Al-Azhar International Medical Journal

Volume 5 | Issue 4 Article 27

4-30-2024
Section: Plastic surgery

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How to Cite This Article

Abd Elrahman, Abd Elrahman Awadeen; khalifa, Mohamed Hosney; and Bendary, Ahmed Bendary Hosney (2024) "Assessment of Outcome of Distraction Osteogenesis for Bone Lengthening in The Hand: Meta-Analysis Study," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 4, Article 27.
DOI: https://doi.org/10.58675/2682-339X.2371

Meta-Analysis

Assessment of Outcome of Distraction Osteogenesis for Bone Lengthening in The Hand: Meta-Analysis Study

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Abstract

Background: ***Distraction osteogenesis (DO), also known as callus distraction, allostasis & osteodistraction, is a technique utilized in podiatric surgery, orthopedic surgery, and oral & maxillofacial surgery for the correction of skeletal abnormalities and reconstructive purposes.***

Aim and objectives: ***To undertake a systematic review and meta-analysis of published publications, including DO in hand; to calculate the time required for distraction, the length obtained, and the rate of complications; and to identify factors impacting case outcomes.***

Patients and Methods: ***This was a systemic review and meta-analysis by utilizing the preferred reporting items for the systemic review & meta-analysis (PRISMA) statement. The search was limited to English articles published between 2012 and 2022. Databases were approached through the Egyptian Knowledge Bank. The search was conducted in December 2022.***

Results: ***Meta-analysis 3 studies assessing changes in length pre- and after show a slight increase in length after but with insignificant differences. 13 studies were included showing significant heterogeneity with an event rate of 7.9%. ROM and outcome score Mean MCP ROM extension (degrees) pre was 20.15 and changed to 8.2 after treatment. The mean EFI days/cm was 61.4, the mean Healing index, d/cm was 54.4, and the mean Kapandji opposition score was 7.65.***

Conclusion: ***The present research demonstrated that DO provides succinct advantages for restoring length following digital amputations. Nevertheless, these benefits are offset by the lengthy treatment duration and elevated complication rates.***

Keywords: Distraction Osteogenesis; Bone lengthening; Meta-analysis Study

1. Introduction

Orthopedic, podiatric, and oral and maxillofacial surgery all employ a technique known as distraction osteogenesis (DO), also known as callus distraction, allostasis, and osteodistraction, to correct skeletal deformities and perform reconstructive operations. [1]

The purpose of distraction is to generate the desired finger length due to the need for the correct finger length for normal function. [2]

The technique includes cutting & progressively separating bone, enabling the bone healing process to fill in the gap. [3]

Within five to six days following the procedure, the distraction process is initiated, and an increment of 0.25 mm is added three times a day in order to achieve 0.75 mm of daily lengthening. In order to generate the distraction increment, the locking screw on the distal fixation unit must first be removed. This allows for some contact to be made between the end of the screw and the flat on the threaded rod that is used to move the distal unit while ensuring that it does not rotate. Once the nut-turning process is complete, the screw has to be fastened in place. Every ten days, a routine x-ray is conducted to check for allostasis. When an uneven regeneration density can be detected in the radiographs or when the distraction callus takes the form of an hourglass, the distraction rate has to be slowed down or even stopped altogether. On average, one or two centimeters are lengthened at each osteotomy level. [4]

Accepted 14 April 2024.
Available online 30 April 2024

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https://doi.org/10.58675/2682-339X.2371

The thumb is the finger that should be spared first after a mutilating injury because of its significance in prehension and all sorts of grasp. In a healthy environment, it contributes 40% of overall hand functionality. When digits are absent or stiff after mutilating trauma, the thumb may perform more than 50% of the functions of the hand. According to the degree of amputation, the priorities for thumb restoration change, but at all levels, reconstruction should aim to reestablish pinch and opposition. [5]

Combining the findings of several research into one cohesive whole is the goal of a statistical method known as a meta-analysis. When many scientific studies describe measures that are likely to be subject to some degree of error, meta-analyses can be done to pool the data from these studies and draw conclusions about the true effect size. Using methods from statistics, we aim to arrive at a pooled estimate that is closer to the unknown common reality, depending on how this error is perceived. In addition to providing an approximation of the unknown common truth, meta-analyses can be used to compare the findings of various studies, thereby illuminating patterns among findings, potential sources of disagreement & other interesting associations. [6]

The goal of this research was to perform a systematic review and meta-analysis of published articles on DO of the hand in order to estimate the time required for distraction, the length gained, and the rate of complications, as well as to identify factors influencing case outcomes & to demonstrate some clinical cases.

2. Patients and methods

PRISMA statement was utilized to complete the systemic review and meta-analysis. [7]

A literature search was done using PUBMED, EMBASE, Science Direct, Google Scholar, and the Cochran Library. The search was limited to English articles published between 2012 and 2022. Databases were approached through the Egyptian Knowledge Bank. The search was conducted in December 2022.

The keywords included “distraction osteogenesis”, “callus distraction”, “allostasis”, “osteodistraction”, “short finger”, “bone lengthening”, and “fingers reconstruction”. The keywords were combined with the Boolean operators “AND” and “OR”.

The titles and abstracts of the results from the primary search across all of the chosen databases were assessed in advance according to inclusion and exclusion criteria.

In cases where the article's title or abstract didn't provide enough information to determine whether or not it met the criteria for inclusion or exclusion, the complete text of the article was surveyed.

In addition, to find other relevant research, the references of relevant papers were hand-searched.

The studies were selected if they fulfilled the following inclusion criteria: retrospective, prospective or cross-sectional studies; Cases with shortened fingers (post-burn or post-traumatic) candidates for reconstruction; Patients with a brachydactyly finger candidate for reconstruction; Comparison between DO and other reconstruction options; at least one outcome measure was reported; and data could be extracted from the entire publications.

Exclusion criteria: All articles that didn't meet the inclusion criteria were excluded. Abstracts, editorials, letters, and reviews without original data, expert opinions, case reports, meta-analyses and studies without a control group were disregarded. Studies in non-English languages were also excluded.

Data collection and data items: According to a predetermined protocol, the data from each research was abstracted and entered into a form with the following parameters: primary author, publication year, type of the study, number of patients, age of patients, level of finger amputation, type of reconstruction, pre distraction length, post distraction length, function after distraction, quality of life after distraction, depression and anxiety before and after distraction and patient satisfaction before and after distraction.

Statistical analysis of the data and synthesis of results: The computer was given the data, and the analysis was performed with the MedCalc software program version 20.100. The level of confidence in the results, known as the confidence interval (CI), was set at 95%, and p-values of 0.05 or less were regarded to be statistically significant. I2, which measures the observed variance for heterogeneity, and Q, which measures the total variance for heterogeneity, were utilized to analyze statistical heterogeneity. The mean and standard deviation of the quantitative data were presented, but the total number of observations and the number of occurrences were detailed in the qualitative data.

3. Results

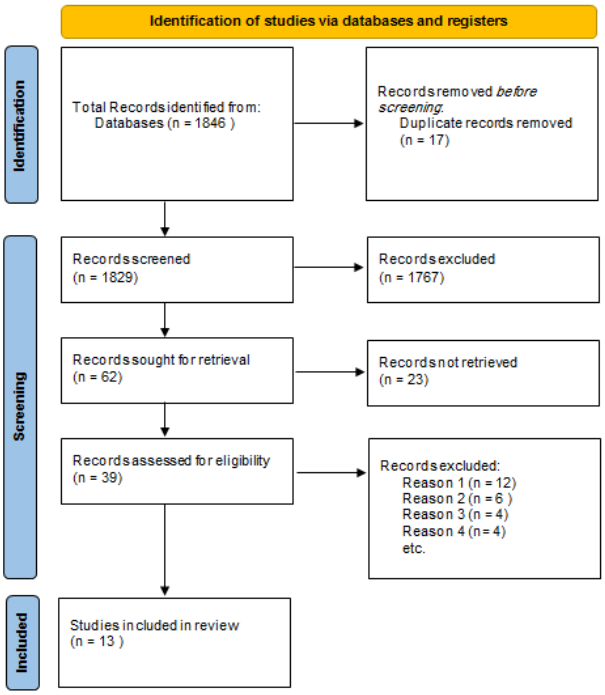


Table 1. Study characteristics

author	type of study
Bashour LE et al.[8]	case series
Jiang Y et al.,[9]	retrospective
Zhang R et al.,[10]	retrospective
Iba K et al.,[11]	retrospective
Kanchanathepsak T et al.,[12]	retrospective
Jia S et al.,[13]	retrospective
Yamamoto Y et al.,[14]	retrospective
Lam A et al.,[15]	retrospective
Ding Z et al.,[16]	retrospective
Vargel I et al.,[17]	retrospective
Vekris M et al.,[18]	retrospective
Cansü E et al.,[19]	retrospective
Bulut M et al.,[20]	retrospective

Thirteen studies were involved 12 were retrospective studies and 1 case series as revealed in Table 1.

Table 2. Patient's characteristics

author	number	age	m\f	side (rt\lt)
Bashour LE et al.,[8]	5	18		
Jiang Y et al.,[9]	95	30	20\75	84\79
Zhang R et al.,[10]	15	24.4	8\7	8\7
Iba K et al.,[11]	2			
Kanchanathepsak T et al.,[12]	15	42.8	13\2	
Jia S et al.,[13]	23	36	21\2	16\7
Yamamoto Y et al.,[14]	12	42	11\1	
Lam A et al.,[15]	4	22.8	0\4	2\2
Ding Z et al.,[16]	104	29.5	68\36	
Vargel I et al.,[17]	7	4.7	4\3	bilateral (7)
Vekris M et al.,[18]	65	20	46\19	23\42
Cansü E et al.,[19]	14	27	13\1	
Bulut M et al.,[20]	4	14.9	1\3	3\1

A total of 365 cases were involved with mean age 26 years as shown in Table 2.

Table 3. Treatment characteristics

Author	distraction period (days)	Starting length (cm)	final length gain (cm	Length gain at end of distraction/cm	Lengthening rate (mm/day)	Consolidation time (days)	Total time in fixator (days)
Bashour LE et al.[8]	21		1.3	1.5	0.75	77	87
Jiang Y et al.,[9]	12			0.7			63
Zhang R et al.,[10]				1.8		43.3	
Iba K et al.,[11]	28		1.7				83
Kanchanathepsak T et al.,[12]	49.2			2.65		149.2	
Jia S et al.,[13]	44	3.9	2.6				63

Yamamoto Y et al.,[14]							
Lam A et al.,[15]	38	3.6	1.2	1.5	0.432	71	109
Ding Z et al.,[16]				2.3	0.8		
Vargel I et al.,[17]	9.9	1.9	.7		0.2	58.3	
Vekris M et al.,[18]	21					35	56
Cansü E et al.,[19]				2			85
Bulut M et al.,[20]	27.7	3.4	1.5	1.5	0.55		79.1

Mean distraction period (days) was 22.8, mean Starting length (cm) was 2.9 and changed to 4.02 after treatment, mean lengthen gain at end of distraction \cm was 1.74, Lengthening rate (mm/day) was 0.7, mean Consolidation time (days) was 63.9 and mean Total time in fixator (days) was 76.8 as shown in Table 3.

Table 4. Comparison between normal pregnancy and miscarriage according to Gestational Sac Size

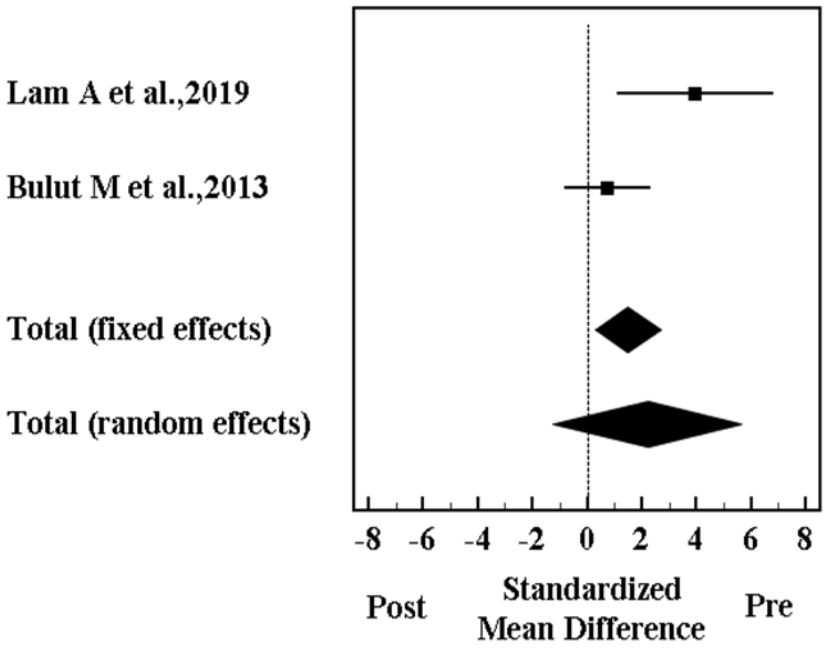
author	*EFI days/cm*	*Healing index, d/cm*	*Kapandji opposition score*	*two-point discriminations before*	*two-point discriminations after*
Bashour LE et al.,[8]	87	64			
Jiang Y et al.,[9]					
Zhang R et al.,[10]	45	78	7.3	8.5	
Iba K et al.,[11]		90			
Kanchanathepsak T et al.,[12]		87			
Jia S et al.,[13]		32.6	8		
Yamamoto Y et al.,[14]					
Lam A et al.,[15]	71.8				
Ding Z et al.,[16]				6.94 ± 0.77	7.06 ± 0.84
Vargel I et al.,[17]					
Vekris M et al.,[18]		27.7			
Cansü E et al.,[19]		43			
Bulut M et al.,[20]		51.7			

Mean EFI days/cm was 61.4, mean Healing index, d/cm was 54.4 and mean Kapandji opposition score was 7.65, mean two-point discriminations before was 7.72 and changed to 7.06 after treatment as shown in Table 4.

Table 5. ROM and outcome score

author	*MCP ROM extension (degrees) pre*	*MCP ROM extension (degrees) post*	*MCP ROM flexion (degrees) pre*	*MCP ROM flexion (degrees) post*	*VAS pre*	*VAS post*	*DASH*
Bashour LE et al.,[8]							
Jiang Y et al.,[9]							
Zhang R et al.,[10]							
Iba K et al.,[11]							
Kanchanathepsak T et al.,[12]							
Jia S et al.,[13]							4
Yamamoto Y et al.,[14]							10
Lam A et al.,[15]	21	0	87	86			
Ding Z et al.,[16]							
Vargel I et al.,[17]							
Vekris M et al.,[18]							
Cansü E et al.,[19]							1.62
Bulut M et al.,[20]	19.3	16.4	78.6	64.3	45.7±3.4	7.2±1.9	

ROM and outcome score Mean MCP ROM extension (degrees) pre was 20.15 and changed to 8.2 after treatment, mean MCP ROM flexion (degrees) pre was 75.6 changed to 82.3 after treatment, mean VAS used by 1 study and was 4.5±3.4 pre and changed to 7.2±1.9 after, mean DASH score was 5.2 as shown in Table 5.



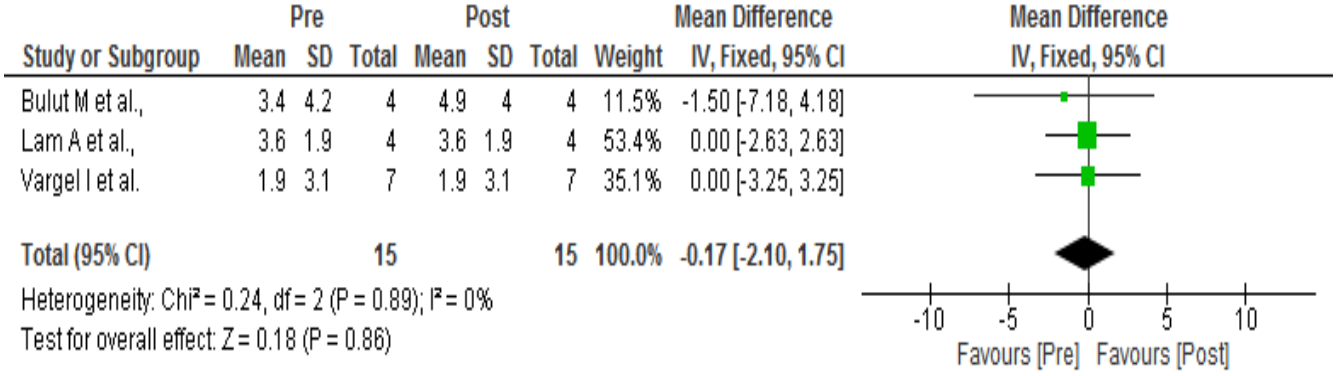


Table 6. Meta-analysis for starting length (cm)

Study	Pre		Post		SMD	SE	95% CI
	No.	Mean ± SD.	No.	Mean ± SD.			
Lam A et al.,[15]	4	3.6 ± 1.9	4	4.8 ± 5.8	-0.242	0.617	-1.752 to 1.269
Vargel I et al.,[17]	7	1.9 ± 3.1	7	2.6 ± 8.4	-0.103	0.501	-1.194 to 0.987
Bulut M et al.,[20]	4	3.4 ± 4.2	4	4.9 ± 4.0	-0.318	0.619	-1.833 to 1.198
Total (fixed effects)					-0.203	0.329	-0.878 to 0.471
Total (random effects)					-0.203	0.329	-0.878 to 0.471
Test for heterogeneity							
Q	0.07770						
DF	2						
Significance level	P = 0.9619						
I^2 (inconsistency)	0.00%						
95% CI for I^2	0.00 to 13.66						

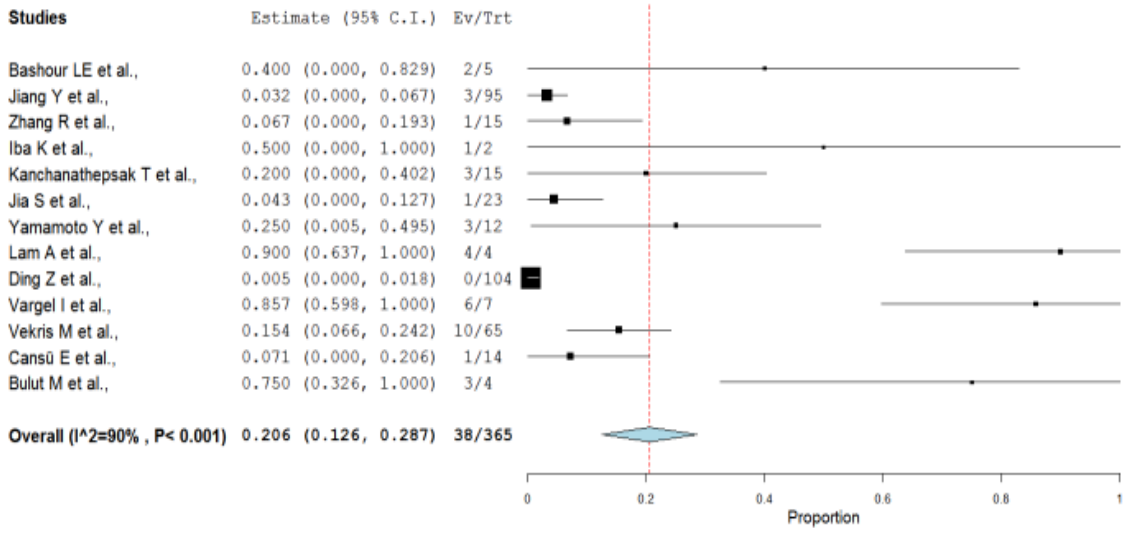
SMD: Standardized Mean Difference
I2: Observed variance for heterogeneity
CI: Confidence interval (LL: Lower limit –UL: Upper Limit)

Meta-analysis 3 studies assessing change length pre and after shows slight increase in length after but with insignificant difference revealed in Table 6.

Table 7. Meta-analysis for Complications

Study	Total number	Event	Event rate (%) (Proportion)	95% CI of rate (%
Bashour LE et al.,[8]	5	2	40.0	5.274 to 85.33
Jiang Y et al.,[9]	95	3	3.158	0.656 to 8.97
Zhang R et al.,[10]	15	1	6.667	0.169 to 31.9
Iba K et al.,[11]	2	1	50.0	1.258 to 98.7
Kanchanathepsak T et al.,[12]	15	3	20.0	4.331 to 48.0
Jia S et al.,[13]	23	1	4.348	0.110 to 21.949
Yamamoto Y et al.,[14]	12	3	25.0	5.486 to 57.186
Lam A et al.,[15]	4	4	100.0	39.764 to 100.00
Ding Z et al.,[16]	104	0	0.0	0.000 to 3.485
Vargel I et al.,[17]	7	6	85.714	42.128 to 99.639
Vekris M et al.,[18]	65	10	15.385	7.632 to 26.478
Cansü E et al.,[19]	14	1	7.143	0.181 to 33.868
Bulut M et al.,[20]	4	3	75.0	19.412 to 99.369
Total (fixed effects)			7.997	5.469 to 11.205
Total (random effects)			24.318	11.774 to 39.648
Test for heterogeneity				
Q	99.4451			
DF	12			
Significance level	P < 0.001*			
I^2 (inconsistency)	87.93%			
95% CI for I^2	81.16 to 92.27			

Thirteen studies were included, showing significant heterogeneity with an event rate of 7.9%, as shown in Table 7.



Forest plot for complications

4. Discussion

This systematic review & meta-analysis included 12 retrospective studies (Jiang et al.,[9]; Zhang et al.,[10]; Iba et al.,[11]; Kanchanathepsak et al.,[12]; Jia et al.,[13]; Yamamoto et al.,[14]; Lam et al.,[15]; Ding et al.,[16]; Vargel et al.,[17]; Vekris et al.,[18]; Cansü et al.,[19]; Bulut et al.,[20]) and 1 case series (Bashour et al.,[8]) with a total of 365 cases of mean age 26 years.

As regards treatment characteristics, the current study showed that the mean distraction period\days was 22.8, the mean Starting length (cm) was 2.9 and changed to 4.02 after treatment, the mean length gain at the end of distraction/cm was 1.74, the Lengthening rate (mm/day) was 0.7, mean Consolidation time (days) was 63.9 and meant Total time in fixator (days) was 76.8. the highest lengthening rate was reported by Ding et al.using a self-designed bilateral tubal-helical external fixator with a rate of 0.8 mm/day. [16]

The healing index is affected by age, with younger patients healing faster than elderly patients. [21]

Literature showed that a younger age at surgery was associated with better outcomes. A systematic review by Kempton et al. included 30 articles that evaluated DO as a surgical option for the treatment of acquired and traumatic hand deformities and found a lower complication rate in pediatric cases contrasted with adults. Still, the distinction did not reach statistical significance (p = 0.0507). [22]

The external fixation index (EFI) was calculated by dividing the total time each patient spent in the fixator by the amount by which they were extended. To check scientifically if the desired lengthening was accomplished. [15]

The present research revealed that the mean EFI days/cm was 61.4, as reported by 3 studies (Bashour et al.,[8]; Zhang et al.,[10]; Lam et al.,[15]), the minimum value was 45, as reported by Zhang et al., [10], while the maximum value was 87 as

reported by Bashour et al., who used internal distractor in metacarpal lengthening. [8]

The present study showed that the mean Healing index, d/cm was 54.4, as reported by 8 studies (Bashour et al.,[8]; Zhang et al.,[10]; Iba et al.,[11]; Kanchanathepsak et al.,[12]; Jia et al.,[13]; Vekris et al.,[18]; Cansü et al.,[19]; Bulut et al.,[20]), the minimal Healing index was reported by Vekris et al., using mini-external fixator 18, while the maximal Healing index was reported by Iba et al., among those with constriction band syndrome who had proximal phalanges lengthened by distraction in an external fixator. [11]

For thumb-elongated cases, the Kapandji opposition test was used to assess its function. [23] The present research revealed that the mean Kapandji opposition score was 7.65, as reported by Zhang et al., 10 and Jia et al.,[13].

The thumb function and appearance were assessed using the expert score (1 = great and 10 = bad). The mean expert score was 8, as reported by Jia et al.; the mean two-point discrimination before was 7.72 and changed to 7.06 after treatment. [13]

Ding et al. revealed that the affected fingers' static two-point discrimination was 6.94 ± 0.77 mm before the extension, and it improved to 7.06 ± 0.84 mm afterward. When contrasting results from before and after lengthening, there was not a significant variance in the static two-point discriminations (P> 0.05). [16]

The mean MCP ROM extension (degrees) pre was 20.15 and changed to 8.2 after treatment. The meta-analysis included 2 studies (Lam et al.,15; Bulut et al.,20) that assessed MCP ROM extension degrees pre and post-treatment, showing a significant decrease in after-treatment p value 0.015.

Also, the mean MCP ROM flexion (degrees) pre was 75.6, which was changed to 82.3 after treatment. The meta-analysis included 2 studies (Lam et al.,15; Bulut et al.,20) that assessed MCP ROM Flexion degrees and showed significant differences between pre and post with p –a value of 0.04.

All patients who had the lengthening treatment reported full extension of their afflicted metacarpals, as described by Lam et al. Also, flexion either returned to normal or was kept at the pre-surgery level following the procedure. [15]

Bulut et al. demonstrated that patients with short metacarpals had a mean extension/flexion of 19.3/64.3 degrees at the MCP joints before surgery, and this improved to 16.4/78.6 degrees at the 12-month mark after surgery. There was a statistically significant (p0.05) rise in the degree of flexion. [20]

In the current meta-analysis, three studies (Lam et al.,[15]; Vargel et al.,[17]; Bulut et al.,[20]) assessed the change in length pre-and post-treatment. They showed an increase in length after but with insignificant differences.

Lam et al. showed that There was an average of a 1.5 cm extension to the metacarpals (range: 1.2–2.1 cm). 15 Average deviation from the ideal length was 1.6 mm (range, 0.04-0.24 cm), as calculated using the mathematical association described by Aydinlioglu et al. For correcting the length of the afflicted metacarpals, this was well within the allowable range of ±0.2 cm. [24]

Also, Vargel et al. showed that at the start of distraction, the phalanges averaged 1.9± 3.1 cm in length, while at the long-term follow-up visit, the length of the distracted phalanx averaged 2.6 ± 8.4 cm. [17]

However, Bulut et al. showed that the mean before and after surgery metacarpal lengths were 3.4 ± 4.2 and 4.9 ± 4.0 cm, respectively, with significant differences (p<0.001). The mean lengthening attained was 1.51 cm (range: 1.4 to 1.7). [20]

The cases' functional statuses were assessed utilizing the Quick DASH score. The mean DASH score was 5.2, as reported by 3 studies (Jia et al.,[13]; Yamamoto et al.,[14]; Cansü et al.,[19]). The highest DASH score was reported by Yamamoto et al., 14 however, the lowest score was reported by Cansü et al. [19]

The VAS was used to measure the degree to which the cosmetic outcome satisfied the patient. Postoperative values increased to 82.9±6.9 from preoperative values of 45.7±3.4, as reported by Bulut et al. (p<0.05). [20]

Regarding, Complications, 13 studies (Bashour et al.,[8]; Jiang et al.,[9]; Zhang et al.,[10]; Iba et al.,[11]; Kanchanathepsak et al.,[12]; Jia et al.,[13]; Yamamoto et al.,[14]; Lam et al.,[15]; Ding et al.,[16]; Vargel et al.,[17]; Vekris et al.,[18]; Cansü et al.,[19]; Bulut et al.,[20]) were included in the meta-analysis and showed significant heterogeneity with event rate 7.9%.

The complication rate ranged from 0% (as reported by Ding et al.,16) to 100% (as reported by Lam et al.,[15]).

Higher than the current study, a systematic review by Kempton et al. revealed that the average complication rate was 26.4% post-DO in hand surgery. [22]

Bashour et al. reported 2(40%) complications in the form of Pin track infection, but no major complications were reported. [8]

Jiang et al. reported that among the 163 thumbs, 16 (9.8%) experienced various complications. Infection of the pin track is the problem associated with distraction lengthening, which occurs the most frequently. Other complications include joint stiffness, angulation, dislocation, and delayed union or nonunion. [9]

Also, Zhang et al. revealed that there was only 1 case (6.6%) where a minor complication (track infection) occurred. No major complications were

reported. [10]

Vargel et al. also reported that Minor complications, for example, pin loosening, were detected in 6 extremities across 4 cases, and 2 cases required treatment for pin tract infection (PTI), but no serious complications occurred. [17]

5. *Conclusion*

In conclusion, the current study showed that The advantages of DO for length restoration following digital amputations are concise: it is technically straightforward, it uses anatomically similar replacements, and it does not result in morbidity at the donor site. The lengthy treatment time and high complication rates offset these advantages, though.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

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