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Coaptation of Digital Nerves (Centro-Central Neurorrhaphy) at the Time of Terminalization of Amputated Digits Lowers the Occurrence of Digital Neuroma

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ABSTRACT

Objective: To compare the frequency of occurrence of neuroma in patients with amputated digits who undergo Coaptation of digital nerves versus standard management.

Study Design: Quasi-experimental study.

Place and Duration of Study: Department of Plastic Surgery, Combined Military Hospital, Rawalpindi, Pakistan from Jan 2020 to Sep 2022.

Methodology: The study was conducted on 120 patients with distal digital amputations. Patients with between the ages of 18 and 60 years, of both genders were included. Patients with multiple amputations, previous surgery to the affected digit, complex injuries or proximal trauma to the affected limb, or those with neurological disorders were excluded. All patients underwent microvascular repair of the amputated digit. Patients in the study arm underwent Coaptation of digital nerve while the control arm underwent traction neurectomy. All patients were followed-up for one-year post procedure for the development of neuromas.

Results: Our study sample was composed of 120 patients with a mean age of 35.80±10.29 years, the majority of whom were male: 83(69.2%). Neuroma formation was seen in 5(8.3%) patients who received nerve Coaptation versus 28(46.7%) in those who received a neurectomy, (p<0.001). The median pain score at one-year post-surgery for the sample was significantly lower with coaptation: 2.00(3.00) versus 4.00(3.00) traction neurectomy, (p<0.001). Lastly, significant pain was present in 9(15.0%) who received nerve Coaptation versus 25(41.7%) in the control arm, (p=0.001).

Conclusion: Nerve Coaptation is associated with a significantly decreased frequency of neuroma formation and better pain outcomes in patients with distal digital amputations.

Keywords: Digital amputation, Nerve coaptation, Neuroma. Neurectomy.

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INTRODUCTION

Amputations most commonly occur as a consequence of trauma, but can be the result of elective surgery for conditions such as diabetes mellitus, peripheral vascular disease or malignancy.[1] This form of distal tissue loss accounts for an estimated 1% of all cases reporting with trauma to the emergency department, with the vast majority comprising of amputations of the digits of the upper limbs: amputations of the terminal phalanx and partial amputations account for most of the presentations, while complete or multiple digital amputations are less common.[2] The primary aim of management of digital amputations is to salvage the amputated portion, and return function to the patient, however, factors such as time elapsed since injury, its mechanism and the presence of wound contamination dictate the odds of success.[3] A number of complications are associated with such repair procedures including haemorrhage, surgical site infection, re-implantation failure and venous congestion or stiffness of re-implant, among others.[4]

Pain following re-attachment surgery is a common complication which results from the damage to the afferent nerve pathways following amputation, and can occur in up to fourth-fifths of all patients who receive amputative injuries.[5] Exposure to chronic pain reduces quality-of-life drastically in such patients; many patients require treatment for depression.[6] Neuroma formation is a common cause of pain following amputation which occurs due to the disorganized regeneration of the axon of the affected nerve, and can result in severe and/or chronic pain.[7] A number of methods have been proposed to reduce the incidence of formation of neuromas following such injuries, some of which include nerve implantation into adjacent tissue, autologous or synthetic capping, epineurial closure, photo- or heat-cauterization, nerve conduit formation and newer techniques such as

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targeted muscle reinnervation and regenerative peripheral nerve interface.[8] Nerve Coaptation is one such method where the cut ends of the affected nerve are anastomosed in a centro-central manner, which is purportedly associated with better nerve healing, the decreased incidence of neuromas and post-operative pain.[9,10] This study was conducted to determine the occurrence of neuromas in patients undergoing repair for digital amputation with nerve Coaptation versus those undergoing traction neurectomy. If found to be significantly reduced with coaptation, this research protocol can form the basis for a guideline on the repair of nerve injuries in patients with digital amputation, which will bring about a significant reduction in morbidity associated with these cases.

METHODOLOGY

We conducted this quasi-experimental study from January 2020 to September 2022 in the Department of Plastic Surgery, Combined Military Hospital, Rawalpindi, Pakistan on 120 patients with digital amputations, after obtaining informed consent vide IERB letter serial number 299. Patients were selected via non-probability, consecutive sampling. The WHO sample size calculator was used to calculate the sample size keeping a level of significance (α) of 5%, an anticipated population proportion 1 (P1) of 0 and an anticipated population proportion 2 (P2) of 0.545, which were the proportion of patients who developed neuromas with nerve Coaptation versus those without, respectively, from Economides *et al*.[11]

Inclusion Criteria: Patients with traumatic distal digital amputations, between the age of 18 and 60 years, of both genders were included.

Exclusion Criteria: Patients with multiple amputations, partial amputations, those who had previously undergoing surgery, those with complex injuries unfit for microvascular repair, those who required flap placement, or trauma involving the proximal limb, or those who had a past history of neurological disorders were excluded.

Patients were divided into two equal groups via block randomization method at the time of inclusion in the study. The edges of the injured digit and amputated portion were examined using light microscopy to assess for whether microvascular repair was possible. In all patients, bone fixation was carried out, followed by debridement and cleaning of the wound (Figure). Subsequently, end-to-end anastomosis was done for blood vessel, or composite grafting was done if blood vessels could not be repaired. In the study arm, patients underwent epineural end-to-end repair of nerves with 9-0 nylon sutures, while the control arm underwent traction neurectomy. All patients were followed-up for one-year post procedure for the development of complications, and assessment of pain according to the Visual Analog Scale (VAS) score, and a pain score of 5 or greater was considered significant.[12] The level of amputation was classified according the Tamai Classification.[13]

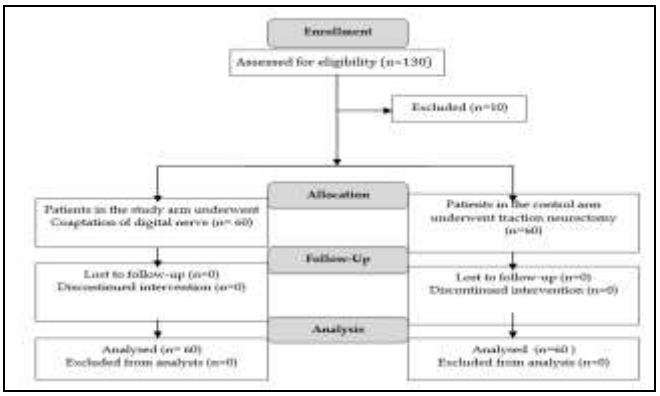

Figure: Patient Flow Diagram (n=120)

Microvascular repair of the amputated digit. Patients in the study arm underwent Coaptation of digital nerve while the control arm underwent traction neurectomy.

Data was analyzed using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows version 26, IBM Corp; Armonk, USA). Mean and standard deviation was calculated for quantitative variables specifically patient age, time from trauma to operating table and Median and IQR was calculated for VAS score at one year. Qualitative variables like gender, whether patient was a smoker, mechanism of trauma, which digit was injured, which hand was involved, amputation level, digit survival at one-year post-surgery, formation of granuloma and the presence of significant pain was recorded in terms of frequency and percentage. Quantitative variables were compared across groups using the independent samples t-test and Mann-Whitney u test while the chi square test was used for qualitative variables and a *p*-value of ≤0.05 was considered significant.

RESULTS

We studied a total of 120 patients divided into two groups, each containing 60 patients. The sample had a mean age of 35.80±10.29 years, with a male majority, who accounted for 83(69.2%) cases. A total of

19(15.8%) patients were smokers. Crush injuries were the most common etiology: 72(60.0%), followed by lacerations which occurred in 37(30.8%) cases, while avulsion injuries were the least common: 11(9.2%). The middle finger was the most commonly amputated: 45(37.5%), the index finger was affected in 37(30.8%) cases, while the ring and little fingers were involved in 28(23.3%) and 10(8.3%) patients. A total of 74(61.7%) patients hand right hand involvement. Zone II injuries were seen in 79(65.8%) cases. The mean time from trauma to the operating table was 10.68±3.99 hours. Table-I shows the patient characteristics at the time of enrollment in the study.

Table-I: Patient Characteristics (n=120)

Variables	Intervention Arm (n=60)	Control Arm (n=60)	*p*-value
Age (years)	34.47±10.19	37.13±10.31	0.157
Gender			
Male	38(63.3%)	45(75.0%)	0.166
Female	22(36.7%)	15(25.0%)	
Smoking History	12(26.8%)	7(11.7%)	0.211
Mechanism of Injury			
Crush	38(63.3%)	34(56.7%)	0.757
Laceration	17(28.4%)	20(33.3%)	
Avulsion	5(8.3%)	6(10.0%)	
Digit Involved			
Middle	25(41.7%)	20(33.3%)	0.600
Index	19(31.7%)	18(30.0%)	
Ring	11(18.3%)	17(28.4%)	
Little	5(8.3%)	5(8.3%)	
Hand Involved			
Right	41(68.3%)	33(55.0%)	0.133
Left	19 (31.7%)	27(45.0%)	
Level of Amputation			
Zone I	24(40.0%)	17(28.3%)	0.178
Zone II	36(60.0%)	43(71.7%)	
Time from Trauma to Surgery	11.05±3.75	10.30±4.21	0.305

Table-II displays the study results according to group. A total of 98(81.7%) had complete survival of the re-implant at one-year post-surgery. Neuroma formation was seen in 33(27.5%) of patients, the majority of whom were in the control arm, (p<0.001). The mean pain score at one-year post-surgery for the sample was 3.08±2.54, and the difference between both groups was statistically significant, with pain being significantly less in the intervention arm, (p<0.001). A total of 34(28.3%) suffered from significant pain at the end of the follow-up period, more in the control arm, (p=0.001).

Table-II: Study Outcomes in terms of Graft Survival, Occurrence of Neuroma and Pain (n=120)

Variables	Intervention Arm (n=60)	Control Arm (n=60)	*p*-value
Re-implant survival	51(85.0%)	47(78.3%)	0.157
Neuroma Formation	5(8.3%)	28(46.7%)	<0.001
Visual Analogue Pain Score at 1 Year (Median(IQR))	2.00(3.00)	4.00(3.00)	<0.001
Significant Pain	9(15.0%)	25(41.7%)	0.001

DISCUSSION

Distal digital amputation repair is fraught with complications that require careful, tailored management, to ensure that the patients has minimal pain, maximum functional ability and an optimal aesthetic outcome. Post-surgery pain is a common complication in patients with digital amputations that has a significant relationship with the development of neuromas due to nerve damage; this study showed that nerve Coaptation repair was associated with a reduction in the occurrence of this complication.[14]

Our study sample had a mean age of 35.80±10.29 years. Mehri *et al*., studied the epidemiological characteristics of traumatic hand and finger amputations in Iran and noted that the males in their population had a mean age of 35.2±11.7 years, while the females had a mean age of 39.8±6.48 years.[15] Larsen *et al*., noted that there study population had a mean age of 42.3 years,[16] while Long *et al*., noted a mean age of 39.3±20.4 years.[17] The higher incidence of traumatic finger amputations around the fourth decade can be attributed to occupational injuries, and are notably more common in the working-class.[18]

The majority of the patients in our study sample were male i.e., 69.2%. This is in keeping with existing studies reporting on the epidemiology of traumatic upper limb, including finger, amputations such as Larsen *et al*., who noted a male preponderance of 84.9%, and Pomares *et al*., who noted 89.8% of the such patients being male in their study.[16,18] Again, this can be attributed to work-related injury wherein the nature of work that males perform such as laborers, construction-workers and power tool operators has likely resulted in an increased risk of digital amputation.[1-3,19]

In our study, the most commonly amputated finger was the middle finger, accounting for 37.5% cases, while the index, ring and middle fingers were

affected in 30.8%, 23.3% and 8.3% patients, respectively. Samantaray *et al.,* noted that the middle finger was also the most involved in digital amputation in their study accounting for 29% of injuries.[19] However, Fakin *et al*., noted that the most common form of digit amputation seen was multiple digit, while as an individual finger the thumb was most commonly affected i.e., in 29.0% cases.[20] While Mehri *et al*., noted that the index finger was most commonly involved in their study, affecting 54.5% cases while the middle finger only accounted for 34.0% of patients.[15] This variation in results may be attributable to the prevalent cause of inciting trauma, which naturally varies from population-to-population, as well as the nature of injuries considered: whereas our study only looked at fingertip injuries, furthermore, a majority of 61.7% had right upper limb involvement in our study. Mehri *et al*., noted that the majority of cases i.e., 61.5% had injuries on their dominant hand, an aspect which requires further study.[15]

Complete survival of the re-implant was seen in 81.7% cases, in our study. This figure was comparable to Usami *et al*., who reported a success rate of 79.5% in their study, while Güntürk *et al.,* (84.9%) and Kaneshiro *et al.,* (87.1%) reported similar figures.[21-23]

Lastly, a total of 27.5% patients developed neuromas in our study: 8.3% with Coaptation versus 46.7% with traction neurectomy, (p<0.001). The mean pain score on the VAS scale was significantly lower with Coaptation when compared to traction neurectomy, (p<0.001), and a total of 15.0% patients suffered from significant pain at the end of our follow-up period with nerve Coaptation versus in 41.7% with traction neurectomy, (p=0.001). Fakin *et al*., noted that 2.0% of patients who underwent Coaptation developed neuromas in their study sample, with a significant reduction in pain in 85.0% of cases which was similar to our study.[20] Econamides *et al*., reported that patients who received nerve repair using Coaptation had significantly lower VAS score at six months of follow-up versus those who underwent traction neurectomy, (p=0.02), likely due to the decreased formation of neuromas: 0% in those who underwent Coaptation versus 54.5% in the control group, (p=0.03).[11] Maslow *et al*., noted that 12.8% developed neuromas with Coaptation repair in their study versus 22.7% in controls, (p<0.05), while the difference between both groups with regards to significant pain was also substantial: 0% versus 11.8%,(p<0.001), respectively.[10]

LIMITATIONS OF STUDY

We performed this study in a single-center, with a relatively small sample size, further multi-center studies with larger sample sizes may be required to demonstrate benefit. A longer duration of follow-up may be required to demonstrate whether benefit for Coaptation repair persists over long-term or not. Additionally, it was not possible to blind the surgeon to the type of surgery being performed, which may have resulted in some degree of confounding within our results. Lastly, we did not look at functional outcomes in-terms of sensory and motor function at the end of follow-up which is an aspect that requires further study.

CONCLUSION

Digital amputation involving the upper limbs involves nerve repair which is commonly associated with neuroma formation resulting in morbidity and reduction in quality-of-life. This complication can result in substantial long-term pain which can be significantly reduced using the Coaptation technique to repair damaged nerves. Future research should focus on the use of Coaptation techniques in amputations involving other parts of the body, as well as the sensory and motor outcomes associated with its use.

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Authors Contribution

Following authors have made substantial contributions to the manuscript as under:

KA & SH: Conception, study design, drafting the manuscript, approval of the final version to be published.

AQ & KUM: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

SA & MWUB: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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