ORIGINAL ARTICLE

Evaluation of versatility and outcomes of the first dorsal metacarpal artery flap in thumb defects

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ABSTRACT

BACKGROUND: It is clinically vital to determine the best technique to reconstruct thumb defects with satisfactory esthetic and functional outcomes. We aimed to quantitatively present the safety, versatility, limitations, advantages, and functional results of the first dorsal metacarpal artery flap (FDMAF) and evaluate its outcomes in thumb defect reconstruction by comparing it with the other current surgical options.

METHODS: A total of 21 patients underwent thumb defect reconstruction. They were evaluated with the following parameters: Etiology, age, timing of reconstruction, flap vitality, Semmes-Weinstein monofilament (SWM) test, static two-point discrimination (2PD) test, pain, cortical reorientation, cold intolerance questionnaire, and Michigan hand outcomes questionnaire. Their functional outcomes were evaluated by comparing their scores with the other current surgical options published in the literature.

RESULTS: The mean follow-up period was 22.3 months. The mean pain score of the flap was 0.4±0.6 and no patient had pain in the donor area (range, 0–10). The sensory outcome was "good" (8.6 mm) based on the static 2PD test. The mean SWM test score was 4.02 g. Patient satisfaction was 4.6 according to the Michigan hand outcomes questionnaire (range, 0–5). The cold intolerance questionnaire scores showed that the patients had mild cold intolerance (mean, 10.5; range 0–100). Complete cortical reorientation was seen in 81% of the patients.

CONCLUSION: Restoration of the innervation of thumb defects is possible with the FDMAF with high satisfaction rates based on our results. The absence of the microsurgical vessel or nerve repair facilitates the surgery, shortens its duration, and reduces morbidity, reserving the microsurgical options for more complicated cases. Therefore, it can be concluded that the FDMAF is an effective flap with great modifications for complicated thumb defects but surgeons should consider their clinical outcomes and prolonged surgery when choosing which technique to be used.

Keywords: Defect; first dorsal metacarpal artery; flap; foucher; littler; moberg; reconstruction; thumb.

INTRODUCTION

Thumb injuries with deep tissue defects, including exposed bone and tendon injuries, are often challenging cases for hand surgeons. Considering that the thumb is responsible for 40% of the hand function, meticulous surgical planning is required to reconstruct the length, stability, sensory sensitivity, curvature, and mobility of the thumb.[1] Especially, pulp defects, which are very important from a functional point of view, should be reconstructed in the safest and simplest way possible with well-vascularized and sensory tissues. In the final functional evaluation, cortical reorientation and finger motor movements are important parameters to be taken into consideration.

Many procedures have been described for the reconstruction of thumb defects in the literature. Several transposition and advancement flaps,[2–5] cross-finger flaps,[6–8] Littler's heterodigital neurovascular flap,[9–11] and partial great toe or free flaps raised from the 1st web space of the foot[12–14] are alternative surgical procedures used in the reconstruction of the thumb defects. Despite all this diversity, each technique has

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its own disadvantages. Among all these techniques, Foucher's first dorsal metacarpal artery flap (FDMAF) is one of the best options for thumb soft-tissue defects today due to its low donor site morbidity, esthetic compatibility, sensation, and cortical reorientation. The FDMAF that can be raised with sensory innervation from the dorsum of the 2nd finger was first described by Hilgenfeldt and developed by Holevich.[15,16] Gebhart and Meissl defined the same flap as extended FDMAF by widening its borders.[17]

The aim of this study is to quantitatively present the safety, versatility, limitations, advantages, and functional results of this flap in patients who have undergone thumb defect reconstruction with FDMAF in our clinic and to compare its outcomes with the other current surgical options.

MATERIALS AND METHODS

A total of 21 patients (four females and 17 males) underwent reconstruction of the thumb defects with FDMAF between January 2017 and June 2020 in our institution. The study was conducted according to the guiding principles delineated in the Declaration of Helsinki and written informed consent was obtained from all patients. The protocol of this study was approved by the Instructional Ethics Committee (GO 21/1024).

The inclusion criteria for the study group were injuries of the thumb with exposed tendon or bone, a defect 1.5 cm^2 or larger in diameter, and the need to reconstruct the sensation or contour of the thumb. The exclusion criteria from the study group were defects <1.5 cm^2 in diameter, conditions accompanied by injury on the dorsal surface of the second finger proximal phalanx or FDMA axis, patients who could not complete the postoperative follow-up period (>1 year), and injuries that can be treated with minimal functional loss with local fingertip flaps, replantation, secondary healing, or grafts.

Patients who meet the inclusion criteria were evaluated with several parameters: Etiology, age, gender, timing of reconstruction (emergency surgery and delayed surgery), flap vitality (partial or complete necrosis and complete survival), Semmes-Weinstein monofilament (SWM) test, static two-point discrimination (2PD) test,[18] pain (donor site and thumb, scores between 0 and 10), cortical reorientation (complete and partial), cold intolerance questionnaire (0, 1–25, 25–50, 51–75, and 76–100, respectively: None, mild, moderate, severe, or very severe),[19] and Michigan hand outcomes questionnaire (scores 1–5).[20,21] The classification proposed by Imai et al.[22] was used to interpret the SWM test scores (normal, ≤2.83; diminished light touch, 2.84–3.61; diminished protective sensation, 3.62–4.31; loss of protective sensation, 4.32–4.56; and anesthetic, ≥6.10). The modified classification adopted by the American Society for Surgery of the Hand (ASSH) was used to assess 2PD test scores (excellent, <6 mm; good, 6–10 mm; fair, 11–15 mm; and poor, >15 mm).[23] Advantages, reliability, limitations, and functional outcomes of the FDMAF were evaluated by comparing its scores with the other current surgical options published in the literature.

Surgical Technique

The operation is performed under regional anesthesia, with the aid of a tourniquet and 2.5 × loupe magnification, while the patient is in the supine position and the arm is abducted on the arm table. After debridement of the defect, the defect area is measured and a flap drawing is performed on the dorsal surface of the proximal phalanx of the second finger accordingly. Care is taken not to go beyond the proximal interphalangeal in flap drawing to prevent post-operative functional disturbance. The radial and ulnar midlines are considered as limits for maximum flap width. A lazy-S incision is made from the proximal flap to the most proximal corner of the first dorsal space (pivot point). At this point, the FDMA emerges from the dorsal branch of the radial artery. The FDMA is a reliable artery and arises just distal to the extensor pollicis longus tendon. The artery travels above the first dorsal interosseous muscle fascia. A total of three branches originate from the dorsal branch of the radial artery, the radial branch to the thumb, the intermediate branch to the first web space, and the ulnar branch to the second finger, and the ulnar branch forms the main arterial supply of the FDMAF.[24] The flap is raised from distal to proximal (Fig. 1). Preservation of the paratenon of the second finger extensor system is vital for graft survival. When the first dorsal inter-

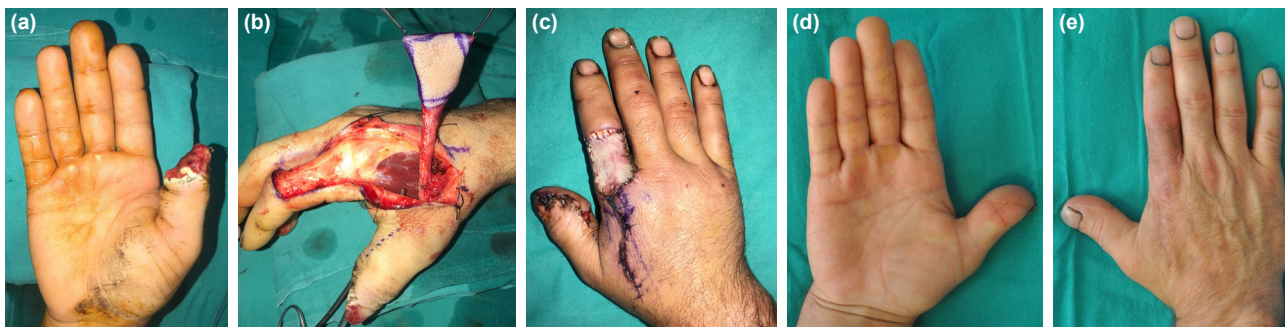

Figure 1. Reconstruction of a thumb pulp defect with the first dorsal metacarpal artery flap (FDMAF). **(a)** Intraoperative view of the defect after debridement. **(b)** Elevation of the FDMAF. **(c)** Appearance of the skin graft at the donor site after 5 days. **(d)** Post-operative 2 years. Note good contour of the pulp and fullness of the flap with favorable esthetic appearance. **(e)** The donor site after 2 years with good esthetic appearance.

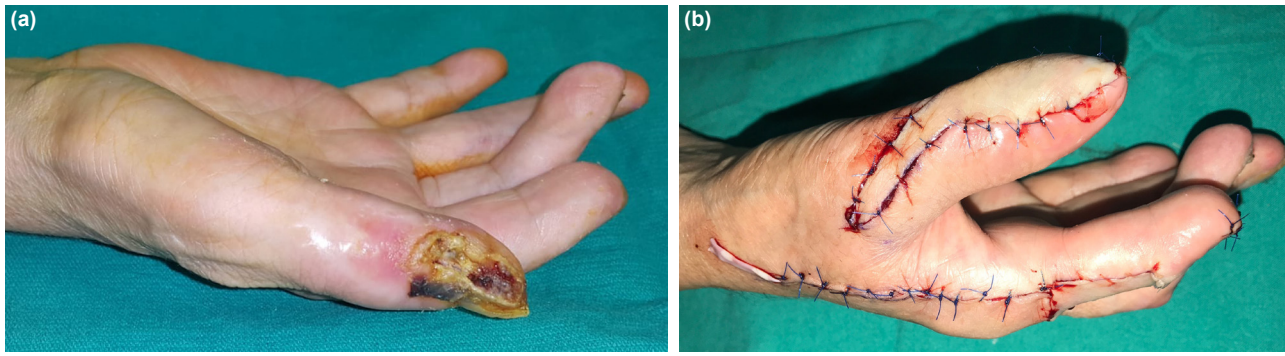

Figure 2. (a) Pre-operative view. **(b)** Reconstruction of the thumb defect after an oncologic resection. Note the skin left above the pedicle.

osseous muscle fascia is seen on the radial side of the second metacarpal bone proximal to the metacarpophalangeal joint, the subfascial plane is entered. The fascia is incised along the radial border of the second metacarpal bone. While dissecting to the proximal in the subfascial plane, the branches going to the muscle are cauterized. The superficial branch of the radial nerve is visible through the skin incision placed above the pedicle and is preserved. The artery is not isolated not to injure the venae comitantes for venous drainage. A small skin can also be left above the pedicle longitudinally which brings additional skin to the thumb (Fig. 2). The FDMAF is elevated until the pivot point by creating a subcutaneous pedicle, incorporating the artery, veins, and nerve. The flap is passed through the subcutaneous tunnel to the thumb defect and inset. Care should be taken that the tunnel is not tight and that the pedicle is not compressed or folded. The tourniquet is opened and flap vitality checked. After careful hemostasis, the donor site is closed with a full-thickness skin graft. The hand is kept above the level of the heart for 3 days postoperatively to facilitate venous drainage. The hand is kept in a protective splint for 10 days. Then, the patient is referred to physical therapy for sensory and motor exercises.

RESULTS

The mean age of the 21 patients included in the study was 48.1±11.0 (range, 29–75 years). Among all patients, 57% had work accidents which were the most common etiology. About 62% of the surgeries were performed as emergency surgery. Patient characteristics and pre-operative data are shown in Table 1.

In the post-operative period, partial necrosis was observed in one flap, which healed by secondary intention without additional surgical intervention, while full survival was observed in the remaining flaps (95%). The mean follow-up period was 22.3±9.7 months. There were no limitations in the range of motion of the proximal interphalangeal and metacarpophalangeal joints of the donor finger compared to the contralateral side. No patient had pain in the donor area, and the mean pain score of the flap was 0.4 ± 0.6 in the thumb (range, 0–10). The sensory outcome of the thumbs was "good" (8.6±1.8 mm) according to the classification adopted by the ASSH based on 2PD test. The mean SWM test score (4.02±0.38 g) of the thumbs, which was the other sensory parameter, was interpreted as diminished protective sensation. Patient satisfaction was 4.6±0.5 according to the Michigan hand outcomes questionnaire (range, 0–5). The cold intolerance questionnaire scores showed that the patients had mild cold intolerance (mean, 10.5±8.5; range 0–100). Complete cortical reorientation was seen in 17 patients (81%) while partial reorientation was seen in the remaining 4 patients (19%) af-

Table 1. Patient characteristics and preoperative data

	Number
Age	48.1±11.0
Gender	
Female	17
Male	4
Etiology/Injury type	
Work accident	12
Home injury	5
Oncologic	3
Hyperalgesic pulp	1
Timing of surgery	
Emergency (<24 hours)	13
Delayed (>24 hours)	8

Table 2. Postoperative data

	Mean±SD
Semmes-Weinstein monofilament, g	4.02±0.38
Two-point discrimination, mm	8.6±1.8
Pain (0–10)	
Donor region	0.0±0.0
Thumb	0.4±0.6
Michigan hand outcome questionnaire (1–5)	4.6±0.5
Cold intolerance questionnaire (0–100)	10.5±8.5

SD: Standard deviation.

ter the follow-up period of at least 12 months. Post-operative outcomes are presented in Table 2.

DISCUSSION

Thumb defects require a flap that can cover exposed tendon or bone structures, reconstruct finger sensation, stability, and esthetics. It also needs to have a good blood supply and innervation. Among the alternatives that can meet these needs, local flaps such as Atasoy, Kutler, and Moberg flaps offer good tissue innervation and blood supply but the inability to move the flap far enough is an important disadvantage.[2,5,25] It is easy to cover the distal thumb defects with the FDMAF by extending the flap design distally up to proximal interphalangeal joint.

Another alternative is the sensate cross-finger flap. However, this flap requires microsurgical nerve coaptation, 3 weeks of passive immobilization of the injured finger, and a second flap detachment surgery.[26] Immobilization and additional surgery increase the morbidity, and microsurgical nerve coaptation prolongs the surgical time. Therefore, it is not wise to opt for this flap when the FDMAF is available.

Littler's neurovascular island flap is a useful and good alternative. However, the necessity of sacrificing a digital artery and causing morbidities such as contracture in the donor area are its disadvantages.[10,11] In the study conducted by Delikonstantinou et al.,[11] they found that Littler's neurovascular island flap may limit the donor finger's range of motion. The mean 2PD test score was 7.5 mm in their study which is interpreted as "good," as in our study based on the ASSH classification. In 2018, Wang et al.[27] described a modification of the Littler flap in which they restore the digital nerve defect by a nerve graft which also requires extra time and microsurgical nerve coaptations.

Several FDMAF modifications have been published in the literature with satisfactory results. In the study conducted by Wang et al.,[28] incorporating the dorsal sensory branch of the radial proper digital nerve of the index finger into the FDMAF and its coaptation to the ulnar stump of the proper digital nerve resulted in better results compared to the control group. Feng et al.[29] found that better sensory outcomes can be achieved by transecting the superficial radial nerve and coapting the dorsal branches of the radial and ulnar digital nerves of the index finger with the proper digital nerves of the thumb in end-to-end fashion. It should be noted that they not only coapted the radial and ulnar dorsal branches of the proper digital nerves of the index finger to the distal stumps of the proper digital nerves of the thumb, but also preserved

Table 3. Comparison of different FDMAF techniques

	Wang et. al.		Feng et. al.		Present study
	Control group	Study group	Control group	Study group	
Semmes-Weinstein monofilament, g	3.57	4.34	4.02	3.84	4.02
Two-point discrimination, mm	11	6.5	7.1	5.9	8.6
Michigan hand outcome questionnaire (1–5)	–	4.85	4.7	4.9	4.6
Cold intolerance questionnaire (average)	–	Mild	Mild	Mild	Mild

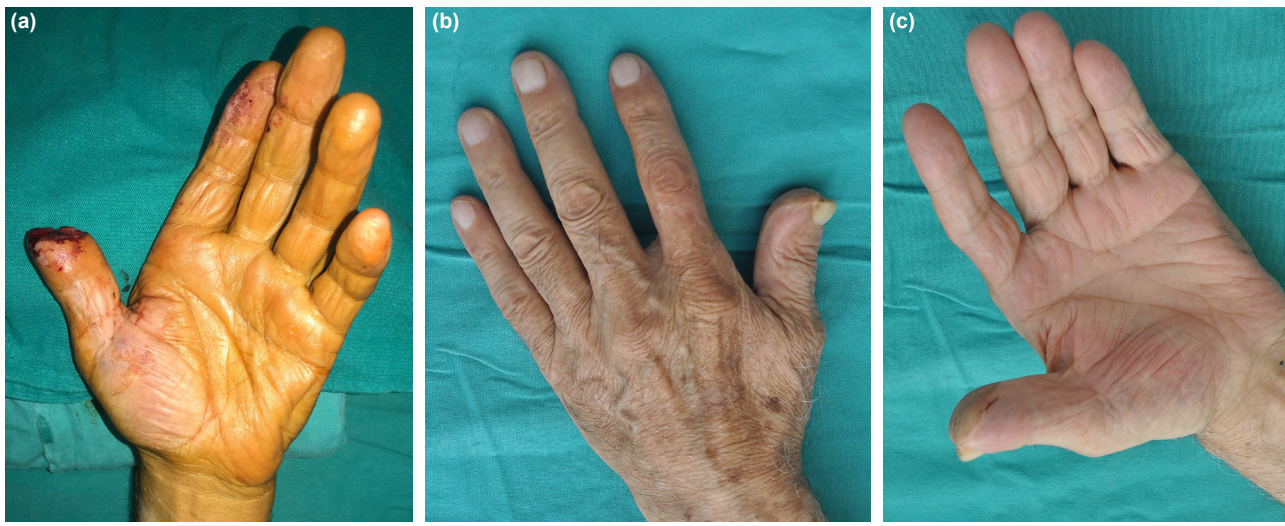

Figure 3. (a) Pre-operative view. **(b** and **c)** Post-operative views 2 years after reconstruction with the FDMAF. Note good contour and fullness of the pulp, and minimal scar at the donor site.

the superficial radial nerve in the control group. Although these studies resulted in better sensory outcomes in 2PD and SWM tests, their patient satisfaction scores were similar to our results in the Michigan hand questionnaire and cold intolerance test (Table 3). Therefore, it can be concluded that the FDMAF is an excellent flap with great modifications for thumb defects but surgeons should consider their clinical outcomes and prolonged surgery when choosing which technique to be used.

Free flaps designed from the big toe, on the other hand, are challenging because they require microsurgical vessel and nerve repairs.[30,31] These procedures carry the risk of microsurgical complications such as flap loss. Moreover, although they have good esthetic and sensory results in the thumb defects, similar satisfactory results with technically simpler interventions such as the FDMAF can be obtained (Fig. 3). Based on our results, it can be concluded that the FDMAF is a great option in thumb defects and has an average Michigan hand outcomes questionnaire score of 4.6/5, "good" sensory outcome based on the ASSH classification, and "mild" cold intolerance score (10.5/100).

Patients with thumb defects reconstructed with the FDMAF may report reduced range of motion in the proximal interphalangeal and metacarpophalangeal joints of the donor finger until scar maturation is complete. As we showed in our patients, there were no limitations in the range of motion of the donor finger compared to the contralateral side in the long term. In addition, discoloration of the donor site is another issue which is usually well tolerated by patients (Figs. 1e and 3b). It should be emphasized that the flap can be passed through a subcutaneous tunnel to the thumb defect with increased cosmetic results; however, if the tunnel is too tight with an increased risk of pedicle compression, a skin incision can be made. In case of skin incision, a small longitudinal skin can be left above the pedicle (Fig. 2b).

There are several limitations in this study that need to be addressed. First, there were no control group in this study because we always preferred simpler alternatives for thumb defects that can be treated with local fingertip flaps, secondary healing, or grafts. For more complicated defects, we always used the FDMAF because it is relatively easy to perform and has satisfactory outcomes. Therefore, we decided to quantitatively compare our results with the alternatives published in the literature. Second, we always performed the Foucher's neurovascular island flap modification of the FDMAF rather than more sophisticated alternatives involving nerve coaptations to show the safety, versatility, outcomes, and advantages of this technique over the other alternatives.

Conclusion

It is clinically vital to determine the best technique to reconstruct thumb defects with satisfactory esthetic and functional outcomes. The FDMAF has a similar structure with the thumb soft tissue. Moreover, restoration of the innervation of the thumb is possible with this flap with high satisfaction rates based on our results. The absence of microsurgical vessel or nerve repair facilitates the surgery, shortens its duration, and reduces morbidity, reserving the microsurgical options for more complicated cases. Because of the aforementioned reasons, the FDMAF could become the first choice for thumb soft-tissue defects which cannot be treated with local fingertip flaps, secondary healing, or grafts.

Ethics Committee Approval: This study was approved by the Hacettepe University Non-interventional Clinical Research Ethics Committee (Date: 05.10.2021, Decision No: 2021/16-14).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Başparmak defektlerinde birinci dorsal metakarpal arter flebinin sonuçlarının ve kullanışlılığının değerlendirilmesi

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AMAÇ: İyi bir estetik ve fonksiyonel sonuçla başparmak defektlerinin rekonstrüksiyonu için en iyi tekniği belirlemek klinik olarak büyük önem taşımaktadır. Bu çalışmada, birinci dorsal metakarpal arter flebinin (BDMAF) güvenirliliğini, çok yönlülüğünü, limitasyonlarını, avantajlarını ve fonksiyonel sonuçlarını nicel veriler ile sunmayı ve ek olarak diğer güncel cerrahi seçeneklerle karşılaştırarak başparmak defekti rekonstrüksiyonundaki sonuçlarını analiz etmeyi amaçladık.

GEREÇ VE YÖNTEM: Toplam 21 hastaya başparmak defekti rekonstrüksiyonu gerçekleştirildi. Bu hastalar etiyoloji, yaş, rekonstrüksiyon zamanlaması, flep yaşamsallığı, Semmes-Weinstein monofilament (SWM) testi, statik iki nokta ayrımı (2NA) testi, ağrı, kortikal reoryantasyon, soğuk intoleransı anketi ve Michigan el sonuçları anketi gibi parametreler ile değerlendirildiler. Fonksiyonel sonuçlar, literatürde yayınlanmış diğer güncel cerrahi seçenekler ile nicel veriler üzerinden karşılaştırılarak değerlendirildi.

BULGULAR: Ortalama takip süresi 22.3 aydı. Fleplerin ortalama ağrı skoru 0.4±0.6 idi ve hiçbir hastanın donör bölgesinde ağrısı yoktu (aralık, 0–10). Duyusal sonuç, statik 2NA testine dayanarak "iyi" (8.6 mm) olarak bulundu. Ortalama SWM testi skoru 4.02 g idi. Hasta memnuniyeti ise Michigan el sonuçları anketine göre 4.6 idi (aralık, 0–5). Soğuk intolerans anketi skorlarına göre hastalar, hafif soğuk intoleransa sahipti (ortalama, 10.5; aralık 0–100). Hastaların %81'inde tam kortikal reoryantasyon olduğu görüldü.

TARTIŞMA: Sonuçlarımız ışığında bakıldığında, başparmak defekti innervasyonunun BDMAF ile restorasyonunda yüksek memnuniyet oranları görülmektedir. Bu teknikteki herhangi bir mikrocerrahi damar veya sinir onarımının olmaması ameliyatı kolaylaştırır, cerrahi süreyi kısaltır ve morbiditeyi azaltır. Böylelikle bu yaklaşım, daha komplike durumlar için mikrocerrahi seçenekleri potansiyel alternatif yaklaşımlar olarak rezerve etmiş olur. Bu doğrultuda düşünüldüğünde BDMAF, kompleks başparmak defektleri için çok çeşitli modifikasyonlara sahip, etkili bir fleptir ve cerrahların bu defektlerde hangi tekniğin kullanılacağını seçerken, tekniklerin klinik sonuçlar açısından birbirlerine üstünlükleri olup olmadığını ve artabilecek cerrahi süreyi göz önünde bulundurmaları gerektiği sonuçlarına varılabilir.

Anahtar sözcükler: Başparmak; birinci dorsal metakarpal arter flebi; defekt; flep; Foucher; Moberg; rekonstrüksiyon.

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