



A Prospective Comparative Study of Ray Resection versus Amputation through Proximal Phalanx for Nonviable Digits of Upper Limb

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Abstract

Background Finger amputations aim at preserving function and optimizing cosmesis. The crucial decision here is whether to preserve a stump or to do a ray amputation. The present study aimed to compare the functional outcome and postoperative quality of life after ray amputation or amputation through the proximal phalanx.

Methods A prospective study was conducted from January 2019 to June 2020 in patients requiring single-finger amputation through the proximal phalanx or metacarpal. Patients were divided into two groups; Group A: amputation through the proximal phalanx and Group B: ray amputation of the finger. The following functional parameters were assessed: grip strength, hand circumference, palmar volume, and webspace span. The Michigan Hand Outcomes Questionnaire (MHQ) score was employed to score hand function and aesthesis at 6 months in both hands.

Results Thirty patients were enrolled. Findings in 26 patients (52 hands) were subjected to further analysis, 12 in Group A and 14 in Group B. Patients in both groups lost grip strength significantly compared with their contralateral normal hands (29.22 ± 14.88 [Group A] and 34.57 ± 19.12 [Group B]); however, it was statistically nonsignificant between the two groups. There was reduced mean palmar circumference in both groups' involved hands, but the decrease in circumference was statistically significant, only for Group B. Group B patients scored better in all the six subscales of the MHQ; however, only the Aesthetics score was significantly superior. The operated hand's webspace span increased significantly with respect to the normal contralateral web by a mean of 4.55 mm.

Conclusion The study concluded that both the surgical options for the level of amputation should be discussed with the patients in detail, taking into account their occupational and personal requirements. Our study findings will help to objectively counsel the patients regarding expectations in functional and aesthetic outcomes following either technique.

Keywords

- ▶ ray
- ▶ resection
- ▶ amputation
- ▶ digits
- ▶ comparison
- ▶ proximal
- ▶ phalanx
- ▶ Michigan score
- ▶ hand grip

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Introduction

Finger amputations are the most commonly encountered upper limb amputations.¹ Traumatic hand injuries are the most frequent cause of finger amputation. Other causes include infections, vascular insufficiency, recurrent Dupuytren contracture, and tumors involving the hand.² Ray amputation involves the removal of the digit, including its metacarpal. It is performed to reduce pain and improve function by the removal of a gap between digits or removing a finger that is not useful or hinders function.³ Single-ray resections are said to have a similar function, better cosmesis, and enhanced patient satisfaction than amputation at the proximal phalanx level. However, loss of grip and pinch strength up to 43% has been reported.⁴

The present study aimed to objectively identify the functional outcome and postoperative quality of life after ray resection versus amputation of the finger through the proximal phalanx, as both procedures have their merits and limitations. Michigan Hand Outcomes Questionnaire (MHQ) was employed for functional outcome analysis. The MHQ is a multidimensional questionnaire with key questions for the assessment of pain and aesthetic satisfaction.⁵ The reliability and validity of the MHQ have been studied and well-documented in different studies.^{6,7}

There are only a few prospective comparisons on postoperative function and quality of life after various levels of finger amputation. Hence this study was performed to assess and compare functional and aesthetic outcomes and patient satisfaction with single-digit ray amputation and amputation through proximal phalanx.

Materials and Methods

This study was conducted from January 2019 to June 2020 at a tertiary care center after receiving approval from the institutional ethics committee and review board. All patients requiring single-finger amputation through proximal phalanx or amputation through the metacarpal level that was considered for ray amputation were included in the study. Patients with multiple finger injuries, bilateral hand injuries, and preexisting upper limb deformities were excluded. A detailed history of injury was taken, followed by an examination of the hand. All patients were followed up for 6 months. A semistructured study proforma was used to record the study data. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients before being included in the study.

The study participants were divided into two groups:

Group A: The patients who underwent an amputation through the proximal phalanx (from the Proximal Interphalangeal [PIP] joint to the Metacarpal phalangeal [MCP] joint).

Group B: The patients who underwent ray amputation of the finger.

The treatment choice between ray resection and amputation through the proximal phalanx was taken after discussing both options with the patient. Following the surgery, all patients underwent supervised physiotherapy. Patients of both groups were followed up for an assessment of the grip strength, hand circumference, palmar volume, webspace span, and MHQ scores of both hands.

Grip strength was assessed by using a hand dynamometer by Camry Scale, CA. The grip strength was measured first on the normal hand and then repeated with the involved hand. A total of three measurements were recorded for each hand, alternating sides. **Hand circumference** was measured in both hands with measuring tape at the level of the distal palmar crease in millimeters. To measure the palmar volume, the hand was cupped as if to hold water and then filled with water, a few drops at a time, using measuring equipment (a 10-mL disposable syringe) until the water started to overflow. The amount of water needed to fill the palm was recorded as the palmar volume of the hand (►Fig. 1). The **webspace span** was measured with a silk thread by holding the thread with two artery forceps at a point at the junction of the MCP crease with the ulnar border of the index finger and the radial border of the ring finger for the ray amputation of the middle finger. The length of the silk thread was then measured with a measuring scale in millimeters. Similarly, the web span was measured for the ray amputation of the ring and index finger, keeping the fingers completely abducted.

The Michigan Hand Questionnaire

The MHQ assesses six domains on a 5-point Likert scale.⁷ A higher score denotes better hand function on all subscales except the pain scale where a higher score indicates greater pain. The scores for responses for each of the subscale items were added and gave the raw scale score. The raw score is then converted from 0 to 100, using definite scoring equations.

Statistical Analysis

The data were analyzed using SPSS version 22. Categorical variables are presented in percentages and tested for the difference using the chi-square test/Fisher's exact test. The Student's paired *t*-test was used to compare the results of each patient's normal and involved hands, and the unpaired Student's *t*-test was used to compare the two groups. A *p*-value of less than 0.05 was considered statistically significant.

Results

A total of 30 patients were enrolled in the study, of which 4 were lost to follow-up. Findings in 26 patients (52 hands) were subjected to further analysis, 12 in Group A and 14 in Group B.

The mean age of study participants was 30.2 ± 13.3 years, ranging from 10 to 60 years. Of the 26 patients, 15 (58%) were



Fig. 1 This figure shows a few methods of measurement used in the methodology of the study. On the left side, the figure shows the measuring of the palmar circumference with the standard measuring tape. In the center, grip strength is measured with the hand dynamometer. On the right, palmar volume is being measured with the cupping of the hand and holding as much water as possible.

male, 11 (42%) were female. The study participants were engaged most frequently as mechanics/motor operators (23%) or were students (23%), followed by housewives (15%), farmers (7%), and others.

The most common indication for amputation was an injury in 21 (81%) patients, followed by postinfective (2; 7.6%), postburn (2; 7.6%), and the presence of a tumor (1; 3.8%). Out of the 21 patients presented with injury, crush injury was seen in 17 patients and cut injury in 4 patients. The right hand was involved in 12 (46%) patients and the left hand in 14 (54%) patients. The index finger was the most commonly injured digit (9; 34.62%), followed by little finger (7; 26.92), ring finger (6; 23.08%), and middle finger (4; 15.38%). The total number of border digits (index + little finger) involved was 16 (61.54%), and central digits (middle + ring finger) were 10 (38.46%). The ratio of border digits to central digits was 8:5. The total number of border digits (index + little finger) involved in Group A was 8 (66.67%), and central digits (middle + ring finger) were 4 (33.33%). The ratio of border digits to central digits in Group A was 2:1. The total number of border digits (index + little finger) involved in Group B was 8 (58%), and central digits (middle + ring finger) were 6 (42%). The ratio of border digits to central digits in Group B was 4:3. The difference between the proportion of border and central digits in Group A and Group B was not statistically significant ($p=0.7015$). Out of 26 study participants, 24 (92.3%) were right-hand dominant, and only 2 (7.7%) had a dominant left hand (→ Figs. 2 and 3).

The mean period of follow-up of patients in Group A was 4.92 ± 2.02 months and in Group B was 5.36 ± 1.45 months. The difference between the mean period of follow-up between the two groups was not statistically significant ($p=0.5245$). This follow-up period was also affected by the present coronavirus disease-2019 (COVID-19) pandemic,

and hence all patients could not be followed up in the exact 6-month time frame.

1. Grip Strength

- The difference in the mean grip strength of the normal hand and the involved hand was statistically significant ($p < 0.05$) for both Group A and Group B.**
- The mean loss of grip strength (%) in Group A was 29.22 ± 14.88 kg and for Group B was 34.57 ± 19.12 kg. **The difference between the mean values of percentage loss of grip strength between Group A and Group B was not found to be statistically significant.**
- The mean loss of grip strength between Group A and Group B was compared by the digit involved and was not statistically significant for any of the digits.

2. Palmar Circumference

- The mean palmar circumference was found to be reduced in the involved hand in both groups but the findings were statistically significant ($p=0.0005$), only for Group B.**
- The mean decrease in palmar circumference between the normal hand and the involved hand in Group A was compared with the mean decrease in palmar circumference between normal and involved hand in Group B. Group B showed a more significant mean decrease in palmar circumference, and the findings were statistically significant ($p=0.00002$).

3. Palmar Volume

- The mean palmar volume of the normal hand was compared with the involved hand for both Group A and Group B. The mean palmar volume was found to be reduced in the involved hand in both groups; however, the findings were statistically significant at $p < 0.05$ only for group B ($p=0.0073$).

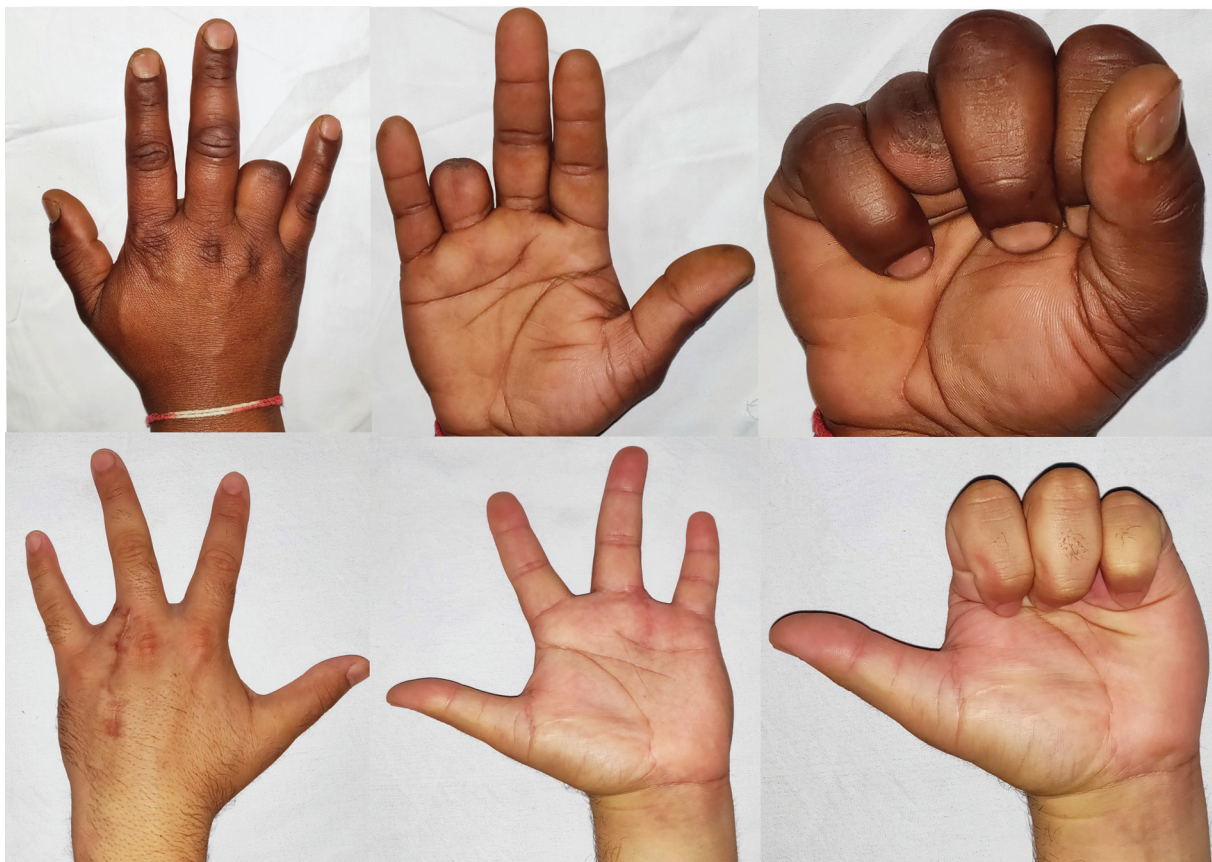


Fig. 2 This figure shows the comparison of postoperative results showing the ring finger amputation. The top half shows the dorsal, volar, and grip in group A. The bottom half shows the corresponding similar view of group B.

2. The mean decrease in palmar volume in Group A was compared with the mean decrease in palmar volume in group B. A greater reduction of mean palmar volume was observed in Group B as compared with Group A; however, the finding was not statistically significant ($p = 0.3305$).
4. Webspace Span
1. In Group A, since the amputation was through proximal phalanx and the webspace span was undisturbed in both hands.
 2. The mean webspace span was calculated for the normal hand and the involved hand in Group B. The mean webspace span was calculated for 11 patients (22 hands) in Group B, as three patients had amputation of the little finger, and consequently, no web lateral to their ring finger. The mean webspace span of the normal hand was 28 ± 19.62 , and that of the involved hand was 32.55 ± 19.88 . The increase in the webspace span in the involved hand was statistically significant ($p = 0.0452$).
 3. The mean increase in the involved hand's webspace span compared with the normal hand was 4.55 ± 6.59 mm.

A comparison of different hand parameters of the normal hand and the involved hand is presented in ►Table 1. The mean decrease in the values of different parameters in Group A and Group B is presented in ►Table 2.

5. Michigan Hand Outcomes Questionnaire Score

The mean scores for all six subscales of the MHQ and the overall MHQ score were calculated and compared for Group A and Group B. Group B patients scored better in all the six subscales of the MHQ; however, only the Aesthetics score was statistically significant ($p = 0.002$). A comparison of the mean MHQ score between Group A and Group B is presented in ►Table 3.

Discussion

Hand function and cosmesis are greatly affected by amputation and the level of amputation. The present study identified significant variations in functional and aesthetic parameters following finger amputations. The difference in the mean grip strength of the normal hand and involved hand was statistically significant ($p < 0.05$) for Group A and Group B. Karle et al⁸ reported a 29 to 34% loss of grip strength after ray amputation. They also reported up to 28% of loss of grip strength after amputation through the PIP joint. Nuzumlali et al⁹ reported a significant decrease in the grip strength between the normal (30 ± 12) kg and the involved hand (38 ± 13 kg; $p < 0.001$) in the ray amputation group, and (32 ± 9) involved hand, (38 ± 8) normal hand in PIP group ($p = 0.001$).

In the present study, the mean loss of grip strength in Group A's percentage value was 29.22 ± 14.88 , and Group B



Fig. 3 This figure shows the postoperative result of the little finger amputation. The top half shows the various views of a patient belonging to group A, while the bottom half shows the results of a patient belonging to group B.

Table 1 Comparison of different hand parameters of the normal and involved hand in group A and group B

Parameters measured	Group A			Group B		
	Normal hand	Involved hand	p-Value	Normal hand	Involved hand	p-Value
Mean grip strength	32.33 ± 11.91	20.38 ± 10.43	0.00372	25.02 ± 10.32	14.63 ± 8.08	0.00001
Mean palmar circumference (in mm)	190.33 ± 25.18	189.17 ± 24.93	0.0836	185.14 ± 25.83	161.36 ± 23.25	0.0005
Mean palmar volume (in mL)	7.59 ± 4.78	5.13 ± 1.897	0.0743	8.97 ± 8.85	4.66 ± 4.61	0.0073
Mean web space span (in mm)	N.A	N.A	N.A	28 ± 19.62	32.55 ± 19.88	0.0452

The difference in mean web space was found to be increased compared with the normal hand in group B. This finding was found to be statistically significant.

Note: The change in mean grip strength compared to normal hand was statistically significant.

The change in mean palmar circumference compared to normal hand was statistically non-significant in group A but statistically significant in group B.

The change in mean palmar volume compared to normal hand was statistically non-significant in group A but statistically significant in group B.

There is no change in the mean web space span in group A but in group B it was statistically significant.

Since metacarpal is intact till MCP joint, the web space span remains unaltered. Hence, comparison to the normal hand remains the same and comparison cannot be made.

Table 2 Comparison of mean decrease of different parameters in group A and group B

S. No.	Parameter observed	Group A	Group B	p-Value
1.	Mean loss of grip strength (%)	29.22 ± 14.88	34.57 ± 19.12	0.4394
2.	Mean decrease in palmar circumference (mm)	1.17	23.79	0.00002
3.	Mean decrease in palmar volume (mL)	2.46 ± 4.318	4.31 ± 5.087	0.3305

The mean decrease in palmar circumference was more in group B than in group A, and this was statistically significant.

Table 3 Comparison of mean Michigan Hand Questionnaire score between group A and group B

S. No.		Group A	Group B	p-Value
1.	Overall hand function	66.67 ± 14.35	71.79 ± 13.81	0.364
2.	Activities of daily living score	67.05 ± 21.58	80.88 ± 23.53	0.133
3.	Work performance score	53.33 ± 30.84	63.21 ± 24.70	0.373
4.	Pain score	24.58 ± 19.82	19.29 ± 15.54	0.452
5.	Aesthetics score	52.60 ± 11.45	70.54 ± 15.00	0.002
6.	Satisfaction with hand function	63.19 ± 17.12	75.29 ± 14.29	0.060
7.	Michigan Hand Questionnaire	63.06 ± 16.24	73.73 ± 15.02	0.074

Group B had a statistically significant and better Aesthetic Score compared with group A.

was 34.57 ± 19.12 kg. Patients lost approximately 30% strength after amputation regardless of the technique. The difference in loss between the two groups was not statistically significant. Karle et al⁸ reported no statistically significant difference between the two groups in grip strength. Bhat et al¹⁰ reported an average loss of grip strength of 43.3% of the contralateral normal hand. Melikyan et al¹¹ have reported a statistically significant decrease in average grip strength of operated hands was 25.5 kg (range 5–55 kg) compared with 35 kg (range 12–49 kg) on the unoperated side. Steichen and Idler¹² have reported an average grip strength of 67% of the dominant hand and 74% of the nondominant hand. In the study by Colen et al,¹³ total grip recovery was 80.2% of the nonoperated side. In the study by Murray et al,¹⁴ the average grip strength was reduced by 20%.

A comparison of a mean loss of grip strength between Group A and Group B by the digit involved was made. The mean loss of grip strength between Group A and Group B was compared by the digit involved and was not statistically significant for any of the digits at $p < 0.05$. **The mean loss of grip strength was the maximum following amputations of the middle finger in both groups.** Similar findings were earlier reported by Bhat et al.¹⁰ In the study by Melikyan et al,¹¹ only central digit amputations as a group had statistically significant differences in grip strength between operated and unoperated hands. Neither index nor little finger amputations as a group had significant differences in any of the measured parameters.

Decreased palmar circumference may lead to difficulty in grasping objects and hence become a matter of concern. **Group B showed a greater mean decrease in palmar circumference ($p = 0.0005$).** Nuzumlali et al⁹ reported that hand circumference was significantly decreased between the normal and involved hand by a mean of 13 mm ($p < 0.001$). Melikyan et al¹¹ reported that resections of the little finger

were associated with a 6% decrease in palm width, whereas resection of the index finger had a 3% decrease. According to them, total palm width after resection of a central finger was decreased by 7%. Although we used the water holding as a method to observe the palmar circumference, not all patients could hold the water properly and a few drops could drip. As a suggestion for future studies, maybe rice or mustard seeds could be used instead of water.

The mean palmar volume was reduced in the involved hand in both groups; the decrease was statistically significant for Group B ($p = 0.0073$). The mean decrease in palmar volume in Group A was compared with the mean decrease in palmar volume in Group B. A greater reduction of mean palmar volume was observed in Group B than in Group A; however, the finding was not statistically significant ($p = 0.3305$). Nizumlali et al⁹ reported that palmar volume was significantly decreased by 2 mL in the involved hand compared with the normal hand after ray resection ($p < 0.001$). Peacock¹⁵ reported decreased palmar volume and width, and decreased hand circumference in ray resection.

The mean webspace span was calculated for the normal hand and the involved hand in Group B. The mean webspace span of the normal hand was 28 ± 19.62, and that of the involved hand was 32.55 ± 19.88. The increase in the webspace span in the involved hand was statistically significant ($p = 0.0452$). The mean increase in the involved hand's webspace span compared with the normal hand was 4.55 ± 6.59 mm. **This is a novel parameter and has not been measured in previous studies.** The reconstructed webspace was significantly larger compared with the contralateral normal web. This could be due to a combination of events. The scar is inherently weaker compared with normal tissue and prone to stretch. Another factor might be the reduced palmar circumference and volume. To mitigate this

reduction, the remaining tissues could be stretching the site of the ray amputation. A long-term comparison of the hand and webspace dimensions can answer this question better.

The mean scores of overall hand function, activities of daily living, work performance, aesthetics score, satisfaction with hand function subscales of MHQ, and the overall MHQ score was higher for Group B than Group A. **Further, the aesthetics score was significantly increased in Group B compared with Group A ($p = 0.002$).** This betterment in scores was despite the fact that the reconstructed webspace was still significantly larger than a normal webspace. For the Group B patients, there was no amputated stump visible for comparison to the adjacent fingers. In the study by Karle et al,⁸ the aesthetic appearance of the operated hand was rated higher after ray amputation. Similarly, Nuzumlali et al⁹ have reported that patients in the ray resection group were pleased with the cosmetic result but expressed concern at having one finger missing. Patients in the amputation group were dissatisfied with the appearance of their hands.

In the present study, MHQ pain ratings were higher in Group A compared with Group B, though the findings were not statistically significant. Karle et al⁸ found that 65.5% of the patients after ray amputation and 91.7% after digital amputation complained of postoperative pain in the operated hand.

The strength of our study is that it is a prospective comparative study, whereas most other studies on this topic have a retrospective study design. Also, MHQ has been used in the present study, a validated and reliable tool, with the advantage of having a separate domain dedicated to hand appearance. We have also included webspace span in our study, which is a novel parameter. The study has some limitations, including a small sample size. Unfortunately, during the COVID-19 pandemic, we lost track of four patients. Although the technique used was the same, different surgeons performed the surgeries. We were unable to analyze any complaints of things slipping through between the fingers during the study. Additionally, we did not analyze the difference in cold sensitivity in our patients.

Conclusion

Patients having amputation at the proximal interphalangeal joint level scored better on objective calculations involving grip strength, palmar circumference, and palmar volume. Overall hand function, the activity of daily living, satisfaction, freedom from pain score, and work performance were better in the ray resection group. Further, the aesthetic scores were significantly better in the ray amputation group. We conclude by stating that both options should be discussed with the patients in detail. The patient and his surgeon's treatment choice should be determined together and may vary with occupational and personal requirements. The study helps to objectively counsel the patients regarding expectations in the functional and aesthetic outcome.

Note

All procedures followed were in accordance with the ethical standards of the responsible committee on human

experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Ethical Approval

This study was approved by the Post-Graduate Institute of Medical Education and Research, Chandigarh, India, with Ethics Committee Reference Number INT/EC/2019/000807, dated: April 10, 2019.

Patients' Consent

Informed consent was obtained from all individual participants included in the study.

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None.

Conflict of Interest

None declared.

References

- Pillet J. The aesthetic hand prosthesis. *Orthop Clin North Am* 1981;12(04):961–969
- Peimer CA, Wheeler DR, Barrett A, Goldschmidt PG. Hand function following single ray amputation. *J Hand Surg Am* 1999;24(06):1245–1248
- Heinze ZCM, Wilkens SC, Lunn KN, Ring D, Chen NC. Factors associated with secondary ray amputation after initial finger amputation at the traumatic level. *Hand Microsurg J* 2020;9(02):76–80
- Blazar PE, Garon MT. Ray resections of the fingers: indications, techniques, and outcomes. *J Am Acad Orthop Surg* 2015;23(08):476–484
- Shauver MJ, Chung KC. The Michigan Hand Outcomes Questionnaire after 15 years of field trial. *Plast Reconstr Surg* 2013;131(05):779e–787e
- Wolte MT, Shauver MJ, Chung KC. Normative values of the Michigan Hand Outcomes questionnaire for patients with and without hand conditions. *Plast Reconstr Surg J* 2017;140:425e–433e
- Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. *J Hand Surg Am* 1998;23(04):575–587
- Karle B, Wittmann M, Germann G. [Functional outcome and quality of life after ray amputation versus amputation through the proximal phalanx of the index finger]. *Handchir Mikrochir Plast Chir* 2002;34(01):30–35
- Nuzumlali E, Orhun E, Oztürk K, Cepel S, Polatkan S. Results of ray resection and amputation for ring avulsion injuries at the proximal interphalangeal joint. *J Hand Surg [Br]* 2003;28(06):578–581
- Bhat AK, Acharya AM, Narayanakurup JK, Kumar B, Nagpal PS, Kamath A. Functional and cosmetic outcome of single-digit ray amputation in hand. *Musculoskelet Surg* 2017;101(03):275–281
- Melikyan EY, Beg MS, Woodbridge S, Burke FD. The functional results of ray amputation. *Hand Surg* 2003;8(01):47–51
- Steichen JB, Idler RS. Results of central ray resection without bony transposition. *J Hand Surg Am* 1986;11(04):466–474
- Colen L, Bunkis J, Gordon L, Walton R. Functional assessment of ray transfer for central digital loss. *J Hand Surg Am* 1985;10(02):232–237
- Murray JF, Carman W, MacKenzie JK. Transmetacarpal amputation of the index finger: a clinical assessment of hand strength and complications. *J Hand Surg Am* 1977;2(06):471–481
- Peacock EE. Metacarpal transfer following amputation of a central digit. *Plast Reconstr Surg* 1962;29(04):345–355