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FAS-1589; No. of Pages 5
ARTICLE IN PRESS
Foot and Ankle Surgery xxx (xxxx) xxx–xxx
Contents lists available at ScienceDirect
Foot and Ankle Surgery
journal homepage: www.elsevier.com/locate/fas

Percutaneous flexor digitorum brevis tenotomy: An anatomical study

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ARTICLE INFO

Article history:
Received 30 October 2020
Received in revised form 13 January 2021
Accepted 25 February 2021
Available online xxx

Keywords:
Anatomy
Cadaveric
Minimally invasive surgery
Hammer
Percutaneous
Claw toe
Elective tenotomy
Lesser toe

SUMMARY

Introduction: A percutaneous selective flexor digitorum brevis (FDB) tenotomy and a proximal interphalangeal (PIP) joint arthrolysis may correct a lesser claw toe deformity keeping flexor digitorum longus (FDL) and active flexion. Our study aimed to verify if the procedure was effective and reliable and if it respects the surrounding soft tissues.
Material and method: Twelve cadaveric lateral toes were used. A dissection ensured the integrity of both digital nerves, FDL and flexor pulleys and assessed the section of both FDB slips and PIP arthrolysis.
Results: A complete section of the two FDB slips was observed in 4 cases (33%). Arthrolysis was achieved in all cases. Surrounding soft tissues were found intact in all cases.
Conclusion: This procedure is effective regarding PIP arthrolysis, but a technical improvement is required to achieve a reliable section of both FDB slips. In the hands of an experienced surgeon, it has proven to be safe.

1. Introduction

Lesser toe deformities are complex clinical entities, resulting from an imbalance between the intrinsic and extrinsic foot muscles caused by improper shoe wear, trauma, inflammatory arthritis, and neuromuscular, metabolic, or degenerative diseases. Lesser toes deformities are a common source of discomfort, pain when wearing shoes and impingement during walking. Several techniques have been described for its treatment which may be performed through an open or percutaneous approach. The original percutaneous technique was described by De Prado, who described a complete tenotomy of both flexor (and extensor) tendons in addition to "à la carte" bone procedures [1]. To preserve the function of FDL tendons, essential during the toe-off phase of gait for propulsion during fast walking, Piclet proposed a modified technique allowing selective FDB tenotomy combined to PIP arthrolysis [2].

To date, no anatomical studies have been performed to assess the safety and efficacy of this technique. For this reason, an anatomical study was designed with the purpose of monitoring the effectiveness of the procedure on an anatomical level, by checking FDB section and secondarily to confirm if the surrounding elements were respected, particularly the plantar digital nerves and the FDL.

One important anatomical fact about the FDB is that it is subjected to anatomical variations. It is always present on the 2nd and 3rd toes, but it is absent on the fourth toe in 3% of cases and on the 5th toe in 3–21.5% of cases [3,4]. For this reason, we designed a study where the 5th toe was excluded.

We hypothesized that claw toe deformity could be effectively corrected with a minimally invasive selective FDB tenotomy combined to PIP arthrolysis, respecting the surrounding soft tissues.

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https://doi.org/10.1016/j.fas.2021.02.011

Please cite this article as: P. Carvalho, M. Dalmau-Pastor, C. Lozi et al., Percutaneous flexor digitorum brevis tenotomy: An anatomical study, Foot Ankle Surg, https://doi.org/10.1016/j.fas.2021.02.011

2. Material and methods

The study was conducted on fresh-frozen specimens: three right feet and one left foot amputated at the midfoot. A total of 12 lateral toes were used: 4 second toes (T2), 4 third toes (T3) and 4 fourth toes (T4), all suffering from proximal claw toes. A right foot and a left foot corresponded to a 55-year-old woman, a right foot to a 95-year-old man, the fourth foot was not referenced. All the toes were operated by the same senior foot and ankle surgeon, with previous experience in minimally invasive surgery and in performing this particular technique.

The study was performed at the Dissecting Room of our Institution and received ethical approval IRB000003099.

2.1. Surgical Technique

A classic FDB percutaneous tenotomy, as described by Piclet-Legre [2], was performed. An incision was placed proximally to the PIP joint, at the junction between the epiphysis and the metaphysis. The approach was performed at the level of the plantar cortex. As the surgeon was right-handed, this incision was medial on the right foot and lateral on the left foot (Fig. 1).

With the PIP in forced plantar flexion, the beaver blade was introduced parallel closely to the plantar cortex of the phalanx, oriented to the contralateral side of the middle phalanx (P2). The FDB tenotomy and PIP plantar capsulotomy were then performed. The beaver blade progressed distally in a rotational movement to carry out the tenotomy of the slip of the contralateral side. In a second step, the section of the plantar plate and the slip closest to the incision was performed. Finally, a forced extension of the toe completely released the attachments of the plantar plate.

2.2. Anatomical dissection

After the surgical procedure, dissection of the specimens was carried out. A longitudinal plantar dissection of all the toes initially treated was performed. Macroscopic integrity of the two plantar digital nerves, the pulleys and the FDL was assessed (Fig. 2). Afterwards, the FDL was deflected and the percentage section of the medial and lateral FDB slips was evaluated and graded as completely, partially, or not at all sectioned. The quality of the plantar arthrolysis by distal disinsertion of the PIP plantar plate was also evaluated (Fig. 3).

3. Results

Both plantar digital nerves were found in continuity and macroscopically intact in all cases. Likewise, the pulleys of the flexor tendons and the FDL were always respected, with no visible lesion (Table 1).

Regarding the efficiency criteria, arthrolysis by distal disinsertion of the PIP plantar plate was complete in all cases, regardless of the FDB slips section. The complete section of both FDB slips was observed in 4 cases (34%). In 3 out of these 4 cases it was a 2nd toe and in one case a 3rd toe. Only one of the two slips was cut in 6 cases (50%). This partial section involved 3 times a 3rd toe and 3 times a 4th toe. In two cases (16.7%) none of the slips were cut, one 2nd toe and one 4th toe (Table 2).

When the surgeon was on the lateral side (left foot), the slip section was complete in 2 out of 3 cases (67%) and limited to one slip in 1 in 3 cases (33%). In this case, the medial slip was not sectioned. When the surgeon worked on the medial side (right feet), the section of the two slips was complete in 2 out of 9 cases (22%), limited to one slip in 5 out of 9 cases (56%) and no slips were cut in 2 out of 9 cases (22%) (Table 3). In the 5 cases where only one slip was cut, it was always the medial one.

A total correction of the deformity was achieved in all cases.

4. Discussion

Regarding the effectiveness, the plantar PIP arthrolysis and correction of the deformity was achieved in all cases. However, the

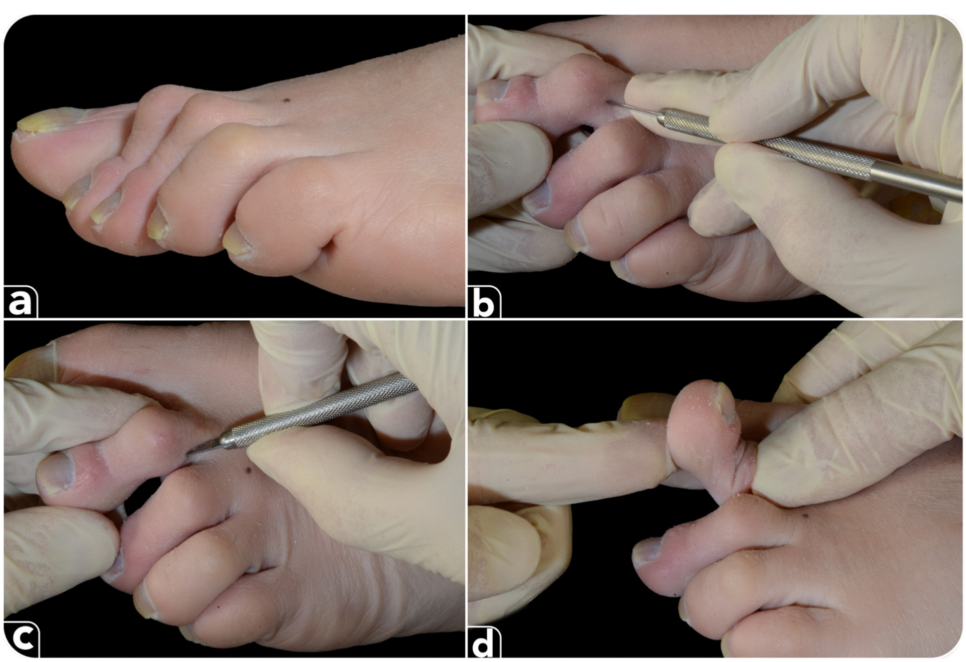


Fig. 1. Steps of the percutaneous flexor digitorum brevis (FDB) Tenotomy. After observing the deformity (a), an incision is performed with the Beaver® blade immediately behind the head of the proximal phalanx (b). The blade progressed distally in a rotational movement to perform the FDB tenotomy (c). The forced extension of the toe completely releases the attachments of the plantar plate (d).

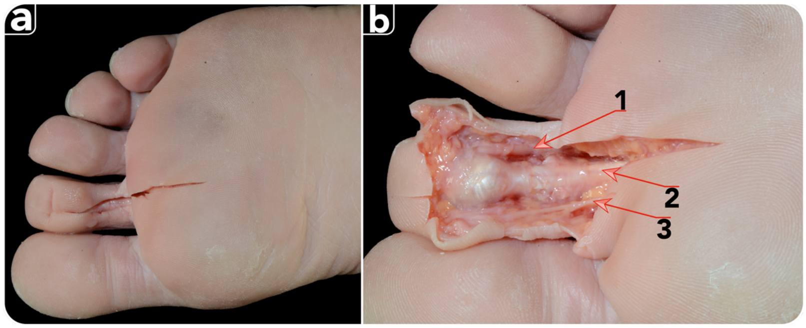


Fig. 2. Plantar view of the superficial dissection. (a) A longitudinal incision in the plantar aspect of the toe is performed. (b) A superficial dissection is performed to assess the integrity of the plantar lateral (1) and medial (3) digital nerves, and of flexor digitorum longus tendon (2). Dissection photo performed at the anatomy laboratory of the University of Bellvitge (Barcelona) by C. Lozzi & Professor Pau Golano.

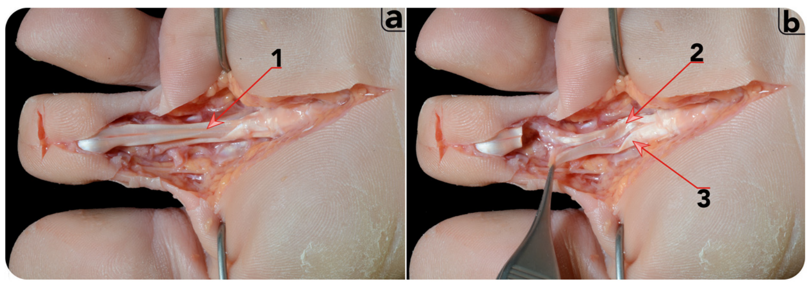


Fig. 3. Plantar view of the dissection performed to assess the release of flexor digitorum brevis (FDB) slips. (1) Flexor digitorum longus tendon. (2) Lateral slip of FDB. (3) Medial slip of FDB. Dissection photo performed at the anatomy laboratory of the University of Bellvitge (Barcelona) by C. Lozzi & Professor Pau Golano.

Table 1
Results.

Case	Toe	Side	Age	Surgeon side	Safety criteria				Efficiency criteria		
					Respected FDL		Integrity medial plantar digital nerve	Integrity lateral plantar digital nerve	Complete section medial slip	Complete section lateral slip	Complete arthrolysis
1	T2	L	55	Lateral	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	T3	L	55	Lateral	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	T4	L	55	Lateral	Yes	Yes	Yes	Yes	**No**	Yes	Yes
4	T2	R	55	Medial	Yes	Yes	Yes	Yes	**No**	**No**	Yes
5	T3	R	55	Medial	Yes	Yes	Yes	Yes	Yes	**No**	Yes
6	T4	R	55	Medial	Yes	Yes	Yes	Yes	Yes	**No**	Yes
7	T2	R	95	Medial	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	T3	R	95	Medial	Yes	Yes	Yes	Yes	Yes	**No**	Yes
9	T4	R	95	Medial	Yes	Yes	Yes	Yes	**No**	**No**	Yes
10	T2	R	/	Medial	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11	T3	R	/	Medial	Yes	Yes	Yes	Yes	Yes	**No**	Yes
12	T4	R	/	Medial	Yes	Yes	Yes	Yes	Yes	**No**	Yes
Total	12				12	12	12	12	9	5	12

section of both FDB slips was inconsistent. According to our study the percutaneous isolated FDB tenotomy is a safe technique, which respects both the FDL and the plantar digital nerves.

Percutaneous tenotomy of both flexor tendons, as originally described by De Prado et al. [1], already proved to be a simple, effective, and safe technique, allowing the correction of claw toe deformities [5–8]. However, the FDL has a capital importance in the balance of the foot due to its major role on the plantar flexion of the distal interphalangeal joint. According to the authors, the absence of FDL leads to a loss of stability when walking. As shown by Fujita [9] in a biomechanical study and Debarge et al. [5] in a clinical one, the role of the FDL in daily walking at a steady pace gait is to keep the necessary pulp support on the ground for the propulsion forces of the last phase of the step. When walking slower, the role of the toes is not necessary for propulsion but remains important for the stabilization of the foot forces. In another biomechanical study, García-González et al. [10] showed that it is better to keep the FDL rather than the FDB in the treatment of claw toes by tendon transfer.

Thus, the FDL sacrifice is responsible for a loss of active flexion and impairs several stages of the gait cycle (especially terminal stance where the pulp contact of all toes contributes to propulsion). These impairments were found to be particularly significant in young and active people [5]. However, this postoperative lack of grip would not limit its indications in elderly and sedentary patients, unless they exhibit particular pre-existing conditions. In particular, Tamir et al. [7] and Schepers et al. [8] have shown a functional benefit from a percutaneous tenotomy of both

Table 2
Effectiveness of the technique depending on the toe.

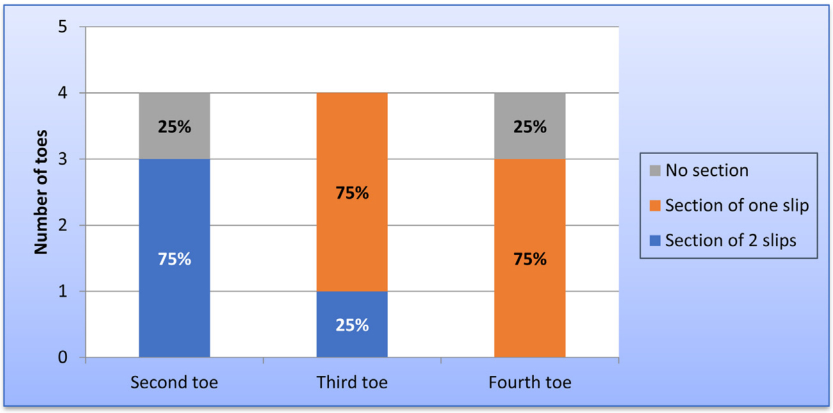
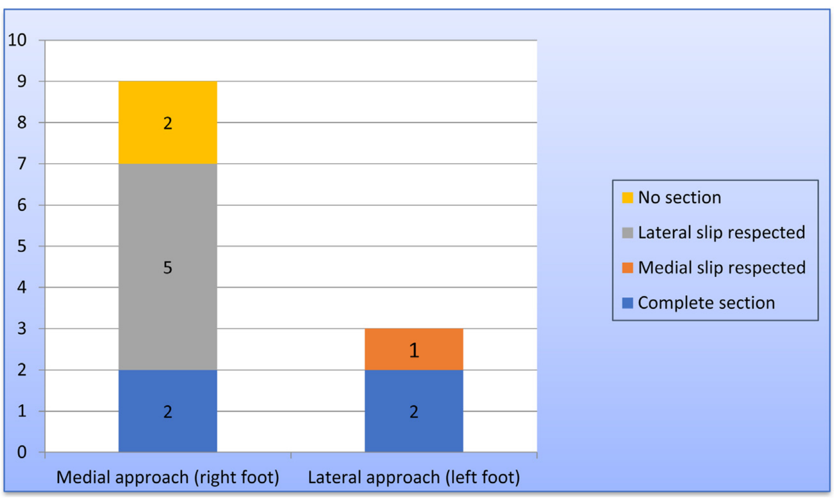


Table 3
Efficiency rate according to the surgeon's side.



flexors in diabetic patients where toe ulcers are a frequent trophic complication of claw toes, regardless of their etiology.

In order to preserve the FDL, a selective tenotomy of FDB is possible due to the morphology of its insertion on P2. The FDB muscle divides in 4 tendons for the lateral toes proximal to the metatarsophalangeal joints. FDB tendons are located plantar to FDL tendons in each toe. Once the flexor tendons reach the toes, each FDB tendon divides in 2 slips that surround the FDL tendon. Both slips re-unite on the dorsal aspect of the FDL tendon to insert on the lateral and medial borders of the plantar aspect of the base of the middle phalanx [12]. The morphology of that insertion and the flexion of the PIP joint that occurs in lesser-toes deformities creates a P2-adjacent plantar space, where this selective FDB tenotomy is safely performed (Fig. 4). From this space, the first structures to be encountered by the blade are both FDB slips, which allow their release while protecting the more plantar FDL tendon.

Piclet described this selective FDB tenotomy and obtained a preservation of active plantar flexion in 86% of cases [11]. This appears to be an effective technique to correct proximal plantar

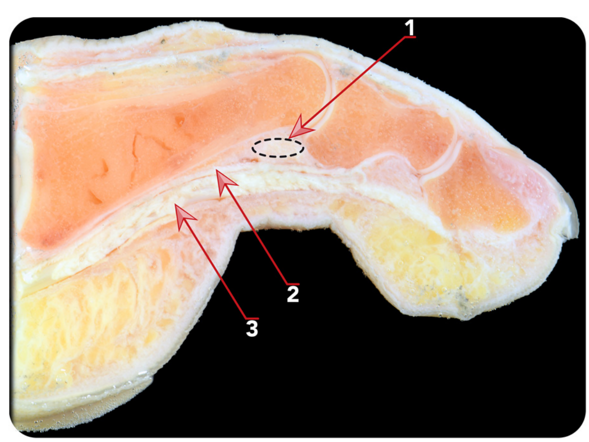


Fig. 4. Sagittal cross-section of a lesser toe showing the insertion of flexor digitorum longus (3) in the base of the distal phalanx and flexor digitorum brevis (2) in the base of the middle phalanx. Dotted line (1) shows the space below the head of the proximal phalanx where the FDB tenotomy is performed.

flexion deformity of the second toe, while preserving active plantar flexion.

Regarding the effectiveness of this percutaneous tenotomy, our study resulted in only 4 of the 12 operated toes (34%) having a tenotomy of both slips, while in 6 out of 12 (50%) only one of the slips was cut. Therefore, the section of both FDB slips was inconsistent in 66% of the cases. Whenever one of the two slips was not cut, it was the contralateral slip the one that remained uncut (opposite to the surgeon). This can be explained by a shallower insertion of the Beaver® blade. However, all 12 cases had a complete plantar arthrolysis with distal disinsertion of the plantar plate and all cases resulted in a correct correction of claw toe deformity. Thus, the arthrolysis may be effective for claw toe correction, and our results indicate that it might be the most important procedure for addressing those deformities. We found that performing the tenotomy described by Piclet achieves that arthrolysis in 100% of cases.

Frey et al. found a correction of the deformity in 89.5% of cases, but in their study patients underwent several surgical procedures which included a P1 osteotomy and, in some cases, a tenotomy of both extensors [11]. An incomplete FDB section like the ones we observed might explain some of the reported failures. This work is the first anatomical study evaluating effectiveness of the isolated FDB tenotomy.

One of the concerns regarding percutaneous surgery is the injury of surrounding soft tissues.

Our dissections showed no injuries, either neurological or tendinous: both plantar digital nerves, FDL tendons and flexor pulleys were found intact. This is consistent with the reports in the literature. In the only review study published on a selective FDB tenotomy, Frey et al. found a rate of complications of 5.2% (all minor and without long-term effects) [11]. However, in their study, other associated procedures such as extensor tenotomy and P1 osteotomy were also performed.

Very few studies evaluate the percutaneous tenotomy of both flexors, which are associated with bone procedures on the proximal phalanx (P1) and/or metatarsals. They did not find neurological or vascular damages [5,6]. There are more studies on the treatment of plantar ulcers of the toes, using this procedure either isolated or associated with a P1 osteotomy [7,8]. All concluded it is a safe procedure with no significant complications [7,8]. Our results are consistent with those and other studies on different percutaneous procedures [13,14].

There is no published anatomical study on percutaneous flexors tenotomy assessing soft tissue damage. Although more studies are needed to increase the number of cases and to widen the spectrum of surgeons regarding their level of experience, our anatomical study seems to confirm the safety of this minimally invasive technique.

There are some limitations to our study. A relatively low number of specimens was use for this study. The same procedure was performed by the same surgeon in 12 specimens (in this case, lesser toes), which is similar to previously published anatomical studies. This study was carried out on amputated feet in the midfoot which could lead to a loosening of the flexor tendons and therefore to a relative modification of the operating conditions making it more difficult to section FDB slips, and easier to avoid injuring FDL. Also, all cases were performed by a single experienced surgeon. It has to be taken into account that percutaneous surgery has an extensive learning curve and that results will differ if a non-experienced surgeon performs the same technique.

Further studies on a larger number of feet, performed by surgeons with different degrees of experience and with amputations above the ankle are probably necessary to confirm our results. In addition, more clinical studies will be necessary to confirm innocuity and efficiency.

5. Conclusion

Percutaneous FDB tenotomy is effective regarding PIP arthrolysis but a technical improvement is required to achieve a reliable section of both FDB slips. Interestingly, while the tenotomy completion rate we reported is far from perfect, the arthrolysis was achieved in 100% of cases. This could indicate that arthrolysis could be the most critical element for claw toe correction.

In the hands of an experienced foot and ankle surgeon specifically trained in percutaneous surgery, this technique has proven to be safe, respecting FDL and plantar digital nerves.

Data statement

Data is not available to access because it is a study on cadaver specimens (which were incinerated)

Conflict of interest

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

Acknowledgements

The authors want to express its gratitude to the late Professor Pau Golanó (1964–2014), who taught us the importance of anatomy and who was without a doubt the most talented anatomist we ever saw. Thank you, Pau, for everything you taught us.

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