DOI: https://doi.org/10.30795/jfootankle.2022.v16.1650

Original Article

Minimally invasive surgery for lesser toe deformity: a clinical audit of a proposed treatment algorithm

Steven Richard Edwards[1], **Madeleine Grace Murray**[2], **Mark Francis Gilheany**[1]

1. Australasian College of Podiatric Surgeons, Victoria, Australia.
2. La Trobe University, Victoria, Australia.

Abstract

Objective: There is increasing interest in the performance of minimally invasive foot surgery (MIS); however, limited evidence and treatment algorithms are available to support its use and guide surgical decision-making. The aim of this prospective clinical audit was to report the efficacy of a treatment algorithm used to treat patients presenting with lesser toe deformities using MIS techniques.

Methods: A prospective clinical audit of 38 patients who underwent 55 MIS procedures for complex and simple lesser toe deformities was conducted between April 2018 and June 2022. All patients were followed up for a minimum of 12 months post-operatively. The audit was conducted following the National Research Ethics Service (NRES) guidelines on clinical audit.

Results: Mean pre-operative Visual Analogue Pain (VAS) score was 3.95 with a median of 5.00. The mean post-operative VAS scores improved to 0.23 after six weeks and 0.43 after 12 weeks. A Mann-Whitney U test concluded that this improvement was statistically significant ($p<0.05$).

Conclusion: This algorithm appears effective in treating lesser toe deformities independent of deformity classification, concomitant surgery, gender or whether the surgery was performed in a hospital or private clinical setting.

Level of Evidence V; Therapeutic Study; Expert Opinion.

Keywords: Clinical audit; Foot deformities; Hammer toe syndrome; Metatarsal bones; Minimally invasive surgical procedures.

Introduction

The global interest in minimally invasive foot surgery (MIS) continues to grow in the peer-reviewed foot and ankle surgical literature[1-8]. MIS is defined as surgery performed through small openings without direct visualisation of anatomical structures. Its practice has increased in popularity due to theoretical advantages, including reduced soft-tissue damage, smaller scars, shorter surgery times and hospital stay, lower post-operative pain and reduced risk of infection[9]. The use of MIS is increasing, but there is limited evidence to support its use in the forefoot. Currently, few treatment algorithms exist to guide surgical decision-making for lesser toe deformities[10].

Lesser toe surgery is often indicated to address painful cutaneous lesions that can lead to ulceration and have not responded to non-surgical measures. The aims of lesser toe surgery include the correction of deformity whilst preserving the biomechanics of the foot, but controversy exists over the best surgical approach[9]. Surgeons must focus on the anatomical structures and contractures involved to guide their decision-making[10]. The ambiguous definitions and treatment strategies regarding diagnosing and managing lesser toe deformities have been well documented[11].

The symptoms of lesser toe deformities are often attributed to callosities and pressure[3]. Conservative treatment involves improving comfort, and its success largely depends on the level of deformity present. Orthoses, footwear advice, protective devices and corticosteroid injections have been employed as non-operative management[12]. When conservative treatment fails, surgery may be indicated.

Study performed at the Australasian College of Podiatric Surgeons, Victoria, Australia.

Correspondence: Steven Richard Edwards. Australasian College of Podiatric Surgeons, 55 Collins Street, Melbourne, Victoria, Australia. **E-mail:** s6edwards@gmail.com **Conflicts of interest:** none. **Source of funding:** none. **Date received:** September 8, 2022. **Date accepted:** November 1, 2022. **Online:** December 20, 2022.

How to cite this article: Edwards SR, Murray MG, Gilheany MF. Minimally invasive surgery for lesser toe deformity: a clinical audit of a proposed treatment algorithm. J Foot Ankle. 2022;16(3):209-14.

There is a paucity of empirical research assessing the efficacy of MIS for lesser toe deformities and no adequate treatment algorithm for surgical management.

An audit assessing the efficacy of a treatment algorithm for the MIS management of lesser toe deformities is an important step towards informing surgical decision-making in this emerging field. The aim of the retrospective clinical audit is to assess the efficacy of a pre-derived treatment algorithm used to surgically treat a cohort of patients presenting with lesser toe deformities using MIS techniques.

Methods

Audit design

The study methods described correspond with the principles of audit activity defined by the National Research Ethics Service (NRES)[12]. Patients were not allocated to a specific treatment group and elected to have their procedure(s) performed by the primary surgeon (MG). The option of open versus percutaneous techniques was not influenced by the severity of the deformity. The perioperative protocols did not deviate from standard practice. This work complies with the ethics in publication policy of the Australasian College of Podiatric Surgeons (ACPS). Consent was obtained from all patients included in this audit.

Inclusion criteria

Inclusion criteria were patients fit for elective surgery presenting with lesser toe deformities that were not responsive to conservative care and that underwent MIS for treating lesser toe deformities by the primary surgeon between April 2018 and October 2022. Patients who underwent concomitant surgery (e.g for hallux valgus correction) were included. The summary of the method is detailed in table 1.

Exclusion criteria

Patients were excluded if they had already undergone surgery on the digit in question.

Perioperative management

Procedures were performed under local anaesthetic (LA) or a combination of LA and general anaesthetic (GA). All procedures were performed either in a clinical procedure room or hospital setting (including surgi-centre) on an ambulatory day-case basis.

Patients who underwent procedures within a hospital environment were administered intravenous antibiotic prophylaxis pre-operatively and a single subcutaneous dose of enoxaparin sodium 20 or 40mg intra-operatively for thromboprophylaxis as part of the routine protocol, often due to additional procedures involving the use of internal fixation (e.g. for hallux valgus correction). Those performed in an office setting did not receive either form of prophylaxis.

Osteotomies

The location of the osteotomy and algorithm used in this audit can be found in figure 1.

Instrumentation

All procedures were carried out using standard MIS hand instrumentation and Osada low-speed/high-torque power instrumentation. Fluoroscopy was utilised as appropriate with a Fluoroscan® InSight 2 Mini C-Arm (Hologic Inc., Marlborough, Massachusetts, USA).

Table 1. Summary of method

1. Pre-surgical consultation	Assessment of presenting concerns with the primary surgeon. Thorough medical history and evaluation to determine the cause of deformity.
2. Deformity classification	Recording of any hyperkeratosis or pressure lesions. Assessment of passive range of motion at all joints to determine if the deformity was reducible or fixed. Deformity was classified into simple or complex based on the involvement of the metatarsophalangeal joint. Digital balance test to define muscular imbalance between the flexors and extensors. Weight-bearing radiographs to confirm baseline deformity and correlate the apex of deformity with the osteotomy to be used. Patient was triaged for surgery following a pre-derived treatment algorithm.
3. Pre-operative data collection	Patient records pre-operative VAS score and frequency. Patient was issued with a consent form detailing surgical intervention and requesting permission to use the data for audit purpose.
4. Surgical intervention	Percutaneous surgical techniques were used to treat all lesser toe deformities. Surgery was performed in a hospital or office setting under LA or GA alongside LA. Surgical procedures were based on the treatment algorithm employed, see Figure 2.
5. Post-operative care	Patients recorded post-operative VAS scores. Routine post-operative care was provided, including analgesic medication, elevation and compression bandages. Digital splinting was used for up to six weeks to maintain alignment, followed by a return to sizeable footwear.

* VAS = Visual Analogue Pain Scale; LA = local anaesthetic; GA = general anaesthetic.

Treatment algorithm

A treatment algorithm developed by the primary surgeon was used to guide surgical decision-making (Figure 2). Upon the presence of a symptomatic lesser toe deformity, a clinical assessment was conducted encompassing the use of the digital balance test to identify the presence of flexor or extensor substitution[13,14]. If surgery was indicated, the surgeon identified the point of most severe soft-tissue contracture correlating with the formation of a lesser toe deformity.

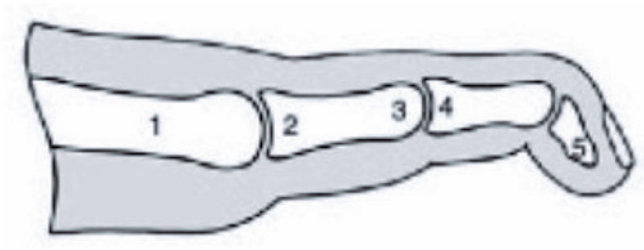

Figure 1. The various osteotomies employed within this algorithm. 1: Middle metatarsal neck 2: Base of the proximal phalanx 3: Dorsal aspect of the head of the proximal phalanx 4: Neck of intermediate phalanx 5: Osteectomy of distal phalanx.

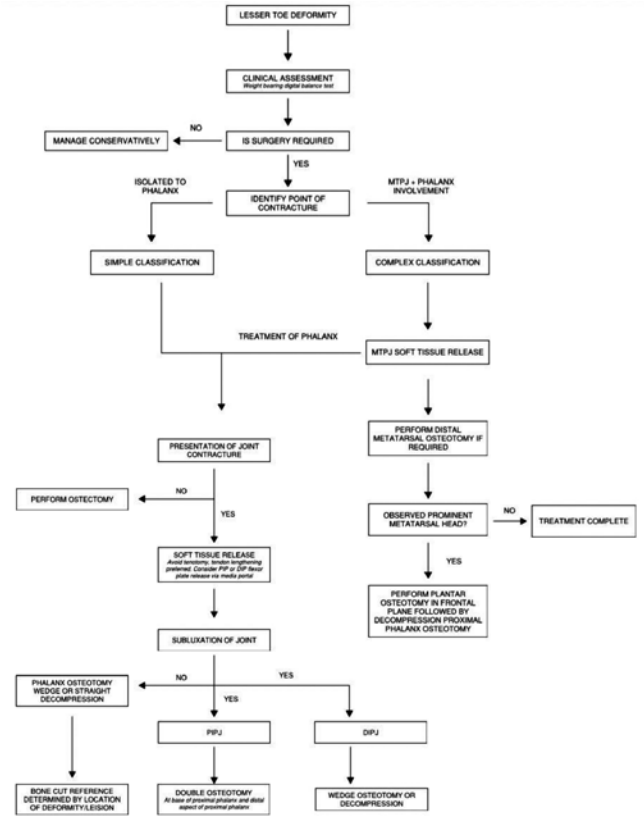

Figure 2. The treatment algorithm.

Digital pathology definitions

Lesser toe pathology was defined as digital deformity resulting in a condition or malposition of the toe(s), which required surgical intervention. Digital deformity was further classified as simple or complex based upon the level of anatomic involvement. The following definitions were applied:

Simple digital deformity was deformity isolated to the phalanges and soft-tissue structures involving the interphalangeal joints. Surgical procedures in this group included percutaneous phalangeal osteotomies and/or osteectomy with or without percutaneous lengthening release procedures to flexor/extensor tendons and capsular releases as required.

Complex digital deformity was defined as a simple digital deformity with the addition of metatarsophalangeal joint (MTPJ) contracture resulting in subluxation or dislocation. In the case of a complex deformity, surgical procedures began with soft-tissue release at the level of the MTPJ and progressed to phalanx osseous work and, when necessary, osseous metatarsal work. A distal metatarsal osteotomy was also performed as required.

The procedures performed were based on the principles and techniques described in Maffulli and Easly[3].

Procedural Approach - Simple Digital Deformity

Deformities isolated to the phalanx were classified as simple deformities. Osseous procedures were performed from distal to proximal. In the absence of joint contracture and the presence of an isolated hyperkeratotic lesion, the primary surgeon performed an osteectomy, removing the exostosis correlating with the location of the lesion. In the incidence of joint contracture, soft-tissue releases were performed.

If subluxation of the joint was not present, a simple phalanx osteotomy was performed using a wedge or straight decompression; the osteotomy correlated with the use of the specific osteotomy outlined in figure 1. A decision on which osteotomy to use was determined based on the location of the deformity and the presence of a lesion.

In the presence of joint subluxation at the proximal interphalangeal joint, the surgeon conducted a double osteotomy using osteotomy cuts 2 and 3. When subluxation was present at the distal interphalangeal joint, a wedge osteotomy or decompression was adopted.

Procedural Approach – Complex Digital Deformity

A complex deformity was defined as incorporating MTPJ involvement. In this case, the procedure always began with a soft-tissue release at the level of the MTPJ and then progressed onto phalanx osseous work. A distal metatarsal osteotomy was performed when necessary, correlating with osteotomy 1. A plantar osteotomy was conducted in the frontal plane, followed by a decompression proximal phalanx osteotomy if a prominent metatarsal head was exhibited.

Post-operative management

Patients were given routine post-operative analgesic medication and allowed to weight-bear in a rigid post-operative sandal. Patients were advised to elevate the affected limb(s) for the first 48 hours. Routine compression bandages were used on the operated foot or feet alongside standard digital splinting protocols. The purpose of splinting was to ensure alignment and continued for up to six weeks post-operatively.

Patients were reviewed by the primary surgeon in the clinical rooms at routine intervals at seven days, then again at 3, 6, 9, 12, 26 and 52 weeks. This regimen reflects the typical post-operative follow-up performed by the primary surgeon and his peers in Australia. Subjective post-operative Visual Analogue Pain (VAS) scale and pain frequency sheets were provided to patients to complete at six and 12 weeks post-operatively to assess pain scores.

Data collection

Vascular assessment was conducted directly following surgery by evaluating clinical signs of colour and temperature together with superficial venous plexus filling time (SVPFT). Neurological status was assessed utilising a Semmes-Weinstein 5.07/10 g monofilament at initial review and six weeks post-operatively. Neurological status was not assessed immediately post-operatively due to long-acting local anaesthesia. Signs of infection were checked for at the initial review and follow-up appointments. Data was explicitly recorded relating to post-operative complications or infections. Objective surgical and general demographic data were collected and recorded in patient charts by the primary surgeon (MG).

Results

Complete data were obtained on 38 patients (3 male, 35 female) that underwent MIS surgery for digital deformity during this period. The age ranged from 19-84 years (mean 63.3 years) with a standard deviation (SD) of 16.4 years, and 81% were 51 years or older. A summary of the study participants can be found in table 2.

Table 2. Characteristics of the sample group

Variable	Description	Value
Sample size	No. Subjects	N=38
	No. Procedures	N=55
Age	Mean	63.3 years
	Median	66 years
Gender	Male	N=3 (7.9%)
	Female	N=35 (92.1%)
Surgery location	Hospital	N=21 (38.2%)
	Office	N=34 (61.8%)
Deformity classification	Simple	N=28 (50.9%)
	Complex	N=27 (49.1%)
Concomitant surgery	Isolated	N=43 (78.2%)
	Concomitant	N=12 (21.8%)

Thirty-four (61.8%) procedures were performed in an office clinical procedure room, and 21 (38.2%) were performed in a hospital setting. Thirty-four (61.8%) were performed under a combination of GA and LA, whilst 21 (38.2%) were performed under LA alone. Local blocks were performed during either 0.75% ropivacaine hydrochloride or 0.5% bupivacaine hydrochloride plain solution.

A total of 55 digits were operated on out of the 38 patients in this study. Of these, 12 patients underwent concomitant procedures (e.g. hallux valgus correction).

Twenty-eight (51%) deformities were classified as simple, and 27 (49%) were classified as complex. Interestingly, patients with simple deformities had higher pre-operative VAS scores compared with complex deformities. Of the 12 procedures performed with concomitant surgeries (e.g. hallux valgus correction), nine (75%) were classified as complex.

The most utilised MIS osteotomy was number 2, referring to an osteotomy at the base of the proximal phalanx. Osteotomies 1 and 3 were used sparingly, accounting for less than 10% of the procedures. Osteotomies 5 and 2 were used predominantly on deformities classified as simple. Complex deformities were predominantly treated with osteotomy 2, accounting for 70% of osteotomies. Osteotomy 1 correlates with an osteotomy of the distal metatarsal, which was used in treating 10% of complex deformities. A summary of the osteotomy frequency used within this audit is detailed in figure 3.

Pre-operatively, the sample mean VAS score was 3.95 (SD = 3.58) with a variance of 12.84, indicative of a large range and dispersed data set. The post-surgical sample mean VAS scores at six and 12 weeks of follow-up consultations were 0.23 and 0.43, respectively (Table 3). Post-operative VAS scores followed a normal distribution and were tightly clustered with a small SD from the mean.

At six weeks, 34 (88.7%) patients reported a VAS score of 0, with 37 (98.1%) reporting a VAS score of ≤2. As a non-parametric statistical test was used to test the significance level in VAS scores pre-and post-operatively, these outliers would not have been considered. Two patients did not record a VAS score at six weeks post-surgery, and four did not record a VAS score at 12 weeks post-surgery resulting in a useful data set of 51 entries.

At 12 weeks, 31 (82.4%) patients reported pain levels at 0, with 36 (96%) reporting a VAS of ≤ 2. This suggests relative effectiveness of the pre-derived treatment algorithm. These results compared with the findings of Yassin et al.[13], who evaluated pre-and post-operative VAS scores in a prospective case-control study comparing percutaneous surgery with traditional techniques, finding the mean post-operative VAS score to be 1.9 at six weeks and 0.43 at the 12 weeks of follow-up. Figure 4 illustrates pre-and post-operative VAS score distributions.

Discussion

In 1991, White[6] mentioned the potential for less post-operative pain and discomfort following MIS forefoot surgery compared to the traditional open approaches due to reduced soft-tissue dissection. The results of this audit add further strength to this argument.

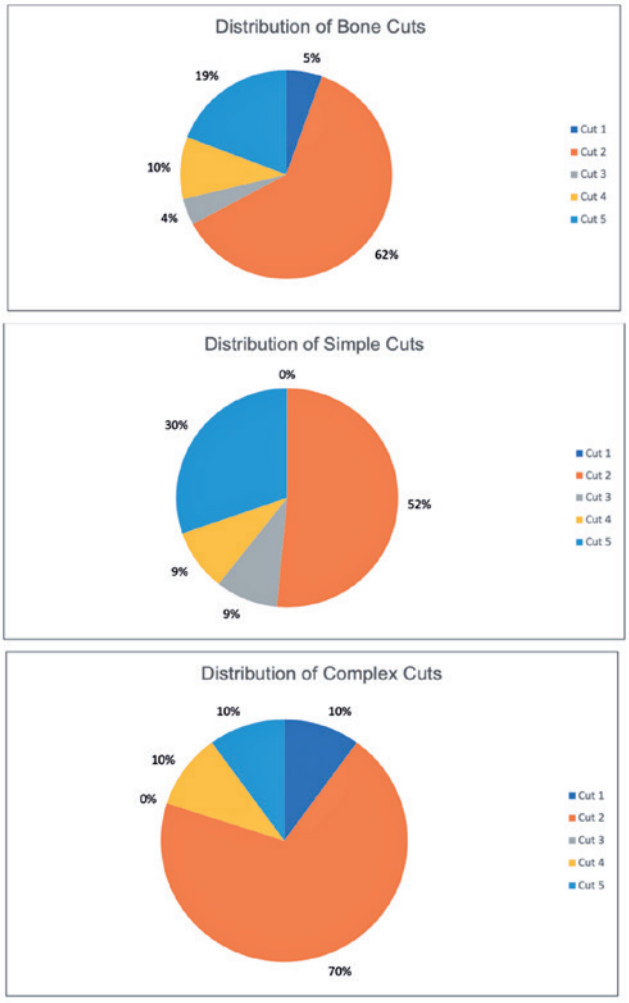

Figure 3. The distribution of osteotomies employed within this audit.

Table 3. Pre-and postoperative VAS score

	N	Range	Mean	Standard Deviation
VAS Score Pre-Surgery	55	9.0	3.95	3.58
VAS Score 6 weeks Post-Surgery	53	3.0	0.23	0.67
VAS Score 12 weeks Post-Surgery	51	7.0	0.43	1.19

The treatment algorithm employed specific osteotomies in this audit to surgically correct lesser toe deformities. The results suggest that through implementing a pre-derived MIS treatment algorithm, lesser toe deformities can be treated effectively. These results were independent of complex or simple deformity classification, location, age, gender, and concomitancy. The second ray was the most common site presenting with deformity, and MIS techniques using osteotomy 2 (osteotomy at the base of the proximal phalanx) were used to conduct 62% of procedures. Pre-and post-operative pain scores were used as the primary outcome measure, and statistically significant improvements in post-operative VAS scores were reported.

The most common osteotomy used was number 2, an osteotomy at the base of the proximal phalanx; 44% of procedures were performed on the second ray, followed by deformities of the fifth ray accounting for 31% of osteotomies. Schrier et al.[10] attribute the second ray as the most commonly affected in the case of lesser toe deformities.

An analysis of such a small size is intended to represent the wider population. To justify the results, it was considered important for the cohort to represent patients receiving surgical treatment for lesser toe deformities. The conclusions drawn from this audit could be strengthened through post-stratification; however, this was omitted due to research time constraints.

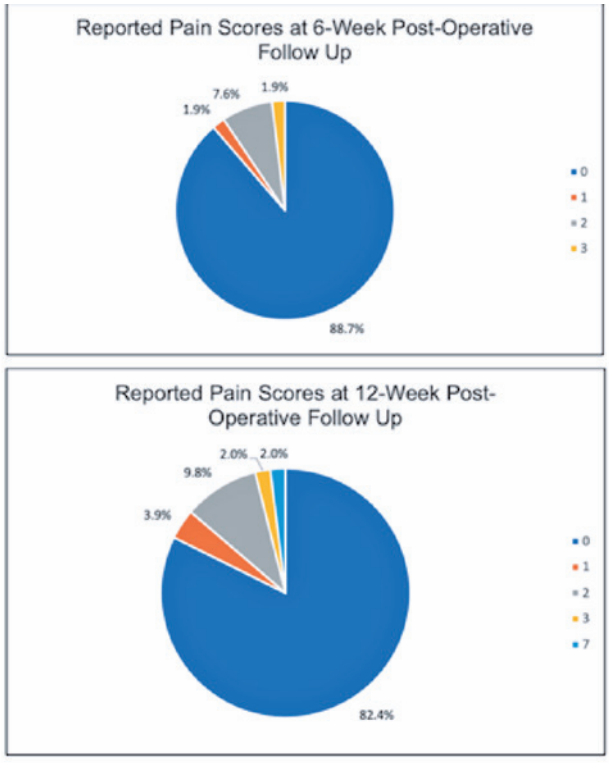

Figure 4. Pre-and post-operative VAS pain score distributions.

These results are consistent with Nieto-Garcia et al.[15], who compared incomplete osteotomies (IO) with and without tenotomies in another retrospective case-control study. They reported at the 12 months of follow-up that the cohort operated on with IO and tenotomy displayed higher rates of complications, including delayed union, hypertrophic callous and fracture of the phalanx at the osteotomy site.

The impact of co-morbidities may provide a counter-argument to explain the lower post-operative VAS scores illustrated within the current study. Yassin et al.[13] reported a high incidence of co-morbidities in the sample population, with one-third diagnosed with diabetes mellitus. The hypertensive patients in the percutaneous cohort did not respond as well to surgery as the non-hypertensive patients. This shows that patients with co-morbidities may not respond as well or heal as fast as patients without it. The data set from this study did not include or refer to co-morbidities present at the time of surgery. If there was a low degree of co-morbidities in the study, it could explain the slightly lower post-operative VAS scores. If the treatment algorithm used within this study were to be deployed, research into the impact of co-morbidities would need to be explored to ensure it could be applied to all patients. The lack of information regarding the presence of co-morbidities is a limitation of the study.

A limitation of this algorithm relies to an extent upon the surgeon's experience and assessment of the anatomical structures leading to contracture to inform what osteotomy to use. The subjectivity of osteotomy selection may lead to variability in different surgeon's use of the treatment algorithm. The treatment algorithm could be improved if the process regarding the selection of which osteotomy was to be clearly defined.

The authors advocate future research to determine the efficacy of the treatment algorithm on a sample group with a higher number of third or fourth-ray deformities, which were limited in this sample group.

Conclusion

This audit illustrated that performing MIS to address simple and complex digital deformities via a treatment algorithm results in favourable reductions in post-operative pain scores. Furthermore, MIS procedures were safely performed in various clinical settings and on varying degrees of digital deformity. Further studies investigating the effectiveness of these techniques are recommended and should evaluate longer post- operative patient-reported outcome measures, as well as refining treatment algorithms to guide clinical decision-making.

Authors' contributions: SRE *(https://orcid.org/0000-0002-9866-0327) Interpreted the results of the study, participated in the review process and approved the final version; MGM *(https://orcid.org/0000-0001-9533-7797) Conceived and planned the activities that led to the study, approved the final version; MFG *(https://orcid.org/0000-0002-8179-7992) Performed the surgeries, data collection and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

References

1. Fanous RN, Ridgers S, Sott AH. Minimally invasive arthrodesis of the first metatarsophalangeal joint for hallux rigidus. Foot Ankle Surg. 2014;20(3):170-3.
2. Van Enoo RE, Cane EM. Minimal incision surgery. A plastic technique or a cover-up? Clin Podiatr Med Surg. 1986;3(2):321-35.
3. Maffuli N, Easly M, editors. Minimally invasive surgery of the foot and ankle. London: Springer-Verlag; 2011.
4. Roukis TS, Schade VL. Minimum-incision metatarsal osteotomies. Clin Podiatr Med Surg. 2008;25(4):587-607.
5. Dhukaram V, Chapman AP, Upadhyay PK. Minimally invasive forefoot surgery: a cadaveric study. Foot Ankle Int. 2012;33(12): 1139-44.
6. White DL. Minimal incision approach to osteotomies of the lesser metatarsals. For treatment of intractable keratosis, metatarsalgia, and tailor's bunion. Clin Podiatr Med Surg. 1991;8(1):25-39.
7. Legenstein R, Bonomo J, Huber W, Boesch P. Correction of tailor's bunion with the Boesch technique: a retrospective study. Foot Ankle Int. 2007;28(7):799-803.
8. de Prado M, Ripoll LP, Golano P. Minimally invasive foot surgery: surgical techniques, indications and anatomical basis. Barcelona, Spain: About Your Health Publishers; 2009.
9. Gilheany M, Baarini O, Samaras D. Minimally invasive surgery for pedal digital deformity: an audit of complications using national benchmark indicators. J Foot Ankle Res. 2015;8:17.
10. Schrier JC, Louwerens JW, Verheyen CC. Opinions on lesser toe deformities among Dutch orthopaedic departments. Foot Ankle Int. 2007;28(12):1265-70.
11. Malhotra K, Davda K, Singh D. The pathology and management of lesser toe deformities. EFORT Open Rev. 2017;1(11):409-19.
12. NHS Health Research Authority. Accessing study support and advice services. Available from: http://www.hra.nhs.uk/resources/before-you-apply/is-it-research/
13. Yassin M, Garti A, Heller E, Robinson D. Hammertoe correction with k-wire fixation compared with percutaneous correction. Foot Ankle Spec. 2017;10(5):421-7.
14. DiNucci K, Hegewald K. Flexor and extensor tendon transfers. In: Cook E, Cook J, editors. Hammertoes: a case-based approach. Cham: Springer International Publishing; 2019. p. 197-208.
15. Nieto-García E, Ferrer-Torregrosa J, Ramírez-Andrés L, Nieto-González E, Martinez-Nova A, Barrios C. The impact of associated tenotomies on the outcome of incomplete phalangeal osteotomies for lesser toe deformities. J Orthop Surg Res. 2019;14(1):308.