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Dorsal suspension for Morton's neuroma: A comparison with neurectomy

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ABSTRACT

Background: The purpose of this study was to investigate and compare the clinical outcomes of dorsal suspension with those of neurectomy for the treatment of Morton's neuroma.
Methods: We conducted a retrospective study of dorsal suspension and neurectomy group. The dorsal suspension was performed by dorsal transposition of neuroma over the dorsal transverse ligament after neurolysis. The visual analog scale (VAS), the Foot and Ankle Ability Measure (FAAM), postoperative satisfaction, and complications were evaluated.
Results: Both groups reported significant pain relief, and there were no significant differences between the groups with respect to postoperative pain. The postoperative FAAM outcomes showed no significant between-group differences. Satisfaction analysis showed 'excellent' and 'good' results in the dorsal suspension and neurectomy groups (95% and 77.7%, respectively). Complications of numbness and paresthesia reported in the dorsal suspension group (5% and 5%, respectively) were significantly fewer than those of neurectomy group (61.1% and 33.3%, respectively) (both, $p < .05$).
Conclusions: With its favorable results, dorsal suspension can be another operative option for the treatment of Morton's neuroma.
Level of Evidence: Level III, retrospective comparative case series.

1. Introduction

Moron's nenroma is a common painful syndrome of the forefoot, which most commonly affects in the third or second web space [1,2]. The first report of the neuroma dates back to 1835 by Civinni, and later by Morton in 1876 [3,4]. The aetiology and pathogenesis of Morton's neuroma remain controversial and it is better referred to as Morton's metatarsalgia [2]. Possible aetiologic factors which have been proposed are chronic repeated trauma [5], ischaemia [6], intermetatarsal bursitis [7], and entrapment neuropathy [8]. The study of Gauthier [8] and Graham [9] led to the belief that Morton's neuroma is a nerve entrapment syndrome involving the DTML [2].

After the report of successful neurectomy results by Betts in 1940, neurectomy has been a standard operative technique for the treatment of Morton's neuroma [6]. Neurectomy showed good results in terms of pain reduction and functional outcomes; however, several studies have reported persistent tenderness, numbness, paresthesia of the involved interspaces, and significant restriction of footwear postoperatively [10]. The cause of both numbness and paresthesia after neurectomy is a "true neuroma", and it is formed by resection of the common digital nerve [11]. Many researchers have commented that the term Morton "neuroma" is a misnomer since it is not actually a tumor, histologically [9,12,13].

Researchers have demonstrated significantly improved or similar results of other techniques compared with neurectomy. Colgrove et al. [14] and Rungprai et al. [15] reported that transposition of the transected interdigital nerve into an intermuscular position provided significantly better long-term results than did neurectomy. However, the evaluation of postoperative numbness was not included in the studies. During the postoperative follow-up period, we often observed cases with complications such as numbness and paresthesia after neurectomy. Based on several studies, the success of neurectomy rarely exceeds 83% [2,10,16–19]. We concluded that transection stump neuroma causes such symptoms and unsatisfactory result, therefore made effort to develop a new operative technique without an excision procedure.

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There is no other peripheral entrapment neuropathy in the human body treated primarily through nerve excision [20]. Decompression procedures have been the mainstay for all other cases of human entrapment neuropathy. In 1979, Gauthier [8] first proposed Morton's neuroma as an entrapment neuropathy and reported symptom improvement in 83% of cases treated with only release of the DTML without nerve excision. Dellon [21] found that 80% of the patients obtained relief with the procedure. However, we considered decompressed neuroma without a dorsal suspension procedure would be unstable between adjacent metatarsal heads. Furthermore, previously sectioned DTML and adjacent soft tissue might repair itself [22,23]. Mann and Reynolds [2,23] have contended that the presence of reformed fibrous ligamentous tissue between metatarsal heads after previous operation argues against simple division of the DTML as the sole treatment for Morton's neuroma. The regenerated soft tissue may compress the neuroma again. Vito et al. [22] reported good results of decompression and a relocation procedure, which were performed by release of the DTML and fixation of a dorsally relocated neuroma by suture of the epineurium to a periosteum of the adjacent metatarsals. However, these procedures have limitations, in that suture of the epineurium can damage the perineural structure.

We hypothesized that decompression and dorsal suspension of neuroma using the dorsal transverse ligament may have favorable results with fewer complications, such as numbness or paresthesia, compared with neurectomy. There is a lack of literature that reports results of dorsal suspension of Morton's neuroma using the dorsal transverse ligament.

The purpose of this study was to investigate and compare the functional outcomes and complications of dorsal suspension versus neurectomy.

2. Material and methods

2.1. Study design

From June 2011 to May 2013, forty-eight patients underwent neurectomy, and from June 2013 to October 2015, forty-six patients underwent dorsal suspension for the treatment of Morton's neuroma that was refractory to conservative treatment. Each patient's medical notes, which included pre- and postoperative notes, radiographs, and pathology reports, were reviewed retrospectively, and their personal interviews were followed up at outpatient clinics. This study was approved by the institutional review board and informed consent was obtained from all patients.

Patients were diagnosed by one orthopedic surgeon based on medical history, physical examination, and ultrasound with or without diagnostic, therapeutic injection, if indicated [2]. Ultrasound has been successfully used in the diagnosis of Morton's neuroma and it is also effective for discriminating from other forefoot diseases, including intermetatarsal bursitis, metatarsophalangeal joint synovitis, and etc. [2,24–26]. Indications of operation included unsuccessful conservative treatment with medication, metatarsal soft pad, shoe modification, massage, or steroid injection for at least 2 months. All anesthesia and operations were performed under an ultrasound-guided femorosciatic nerve block by the same surgeon [27,28]. All excised specimens were evaluated histologically to verify neuroma. The minimum follow-up for both techniques was 24 months. Exclusion criteria of the study are patients (1) diagnosed with a concomitant foot disorder, including hallux valgus, metatarsophalangeal joint bursitis, intractable plantar keratosis, a lesser toe deformity, etc., (2) previously or concomitantly underwent surgery for diseases listed in (1), (3) diagnosed with peripheral vascular disease or inflammatory spondyloarthropathy, including rheumatoid arthritis and ankylosing spondylitis, patients who have (4) local wound or infection of the foot, (5) proximal neuropathy, including tarsal tunnel syndrome or lumbar radiculopathy, (6) another adjacent Morton's neuroma that was not operated on concomitantly, (7) patients who did not provide informed consent or unable to complete the outcome assessments.

2.2. Surgical technique

2.2.1. Neurectomy

Neurectomy was performed by a standard procedure [29].

2.2.2. Dorsal suspension

A 3-cm dorsal straight incision was made on the center of the affected web space. Soft tissue was dissected with Metzenbaum scissor and two metatarsal bones were distracted using a lamina spreader. After identifying the dorsal transverse ligament (Fig. 1), one side of attachment to the extensor hood was resected using an open-book pattern (Fig. 2). After resection of the DTML, we identified the neuroma within range from the common digital

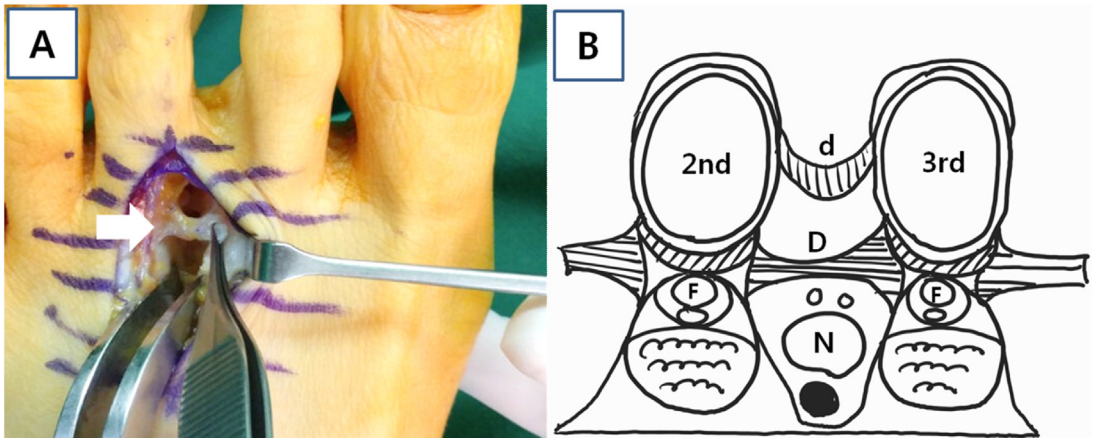

Fig. 1. (A through B) Intraoperative photograph and illustration image of a 53-year-old female patient with Morton's neuroma in left second web space. (A) The dorsal transverse ligament between second, third metatarsal head was identified after dissection of adjacent soft tissue. The arrow indicates the dorsal transverse ligament. (B) Image of a cross-section through the second and third metatarsal heads is shown. d: Intact dorsal transverse ligament, D: deep transverse metatarsal ligament F: flexor digitorum longus over flexor digitorum brevis in tendon sheath N: enlarged Morton's neuroma under common digital vessel and over lumbrical.

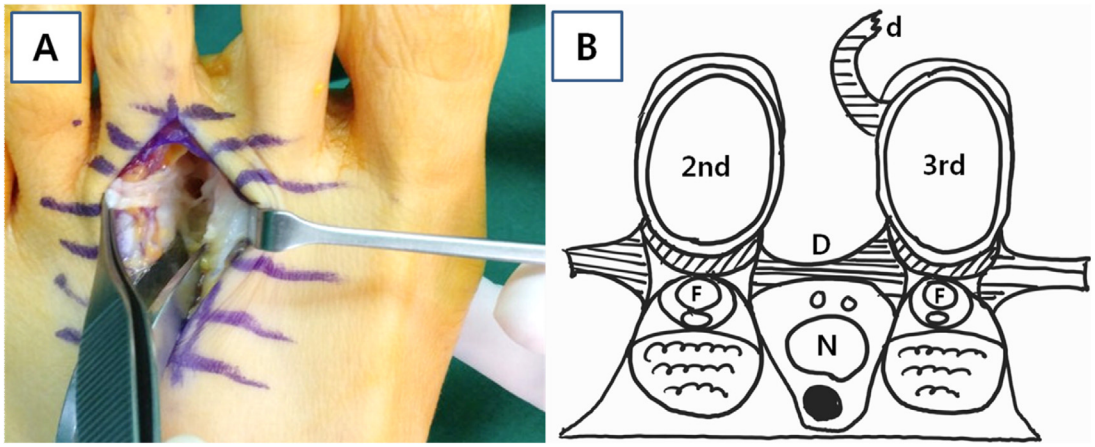

Fig. 2. (A) The dorsal transverse ligament was detached from the second metatarsal extensor hood. (B) Illustration image of detachment of the dorsal transverse ligament is shown.

nerve to the proper digital nerve, and nerve neurolysis was performed. After the procedure, dorsal transposition and suspension of the neuroma over the dorsal transverse ligament were performed by reattaching the dorsal transverse ligament to the adjacent extensor hood with 3–0 Vicryl to stabilize the dorsally transposed neuroma (Fig. 3). By slight traction of the suspended nerve with a small Langenbeck, we confirmed little tension of the nerve by excursion. A Mediclore (CGBio, Korea), adhesion barrier was used, and a silicone drain was inserted to prevent hematoma. The subcutaneous layer and skin were repaired with 3–0 Vicryl and a skin-strip (3M, USA), respectively.

2.2.3. Postoperative care

Heel and lateral weight bearing was allowed for two weeks followed by tolerable weight bearing. Additionally, massage for the affected web space and passive full flexion exercise of the toe were emphasized.

2.3. Postoperative assessment

Of the forty-six consecutive patients who underwent dorsal suspension during the index period, eight were excluded since they had a concomitant disorder, including four cases of hallux valgus, two case of bursitis, and two case of intractable plantar keratosis. Of the forty-eight patients who underwent neurectomy, twelve were excluded because six were unable to complete the outcome assessments and six had a concomitant disorder, including four cases of hallux valgus and two cases of ganglion. Finally, we assessed the remaining thirty-eight [82.6%] and thirty-six [75%] patients of the dorsal suspension and neurectomy groups, respectively. All patients were followed-up at two weeks, at two, five, and twelve months after operation, and annually thereafter. Postoperative pain, functional outcomes, satisfaction analysis, postoperative complications were evaluated as part of clinical care at the 24 month follow-up. Pre- and postoperative pain data were obtained using a 100-mm VAS, on which 0 indicates no pain and 100 indicates the worst pain. The Foot and Ankle Ability Measure (FAAM) [30–33] was used to investigate patient-reported functional outcomes. Satisfaction with the results from surgery was evaluated using Coughlin scale [34] (Table 1). Additionally, histological comparison of primary neuroma and transection stump neuroma was performed for one recurrent case.

2.4. Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22 software for Windows (SPSS Inc.). Sample size was calculated by power analysis using the G* power (ver. 3.1.9,2.). We set up effect size .5. For an α of .05 and 80% power, these assumptions resulted in a projected sample size of 34 per group.

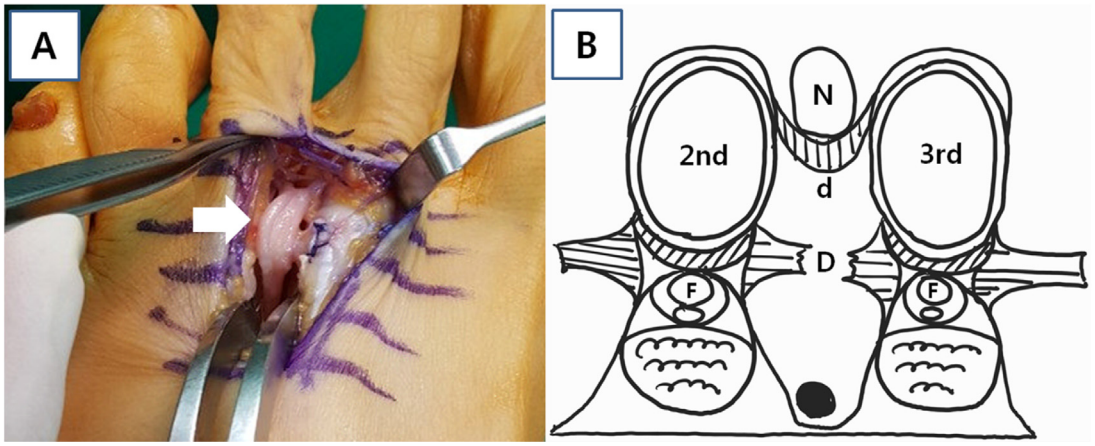

Fig. 3. (A) The deep transverse metatarsal ligament was dissected and Morton's neuroma was dorsal suspended by reattaching dorsal transverse ligament to second metatarsal extensor hood. The arrow indicates Morton's neuroma over the dorsal transverse ligament. (B) Illustration image of dorsal suspension of Morton's neuroma is shown.

Table 1
Coughlin scale.

Excellent	If they have no problems related to the foot, are very satisfied, have mild or no pain, and walk without difficulty
Good	If they have few problems, are satisfied, have mild pain, walk without difficulty or with mild difficulty, and would have the surgery again under similar circumstances
Fair	If they have moderate pain, some difficulty walking, and reservations about the success of the surgery
Poor	If they have continued pain, little improvement in walking, and regret having had the surgery

The Wilcoxon signed-rank test was used to compare pre- and postoperative VAS and FAAM scores. The Mann–Whitney U-test was used to compare the VAS and FAAM scores between the two groups. The chi-square test was used to compare the complications between the two techniques. p-value under .05 was considered statistically significant.

3. Results

The mean follow-up duration of the both groups was thirty-four months (range, 24–62 months) (Table 2).

3.1. Postoperative assessment

Postoperatively, the mean VAS pain scores were reduced significantly compared with preoperative values in both groups ($p < .01$). There was no significant difference between the two groups for postoperative VAS pain score ($p = .09$). Postoperatively, the mean FAAM scores had improved significantly in both groups for both activities of daily living ($p < .01$) and sports subscale ($p < .01$). There was no significant difference in the postoperative mean FAAM scores between the two groups for both activities of daily living ($p = .217$) and sports subscale score ($p = .97$).

According to the satisfaction analysis in the dorsal suspension group, 'excellent' was reported for twenty-four (60%) cases; 'good' for fourteen (35%) cases; 'fair' for two (5%) case; and 'poor' for 0 cases; in the neurectomy group, 'excellent' was reported for fourteen (38.9%) cases; 'good' for fourteen (38.9%) cases; 'fair' for four (11.1%) cases; and 'poor' for four (11.1%) cases. Overall, 95% of cases in the dorsal suspension group had 'excellent' and 'good' results, while 77.8% of cases in the neurectomy group had 'excellent' and 'good' results. After converting the Coughlin scale to a four-step Likert scale, there was no significant difference in satisfaction between the two groups according to the Mann–Whitney U-test ($p = .149$).

Few complications were reported in the dorsal suspension group. Two (5%) cases of postoperative numbness and two (5%) cases of paresthesia were reported. However, four (10%) cases of superficial infection of the incision site were reported. In the neurectomy group, postoperative numbness was reported in twenty-two (61.l%) cases; however, only four (11.1%) patients reported severe numbness that interrupted their activities of daily living. Paresthesia was reported in ten (27.7%) cases; among those patients, two (5.6%) underwent reoperation and recurrent neuroma was confirmed histologically. There were significant differences between the two groups for complications of both numbness (Pearson's chi-square = 13.8, $p < .01$) and paresthesia (Pearson's chi-square = 5.1, $p < .01$).

All histological results of neurectomy confirmed by pathologist and all gross findings of dorsal suspended neuroma inspected by the surgeon were identified as Morton's neuroma. The mean duration of operation showed no significant difference ($p = .247$) between dorsal suspension (mean, 25.7 min, range, 21–30 min) and neurectomy (mean, 26.8 min, range, 23–32 min).

4. Discussion

In the present study, dorsal suspension of neuroma using the dorsal transverse ligament showed comparable clinical results with fewer complications compared with neurectomy.

The pain relief associated with dorsal suspension may have been linked to the release of the DTML that eventually reduced the entrapment pressure of neuroma. Additionally, the dorsal suspension group showed satisfactory mid-term follow-up results that may have been related to the stable dorsal suspension of neuroma over the dorsal transverse ligament. Although there was a significant reduction in postoperative pain in the neurectomy group, the VAS of the neurectomy group (mean, 25.8, range, 0–90) was higher than that of the dorsal suspension group (mean, 12.0, range, 0–40), although the difference was not significant. Persistent pain is a common symptom after resection of Morton's neuroma. A long-term follow-up study performed by Lee et al. [35] demonstrated that long-lasting pain was found in many patients after surgery. Colgrove et al. [14] described a 36–48 month pain survey in which the resection group reported worse pain compared with the 12-month findings. The major cause of persistent pain is due to the development of a symptomatic stump neuroma [8,23].

The FAAM provides essential details of patient-reported clinical function during activities of daily living and sports. The FAAM has been used for its validity, reliability, and responsiveness [30,32]. It provides a better indicator of physical function than the Foot Function Index and American Orthopaedic Foot & Ankle Society (AOFAS) scale [30,33]. Postoperatively, the mean FAAM scores in both groups were significantly improved for both activities of daily living and sports subscale without a significant between-group difference. In the preoperative survey for the activities of daily living, the most difficult activities for patients with Morton's neuroma included going up stairs, going down stairs and walking

Table 2
Demographics and clinical variables.

	Dorsal suspension group	Neurectomy group
Number of patients/feet/neuromas	38/40/40	36/36/36
Sex (M:F)	10:28	8:28
Age (year)[a]	52.9 (31–71)	50.7 (26–72)
Duration of follow-up (mo)[a]	32.5 (24–39)	38.4 (26–62)
Location of neuroma (2nd/3rd/multiple web spaces)	2/38/0	10/26/0
Side (right/left/bilateral)	20/16/2	22/14/0
Pre/postoperative VAS score[a,b](p-value)	78.8 (50–90)/12.0 (0–40) ($p < .001$)	83.9 (70–90)/25.8 (0–90) ($p < .001$)
Pre/postoperative FAAM (%) activities of daily living score[a,c] (p-value)	26.8 (10–40)/89.5 (75–100) ($p < .001$)	26.1 (10–60)/77.2 (10–100) ($p < .001$)
Pre/postoperative FAAM (%) sports score[a,c] (p-value)	17.8 (0–40)/85.5 (50–100) ($p < .001$)	20.1(0–50)/69.4(0–100) ($p < .001$)

[a] Values are reported as the mean ± standard deviation.
[b] VAS = visual analog scale.
[c] FAAM = Foot and Ankle Ability Measure.

15 min or longer. Postoperatively, many patients in both groups were reluctant to enjoy sports, including running, hiking, climbing, etc.; therefore, the sports subscale of the FAAM scores may be somewhat inaccurate and should be analyzed further to determine its relevance.

Dorsal suspension caused fewer complications of paresthesia and numbness than neurectomy. Numbness in some cases of Morton's neuroma might preexist preoperatively. So, "numbness" in the present study was defined as a postoperative reduction of sensation in the plantar web space, between digits, and tips of the digits [16]. Sensation of dorsal web space was not included since it is not a dermatome of the common plantar digital nerve and is usually injured by dorsal incision during the approach, which often causes temporary tenderness or tingling. Postoperative numbness was reported in two (5%) cases which did not cause any interruption to their activities of daily living. Paresthesia was reported in two (5%) cases. The cause of paresthesia was confirmed by ultrasound as adhesion of neuroma to the soft tissue, which was improved by adhesiolysis using ultrasound-guided lidocaine-steroid injection. Other complications were four (10%) cases of operative site superficial infection. We assume that they were occurred by hematoma due to omission or early removal of silicone drain, not by operative technique problem, itself. All cases of infection were improved by intravenous antibiotics within one week.

In the neurectomy group, postoperative numbness was reported in twenty-two (61.l%) cases, all of which were determined to initiate or aggravate postoperatively. Paresthesia was reported in ten (27.7%) cases. In several studies, postoperative numbness in the web space was reported to range from 38% to 67% [35]. A transected interdigital nerve is classified as "neuromatosis" according to Sedon [36,37] and third-, fourth-, and fifth-degree injury according to Sunderland [37,38]. These nerve injuries are likely to form a neuroma, secreting chemical substances which can cause pain and be a spontaneous pain generator that may eventually induce a condition such as complex regional pain syndrome [20,37]. In the present study, a 37-year-old patient with persistent severe numbness and paresthesia after primary neurectomy (Fig. 4) was confirmed as stump neuroma (Figs. 5 and 6) by reoperation. It was coincided with typical findings of neuroma, which are dense fibrous tissue formation with irregular axonal or fascicular proliferation, and small proliferating fascicles of a nerve enveloped in collagen [11]. This result disputes outcome of another study [39] in which histologic examination of presumed recurrent Morton's neuroma revealed fibrous tissue but no sign of peripheral neural tissue, and these conflicting results require further study.

In the present study, satisfaction analysis showed 'excellent' and 'good' results in the dorsal suspension and neurectomy groups (95% and 77.7%, respectively). A 'fair' result was reported for two (5%) case in the dorsal suspension group, which reported complication of operative site infection. We demonstrated relatively better results in the neurectomy group than previous studies. Four (11.1%) cases reported 'fair' results, whereas an additional four (11.1%) cases reported 'poor' results; all eight cases complained of severe paresthesia. Although there were twenty-two (61.1%) cases of numbness in the neurectomy group, only four (10.5%) had severe numbness that interrupted their activities of daily living. We believe this situation accounted for no significant difference between the two groups. In contrast, the long-term follow-up study of neurectomy by Womack et al. [40] and Lee et al. [35] showed 'good' or 'excellent' results for only 50% and 61.5% of cases, respectively.

In additional comparison to open neurolysis of Gauthier [8] and Dellon [21], dorsal suspension also showed higher satisfaction in the present study. We believe dorsal suspension procedure prevented neuroma from recompression and adhesion among adjacent metatarsal heads, spontaneously repaired DTML and soft tissue [2,21,23] which can occur only if neurolysis is done. Mann and Reynolds [2,23] also concluded that sectioning of the DTML alone would not provide adequate long-term relief of symptoms of Morton's neuroma. From these results, we strongly suggest the

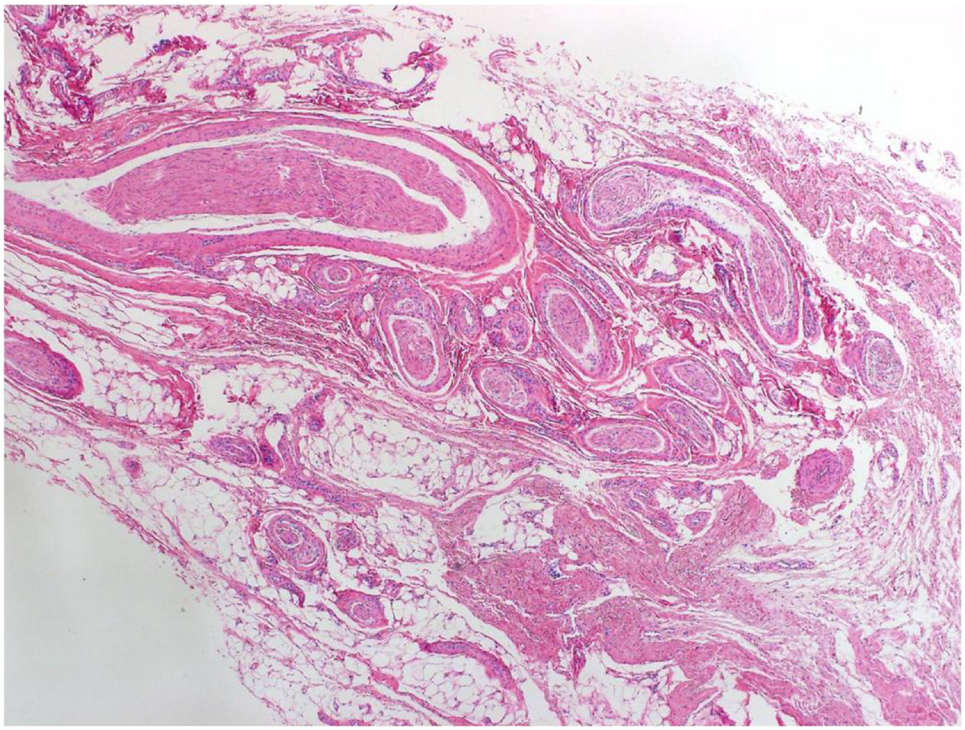

Fig. 4. A histologic cross-section image of several nerve fascicles from a Morton's neuroma (40×, Hematoxylin and Eosin) excised from 37-year-old male patient. Nerve hypertrophy which was haphazardly arranged with collagen tissue is shown.

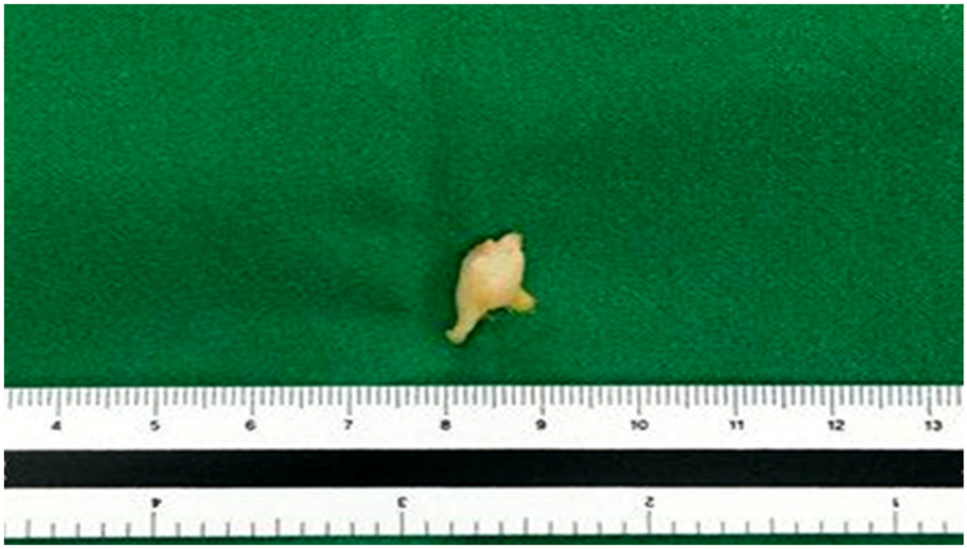

Fig. 5. A gross photo of stump neuroma.

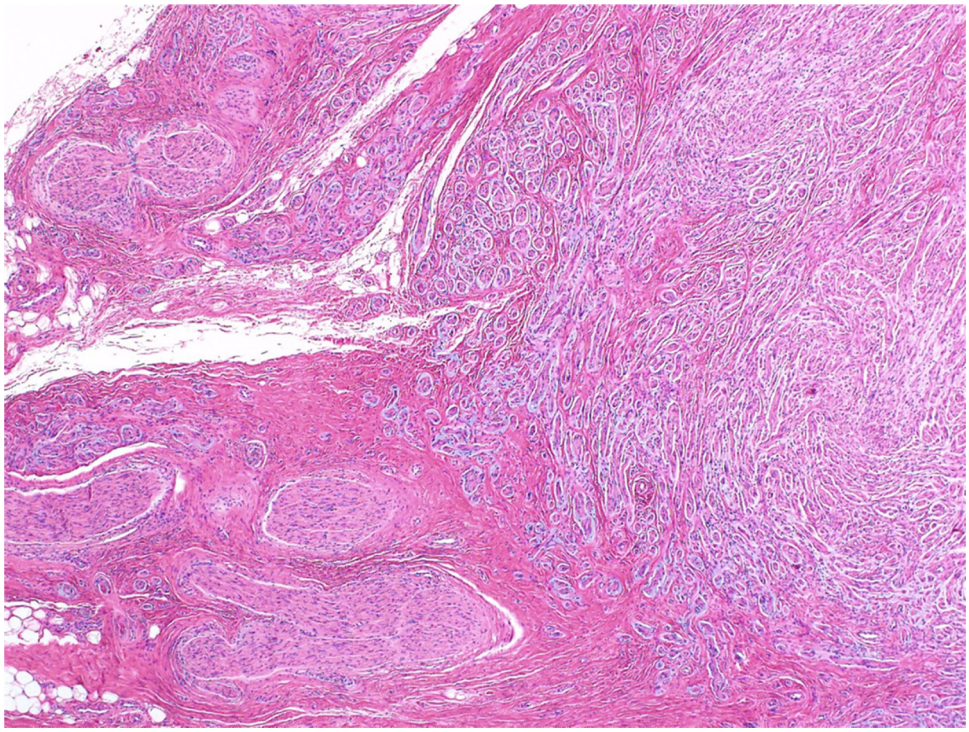

Fig. 6. A histologic cross-section image of several nerve fascicles from a stump neuroma (40×, Hematoxylin and Eosin) after reoperation. Intensely large nerve bundle with small nerve bundles penetrating into collagen tissue are shown.

dorsal transposition and stabilization of neuroma are essential. However, further long-term comparative study with other advanced procedures of neurolysis without nerve transpostition [20,41] is needed.

The dorsal transverse ligament [42], formed by the intertendinous interaxial portion of the dorsal common aponeurosis and the interosseous aponeurosis, is located between two adjacent metatarsal heads at the level of the metatarsophalangeal joint. It is a comparatively substantial structure; therefore, it may serve as an effective structure to produce a dorsal suspension effect of neuroma if it is detached during approach in the open-book pattern and reattached to the adjacent metatarsal head after dorsal transposition. In the present study, the dorsal transverse ligament was an effective structure that can suspend neuroma dorsally without much nerve excursion and tension. However, there are few descriptions about the dorsal transverse ligament [42].

The strengths of the present study were that all diagnoses, preoperative nerve blocks [27,28], and operations were performed by one orthopedic surgeon. It was also the first comparison of the dorsal suspension technique using the dorsal transverse ligament with neurectomy. Functional outcomes were investigated using a validated outcome measure [30,33]. The retrospective chart review, along with collected data, was examined by one author; the follow-up rate of the participants was 92.5%.

The limitations of our study were that it was a retrospective study and investigation of the data was performed with mid-term rather than long-term follow-up data. The exclusion criteria of the patients which were required to standardize outcome measures were rather strict and this might have induced inclusion bias as the less pronounced cases of forefoot insufficiency with more limited neuromas were selected. Long-term image findings followed by ultrasound or magnetic resonance (MR) image of dorsal suspended neuroma is needed and these radiologic results can be compared with MR imaging after neurectomy [39]. Also long-term cadaver study of dorsal suspension group is needed.

5. Conclusions

In conclusion, dorsal suspension provided pain relief and functional improvement that was comparable to neurectomy. Dorsal suspension showed fewer complications than neurectomy. The duration of both techniques was similar. Due to its good results and feasible technique, we suggest dorsal suspension can be another operative option for the treatment of Morton's neuroma.

Conflict of interest statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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