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Fixation of Mallet Fractures Using a Modified Hook Plate Technique: A Prospective Case Series of 17 Patients*

Fixação de fraturas em martelo com técnica de placa de gancho modificada: Uma série de casos prospectivos de 17 pacientes

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Abstract

Objective Various modalities have been suggested to manage mallet fractures; however, inappropriate treatment can lead to extension lag, a swan neck deformity, or arthritis of the distal interphalangeal joint (DIPJ). The current study aimed to evaluate the results (functional, radiological, and complications) of open reduction and internal fixation (ORIF) of mallet fractures using low-cost hook plates fabricated from low-profile titanium mini plates.

Methods A prospective case series of 17 consecutive patients (average age of 32.3 years) with mallet fractures (six were Wehbe Type IB and 11 were Wehbe Type IIB). Eleven (64.7%) were males. The affected hand was dominant in all patients, and the affected digit was the index in 6 (35.3%), the ring in 5 (29.4%), the small in 3 (17.65%), and the middle in 3 (17.65%) patients. The same fellowship-trained hand surgeon performed all surgeries.

Results The average operative time was 37.65 minutes. After an average follow-up of 10.94 months (range 6–27), the average DIPJ motion was 50° ° (range 20°–70°), the extensor lag was noted in 4 (23.5%) patients, and complications were reported in 6 (35.29%) patients. According to Crawford criteria, 6 (35.3%) patients achieved excellent results, 7 (41.2%) achieved good results, and 4 (23.5%) achieved fair results.

Conclusion The modified hook plate technique for fixation of mallet fractures is a beneficial, economical, yet demanding technique that adequately provides stable fixation to allow early DIPJ motion with acceptable functional outcomes.

Keywords
- bone plates
- finger injuries
- finger joint
- fractures, bone
- fracture fixation, internal

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Resumo

Objetivo Diversas modalidades têm sido sugeridas para o tratamento de fraturas em martelo; no entanto, o tratamento inadequado pode causar retardo de extensão, deformidade em pescoço de cisne ou artrite da articulação interfalangiana distal (AIFD). Este estudo teve como objetivo avaliar os desfechos (funcionais, radiológicos e complicações) da redução aberta e fixação interna (RAFI) das fraturas em martelo com placas de gancho de baixo custo fabricadas com mini placas de titânio de baixo perfil.

Métodos Série de casos prospectivos de 17 pacientes consecutivos (idade média de 32,3 anos) com fraturas em martelo (seis do tipo IB e 11 do tipo IIB de Wehbe). Onze (64,7%) pacientes eram do sexo masculino. A mão acometida era a dominante em todos os pacientes, com acometimento do dedo indicador em seis (35,3%), anelar em cinco (29,4%), mínimo em três (17,65%) e médio em três (17,65%) pacientes. O mesmo cirurgião de mão experiente realizou todas as cirurgias.

Resultados O tempo operatório médio foi de 37,65 minutos. Após um acompanhamento médio de 10,94 meses (intervalo de 6 a 27), observou-se movimento médio da AIFD de 50° (intervalo de 20° a 70°), retardo de extensão em quatro (23,5%) pacientes e complicações em seis (35,29%) pacientes. De acordo com os critérios de Crawford, os desfechos foram excelentes em seis (35,3%), bons em sete (41,2%) e regulares em quatro (23,5%) pacientes.

Conclusão A técnica da placa de gancho modificada para fixação de fraturas em martelo é benéfica e econômica, mas exigente; permite fixação estável e adequada para permitir a movimentação precoce da AIFD com desfechos funcionais aceitáveis.

Palavras-chave

- placas ósseas
- traumatismos dos dedos
- articulações dos dedos
- fraturas ósseas
- fixação interna de fraturas

Instruction

Traumatic mallet finger is a common injury involving the extensor tendon of the distal interphalangeal joint (DIPJ),[1] which could involve a fracture with bony avulsion of a variable-sized fragment together with the attachment of the extensor tendon, also known as the "bony mallet finger" or a "mallet fracture."[2] Inadequately treating such injuries could lead to various complications, including extensor lag, swan neck deformity, arthritis, pain, and loss of function.[3,4] Mallet fractures are usually managed non-surgically using an orthosis such as the Stack orthosis or custom-made splints.[5] Although no consensus exists on the indications for surgical management, most surgeons would consider surgical options when the fracture involves more than a third of the articular surface or in the presence of joint subluxation.[6]

Many techniques have been described for the operative treatment of mallet fractures, including extension block pinning and open reduction internal fixation (ORIF) using varieties of implants such as wires, tension band wiring, screws, or plates.[2,5,7] None of these techniques has proved superior to the others, and all had significant reported complications up to 54%.[7–9] In 2007, Teoh and Lee[10] introduced a novel approach of mallet fractures ORIF using a hook plate which showed excellent results in their hands. Since then, only a limited number of reports have been published in the literature assessing the results of this technique, with some challenging the reproduction of the results initially reported.[11]

In the current study, we aimed at reporting our early experience and results (clinical, radiological, and complications) after using low-cost hook plates fabricated from low-profile titanium mini plates for ORIF of mallet fractures.

Methods

This prospective case series study was performed on patients presented with hammertoe fractures treated in a specialized hand surgery unit at a level one trauma center by a fellowship-trained hand surgeon between April 2016 and July 2019. We included skeletally mature patients (above 18 years old) presented with fresh mallet fractures (those who presented up to 4 weeks following the injury) of any of the ulnar four digits classified as Wehbe type IB and IC (fractures involving more than one-third of the articular surface), and Wehbe type II (fractures associated with palmar subluxation of the distal phalanx) according to Wehbe and Schneider classification,[12] and agreed to participate in the study. An institutional Review Board approval was obtained (Approval no.: 17101844), Informed consent was obtained from all participating patients.

Demographic data of patients, including age and sex, mode of trauma, the time interval between trauma and surgery, were collected. Preoperative standard anteroposterior and lateral X-rays of the digit were used to determine fragment size and displacement, percentage of articular surface involvement, joint subluxation, and fracture classification.

Surgical Technique

Under digital block anesthesia and after preparation of the affected limb, a rubber glove was used as a tourniquet then a dorsal H-shaped skin incision was made centered over the extension crease of the DIP joint (►**Fig. 1A**). To expose the extensor tendon and the avulsed fragment, a thick skin flap was raised and retracted proximally and distally (►**Fig. 1B**).

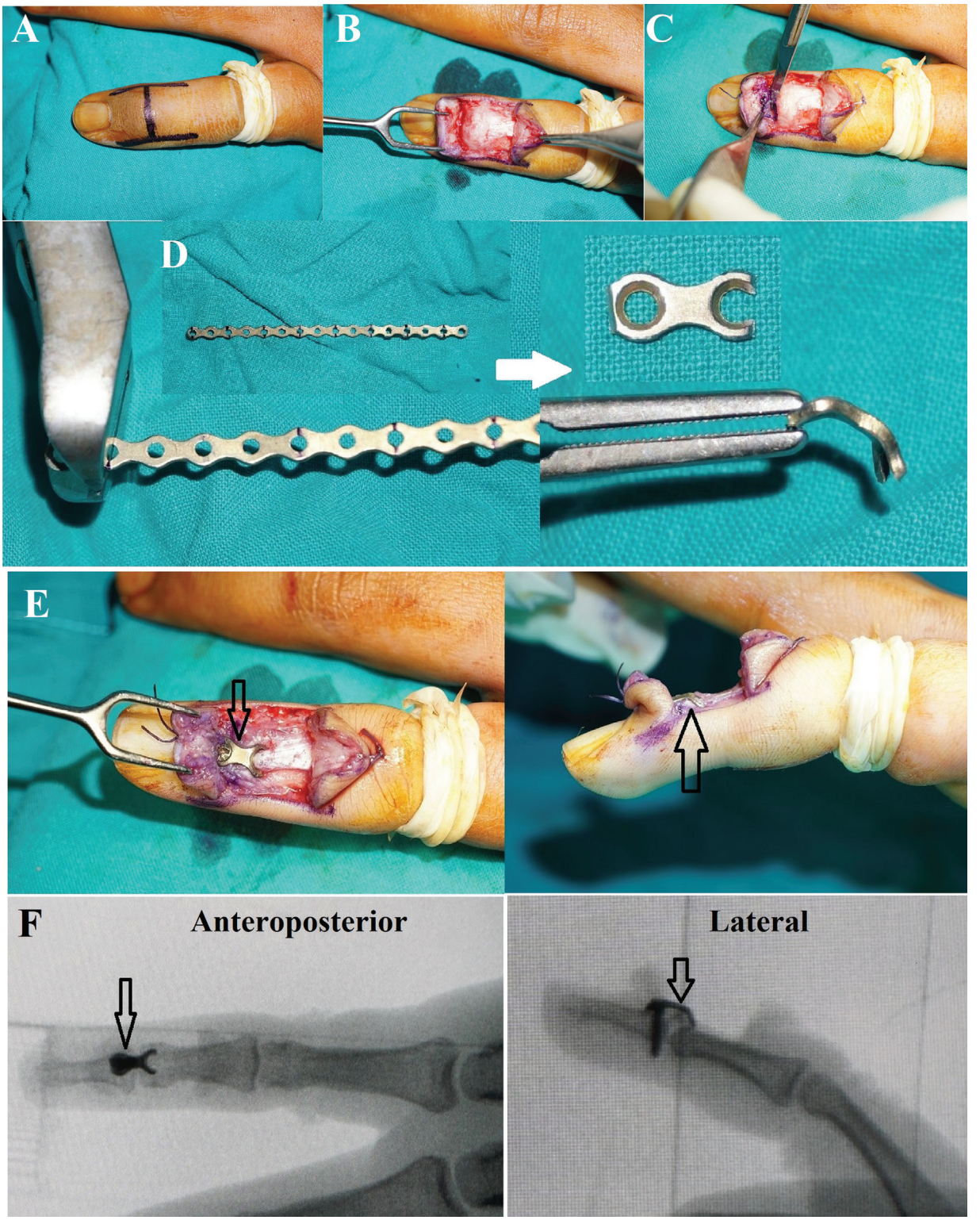

Fig. 1 Surgical technique, (**A**): A dorsal H-shaped incision is made over the distal interphalangeal joint. (**B**): Thick skin flaps are raised proximally and distally. (**C**): Sub-periosteal elevation for placement of the hook plate. (**D**): Hook plate fabrication from a mini plate. (**E**): Intraoperative placement of the hook plate showing its low profile and less prominence (black arrowhead). (**F**): intraoperative fluoroscopy to check plate position and reduction (black arrowhead).

The fracture site was exposed and cleaned up. The periosteum was elevated distal to the fracture site on the dorsal surface of the distal phalanx, allowing for subperiosteal placement of the hardware; this could facilitate fracture reduction and minimize soft tissue complications such as skin breakdown and nail deformities (►**Fig. 1C**). The hook plate was prepared from a multiple-hole 2.0 mm titanium miniplate (Orthomed-E), classically used for phalangeal and metacarpal fractures, by fashioning a hook plate by cutting two holes from the plate, then one of the holes was cut to remove a third of its circumference, and the ends of the remaining crescent was bent to form two pointed hooks (►**Fig. 1D**).

The avulsed fragment was then reduced and held in place with forceps, the hooks of the plate were anchored in the tendon, applying traction on the bony fragment and holding it in the reduced position with the DIPJ in full extension, the plate placed in position on the dorsal surface of the distal phalanx. A 1.5 mm drill bit is used to create the hole for the screw perpendicular to the dorsal surface, and a 2.0 mm screw was inserted. Bicortical screw purchase is better to achieve good fixation (►**Fig. 1E**), intra-operative C-arm images were used to check the fracture reduction, correction of subluxation, screw placement and length, and stability of the fixation was tested by a lateral image with mild flexion of the DIP (►**Fig. 1F**).

Postoperative Rehabilitation and Follow Up Protocols

A temporary extension aluminum splint is included in the postoperative dressing, replaced with a Stack splint on the next day. The patient is instructed to remove the splint for 10 minutes every hour to do DIPJ active flexion exercises in the form of making a full fist. This is continued for the first two weeks, which is replaced by protected mobilization for six weeks. The splint is worn continuously in between exercises for six weeks and only at night for the next two months.

The patients were followed at the outpatient clinic on the first postoperative day, at two weeks, six weeks, three months, six months, 12 months, and then annually. Serial anteroposterior and lateral radiographs of the affected digit were taken immediately postoperative and at the follow-up visits to assess fracture union and any evidence of complications (►**Fig. 2**). Functional outcomes were evaluated using the Crawford criteria[13] (►**Table 1**), range of motion and extension lag at the DIP Joint were measured with a goniometer. We adopted the criteria reported by Teoh and Lee,[10] where they considered an active DIP joint flexion of 70° was considered full, and 60° or more was considered normal, and a good result was ruled out by pain or stiffness at final follow up. Any complications (perioperatively or during the follow up) were reported.

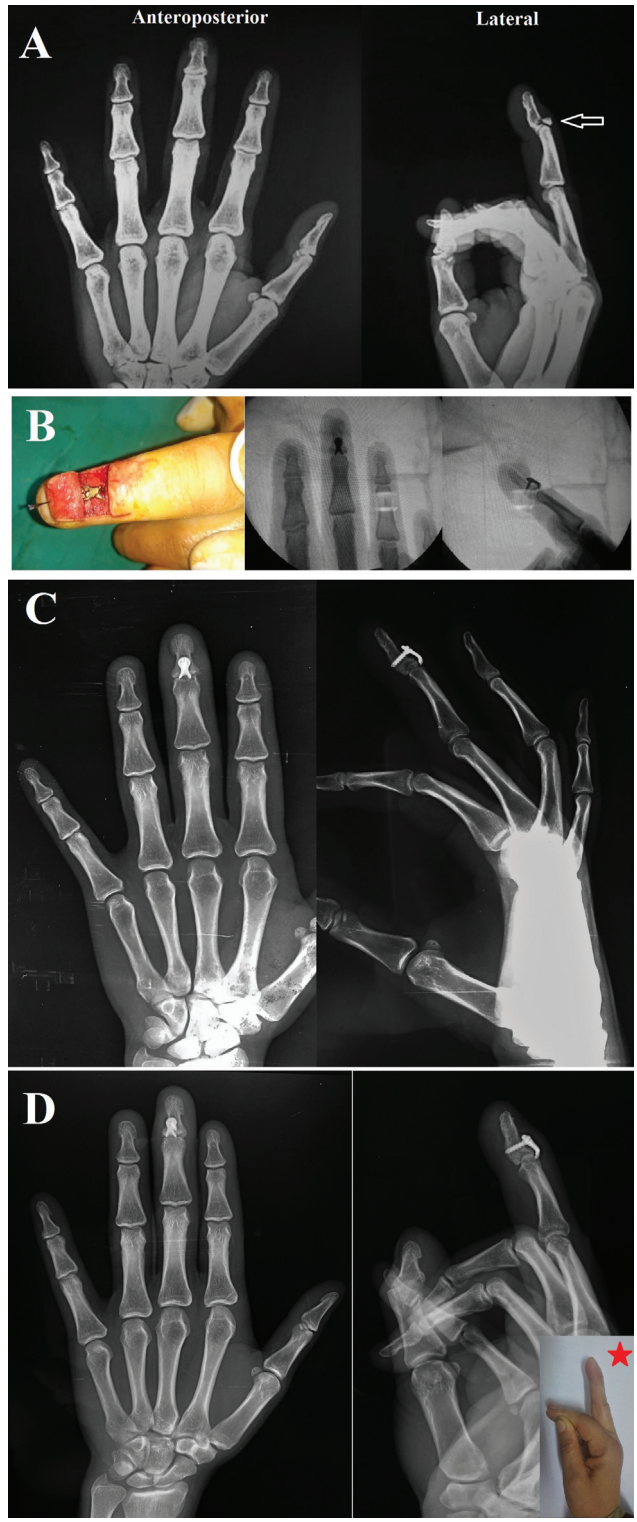

Fig. 2 Female patient, 35 years old, presented with mallet fracture Wehbe Type II B, (**A**): preoperative anteroposterior and lateral plain radiograph (fracture indicated by white arrowhead). (**B**): intraoperative clinical and fluoroscopic images showing fracture reduction and plate position. (**C** and **D**): six months and one year follow up radiographs respectively, showing fracture healing and maintained plate position.

Results

Details of the study cohort are reported in (►**Table 2**). The average age of patients was 32.3 years (range 18–50). The affected hand was the dominant hand in all patients; The affected digit was the Index in 6 patients (35.3%), the ring in 5 (29.5%), the little in 3 (17.6%), and the middle in 3 (17.6%).

Table 1 Crawford criteria for mallet finger evaluation

Grade	Extension loss	Flexion	Pain
Excellent	None	Full	None
Good	0–10	Full	None
Fair	10–25	Any loss	None
Poor	>25	Any loss	Persistent

The average percentage of articular surface involvement (evident in lateral radiographs) was 47.9% (range 30–65%). Palmar subluxation of the distal phalanx was present in 11 (64.7%) patients. Regarding fractures classification, 6 (35.3%) were Wehbe Type IB, and 11 (64.7%) were Type IIB fractures.

The average time from injury to surgery was 12.1 days (range 1–20), while the average time from admission to surgery was 6.59 hours (range 4–12 hours). The average operative time was 37.65 minutes (range 25–45). The average time of hospital stay was 8.59 hours (range 6–14).

After an average follow-up period of 10.94 months (range 6–27), all fractures showed radiographic union, which was detected by the 6th postoperative week, and the DIPJ showed congruency. The average active range of DIPJ motion was 50° (range 20°–70°). An extensor lag was noted in 4 (23.5%) patients with an average of 3° (range 0° - 20°). According to Crawford criteria, 6 (35.3%) patients achieved excellent results, 7 (41.2%) had good results, and 4 (23.5%) had fair results. No poor results were recorded in this study.

Complications were reported in 6 (35.29%) patients. Two patients had fracture re-displacement with persistent deformity, which was due to early forceful passive movement of the DIPJ within the first two weeks post-operatively, fixation was revised in both patients; however, they reported limited range of motion by the last follow up and graded as having fair results according to Crawford scale. Two patients had a postoperative infection, one presented after one week and the other after three months, and both were treated by debridement and metal removal; at final follow up, both had limited range of motion and extension lag with a fair result on the Crawford scale. Six (35.3%) patients (including the previous four patients) had nail deformities which improved after one year of follow up. Worth noting that a dorsal prominence of the plate was a complaint among some of the patients in the early postoperative period; however, this complaint was resolved spontaneously, needing no particular intervention, and did not affect the functional outcomes. None of the patients had any residual pain at the time of final follow up.

Removal of the hardware was not routinely done in this series. Indications for removal were the occurrence of a complication or a nail deformity, or as per the patient's request. Twelve out of 17 patients underwent removal of the hardware.

Discussion

The ideal management of mallet fractures remains a matter of dispute[6]; however, most surgeons agree that inadequate management of such injuries can lead to extensor mechanism problems such as extension lag or a swan neck deformity, or DIPJ arthritis with subsequent impaired function.[3,10,12] Although nonoperative management showed optimum results, it is widely accepted that an intra-articular fracture involving more than a third of the articular surface or subluxation of the DIPJ is an indication for surgical intervention.[1,2,7]

Although various techniques have been developed for surgical treatment, including percutaneous and open techniques, utilizing different fixation methods such as wires, sutures, plates, and screws, none was without complications.[6,7]

Many surgeons had widely reported on using wires, four different techniques for fixation using various forms of wires configurations (K-wire, figure-of-eight wire, tension band wire, and tension band suture) were compared in a biomechanical study by Damron et al.,[14] the authors found that tension band constructs were superior to other forms of fixation. Extension block pinning introduced by Ishiguro et al.[15] and later modified by others is a widespread technique adopted by many hand surgeons,[15–18] though not without poor outcomes and complications, including loss of reduction, pin migration, wire migration, and the delayed motion due to trans articular wires.[9,10,19] Furthermore, the use of ORIF with a mini-screw was reported to have higher complication rates than percutaneous wires fixation techniques.[20]

To avoid the complications mentioned above, Teoh and Lee[10] in 2007 introduced a novel hook plate fixation technique to provide stable internal fixation, utilizing the biomechanical superiority of the tension-band method, with a stable implant that is anchored away from the fractured fragment. They presented excellent results in their series of 9 patients after an average follow up of 17 months; their patients achieved an average active DIPJ flexion of 64°, no extension lag, no complications, and all patients were either excellent or good on the Crawford scale.[10] In the current study, we adopted the same technique described by Teoh and Lee; however, we used an H-shaped incision instead of a transverse dorsal incision, all our patients were operated on under digital block anesthesia, and all were discharged on the same day of the surgery. Our study presented a prospective cohort with 17 subjects, which we believe is a considerable number. Although we operated on more patients than Teoh and Lee in the current study, and all achieved fracture union, our results were relatively less optimum than their reported results. Our results conform to the previously published studies of the same technique with an average active flexion of the DIP joint of 50°, extension lag in 23.5% averaging 3°, excellent and good results on the Crawford scale were 76.5%, and the complications rate was 35.3%.

Since the introduction of the hook plate techniques, few studies reported their outcomes, some with larger numbers

Table 2 Detailed demographic characteristics, injury circumstances, operative details, and results of study populations

Patient No.	Age	Sex	Digit	Dominant Hand	Mode of Trauma	Time to Surgery (days)	Operative Time (minutes)	Subluxation	% Of Articular Fragment	Wehbe Type	Time to Union (weeks)	Follow up (months)	Final DIPJ ROM (Degrees)	Crawford Scale	Complications
1	40	F	Middle	not	Domestic	10	30	yes	60	II B	6	12	0–60	GOOD	no
2	28	M	Little	yes	Domestic	11	25	yes	50	II B	6	12	0–70	Excellent	no
3	35	M	Middle	yes	RTA	12	40	no	35	I B	7	27	20–40	Fair	Early Infection
4	23	M	Ring	yes	Sport	13	30	no	40	I B	6	24	0–70	GOOD	Nail Deformity
5	35	F	Middle	yes	Domestic	14	35	yes	65	II B	6	6	0–60	GOOD	no
6	30	M	Index	not	Sport	15	35	yes	60	II B	6	8	0–60	GOOD	no
7	35	M	Little	yes	Sport	16	40	no	50	I B	6	6	0–70	Excellent	no
8	18	F	Ring	not	Domestic	17	40	yes	45	II B	6	10	0–70	Excellent	no
9	50	M	Index	yes	Machine injury	18	45	yes	45	II B	6	10	20–40	Fair	Displacement
10	21	M	Little	yes	RTA	19	40	no	30	I B	7	8	20–40	Fair	Infection
11	28	F	Ring	yes	Domestic	20	45	yes	50	II B	8	8	20- 40	Fair	Displacement
12	26	F	Index	yes	Domestic	21	45	yes	40	II B	6	16	0–70	Excellent	no
13	30	F	Ring	not	Domestic	22	40	no	55	I B	6	12	0–60	GOOD	no
14	36	M	Index	yes	Sport	23	35	yes	40	II B	6	6	0–60	GOOD	Nail deformity
15	40	M	Index	not	Machine injury	24	30	no	40	I B	6	6	0–60	Excellent	no
16	24	M	Index	not	Sport	25	40	yes	55	II B	6	8	0–70	Excellent	no
17	50	M	Ring	yes	RTA	26	45	yes	55	II B	6	7	0–60	GOOD	no

Abbreviations: DIPJ, Distal Interphalangeal joint; F, Female; M, Male; No., number; ROM, Range of Motion; RTA, Road Traffic Accident.

Table 3 Comparing the results of the current study with previous studies Reported Hook Plate Fixation of Mallet fractures

Study	Year	patients Number	Average (range) Days to Surgery	Operative Time (minutes)	Follow up (months)	Active Flexion Range of DIPJ	Extension Lag		Crawford Scale	Complications
							Patients number	degree		
Teoh & Lee [10]	2007	9	18 (6–30)	–	17 (6–37)	64° (60–70°)	0	–	Excellent 4 (44.4%) Good 5 (55.6%)	none
Acar et al. [19]	2015	13	1.6 (1–3)	46 (36–54)	18 (12–26)	64° (50–70°)	5 (38.5%)	4° (0–10°)	Excellent 8 (61.5%) Good 5 (38.5%)	3 (23.1%) nail deformities
Toker et al. [22]	2015	6	12 (1–38)	–	13 (3–26)	80°	4 (66.7%)	6° (5–10°)	Excellent 2 (33.3%) Good 2 (33.3%) Fair 2 (33.3%)	1 (16.7%) skin necrosis and delayed wound healing
Imoto et al. [21]	2016	25	–	–	18	–	7 (28%)	5°	Excellent 10 (40%) Good 15 (60%)	4 (16%) chronic pain
Thirumalai et al. [23]	2017	35	–	–	–	40°	10 (28.6%)	5°	–	11 (31.4%) total 6 (17.1%) nail deformities 5 (14.3%) plate extrusions
Tie et al. [11]	2017	31	7 (0–40)	–	8 (1–34)	56° (30–80°)	0	–	Excellent 9 (29%) Good 8 (25.8%) Fair 12 (38.7%) Poor 2 (6.5%)	7 (22.6%) total 1 (3.2%) nail deformity 3 (9.7%) skin necrosis 3 (9.7%) fracture re-displacement
Current Study	2022	17	12.1 (1–20)	38 (25–45)	11 (6–27)	50° (20–70°)	4 (23.5%)	3° (0–20°)	Excellent 6 (35.3%) Good 7 (41.2%) Fair 4 (23.5%)	6* (35.3%) total 2 (11.8%) skin necrosis and infection 2 (11.8%) fracture re-displacement 6 (35.3%) nail deformities

*The total number of patients with complications was 6 as the 2 with skin problems and the 2 with fracture re-displacement had concomitant nail deformities. DIPJ: distal interphalangeal joint.

of study subjects up to 35 digits, and all showed variable results, which were less than optimal compared with Teoh and Lee's results[11,19,21–23] (►**Table 3**).

The theoretical advantage proposed by the hook plate technique was to overcome some of the complications of its predecessor technique, the extension block wiring, which included mainly malunion, decreased range of motion, and osteoarthritis.[19,24] Although the hook plate allows an early range of motion, there was no actual superiority in the range of motion as extension block pinning has provided a good DIPJ range of motion of 72° as reported by Lucchina et al.[20] and 83° by Lee et al.[25] In two retrospective comparative studies by Acar et al.[19] and Toker et al.[22] done to compare the results of extension block pinning and hook plate fixation, there was no significant difference between the two groups as regards to the range of motion and functional outcomes. However, the wire blocking technique was reported to have a longer time of fluoroscopy use, delayed bone union, and longer time to return to work.[19]

Toker et al.[22] performed a cost analysis in their study where they showed that the hook plate technique was seven times the cost of using the extension block pinning, where the used plate was the 0.6 mm hook plate (Medartis; Basel, Switzerland) costs about $420, comprising over two-thirds of the total incurred costs. In our study, we adopted the technique devised by Teoh and Lee, where the plate is fabricated from a multiple hole miniplate that can be cut into smaller single hole plates, each can be used for a patient, thus substantially lowering the cost. We used a locally produced plate for this purpose, which made the plate and one screw cost about $20 per patient. Worth mentioning that the reduced operative time, less intraoperative fluoroscopy, shorter hospital stay, faster union, and return to work should be considered when determining the actual cost analysis and benefits of using the hook plates.

The current study has some limitations; first, this was a cohort non-comparative study, so we could not compare the results of the provided technique with other modalities for managing mallet fractures. Second, relatively few patients were included in the study. Lastly, the short follow up period precluded a confident conclusion concerning probable long-term complications like DIP joint osteoarthritis.

Conclusion

Using the fabricated hook plate technique for open reduction and internal fixation of mallet fractures is a relatively demanding but beneficial and cheap technique that is thought to provide adequately stable fixation allowing early DIPJ motion, accepted functional and radiological outcomes. Properly designed randomized controlled trials are encouraged to compare the results of this technique with other popular techniques to evaluate its superiority and safety.

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Conflict of Interest
The authors declare that they have no conflict of interest.

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