the nerve conduit at 1 month (A), 2 months (B), and 6 months (C) after surgery. Arrowhead and arrow showing the biodegradable nerve conduit and disappearance of the neuroma respectively.

Figure 3

A



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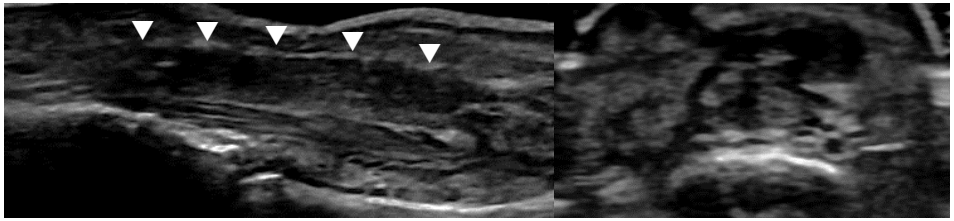

C