

Evaluation of Reversal Osteofixation Using K-Wires in Digital Replantation

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SUMMARY

Introduction Modified, reversal technique of fixation in digital replantation using K-wires was analyzed. The results obtained from the standard technique and reversal technique of fixation using K-wires were compared.

Objective The aim was to compare the results of osteofixation using K-wires in digital replantation when either standard or reversal, modified technique was used.

Methods A retrospective study included 103 replanted fingers in 72 patients. The first group included standard fixation using K-wires and the second group included fixation using K-wires, but with a modified technique. Modification consisted of the opposite order of moves during the phalangeal fixation compared to the standard technique: first, K-wire was introduced intramedullary in the proximal phalanx and the top of the wire was drawn out through the skin in proximal part of the finger or hand. Second, distal part of the wire was introduced in the phalanx of the amputated part of the finger intramedullary until the wire entered the cortex.

Results Duration of bone healing after digital replantation was shorter in cases where reversal technique was used in comparison with standard technique (7.2 weeks compared to 7.5 weeks).

Conclusion The comparison of standard and reversal technique of phalangeal fixation with K-wires in digital replantation shows that both techniques are useful. Reversal technique expands the choice of operative techniques for bone fixation during the replantation. It shows some advantages and enables avoidance of vein injuries.

Keywords: digital replantation; osteofixation using K-wires; bone healing

INTRODUCTION

Osteofixation is necessary step before reconstruction of all cut structures in the procedure of digital replantation. It also has a great importance for good functional outcome after the replantation [1]. Secondary procedures related to bone fixation account for 12% in cases of digital replantation [2]. There are many techniques which can be used for fixation of digital phalanges and bones in hand area [3, 4, 5]. The common, described techniques are: 1. Single intramedullary fixation; 2. Fixation using two parallel intramedullary K-wires; 3. Fixation using one intramedullary and one oblique K-wire; 4. Fixation using two crossed K-wires; 5. Interosseous wire fixation; 6. Parallel interosseous wires fixation; 7. Crossed interosseous wires fixation; 8. Oblique K-wire with interosseous wire fixation; 9. Screw and plate fixation; 10. Screw fixation without the plate (Ikuta); 11. Intramedullary screw fixation (Tamai).

In digital replantation, osteofixation should be simple, carried out in a short period of time, not make large bone exposure, include small part of the bone, provide solid stability at the place of fracture, provide movements as soon as possible. In addition, the volume of inserted fixational material needs to be smaller [3]. The

choice of fixation technique depends on the level of replantation. For distal phalanges, a single K-wire is more common, but for proximal parts two K-wires or the combination of intramedullary K-wire and interosseous wire is common. For metacarpal bones, the screws and plates can be used, too.

Properly placed osteofixation, adequate choice of procedure and successful revascularization provide good fracture healing and early movements. Osteofixation in digital replantation has been reviewed in English- and Russian-language literature and the results are mostly the same [4-8]. The insertion of the K-wires is associated with the risk of neurovascular bundle damage, either directly or indirectly by causing mechanical obstruction by tethering a vessel or its supporting ligaments – this was noticed few decades ago [7].

OBJECTIVE

The aim of this paper was to describe modified technique for fixation of finger phalanges using K-wires in digital replantation and also to point to the advantage of this technique – save the soft tissue covering the replanted part of the finger.

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METHODS

The analysis of osteofixation in replanted fingers included patients with digital replantation who underwent osteofixation using K-wires. Replanted fingers survived in 83.3% of cases. The cases (16.7%) whose circulation could not be maintained were excluded and their fingers were subsequently reamputated. Authors analyzed 103 replantations in 72 patients (64 males and 8 females), which had been performed during the period of 15 years. Digital amputations according to the type of injury were as follows: clean cuts – 22 (21.4%), local crushes – 56 (54.4%), avulsions – 17 (16.5%) and crushes – 8 (7.7%).

According to the type of osteofixation, patients were divided in two groups. In the first group of patients, osteofixation using K-wires was performed by standard technique and the second group was treated by modified, reversal technique of osteofixation using K-wires.

The first group included 47 cases which were all treated by the standard technique: first, the K-wire was introduced intramedullary in the amputated part and drawn out through the top of the finger or periarticularly through the skin (in case of medial or proximal phalanx). In the next step, the proximal part of the same wire was introduced intramedullary in proximal part of the phalanx and in this way the fracture was fixed. After the fixation was done, the tops of the wires were sticking out in distal, replanted parts of the finger and they should be curved for 90°. When it was obvious that the fracture as healed, the wires should be pulled out distally.

The second group included 56 cases. These patients were operated using modified surgical technique. Modification included: first, the K-wire was introduced intramedullary in the proximal part of the phalanx and the top of the wire was drawn out through the skin in proximal part of the finger or hand (Figure 1A). In the second step, distal part of the wire was introduced intramedullary in the phalanx, until the wire entered the cortex and at this point

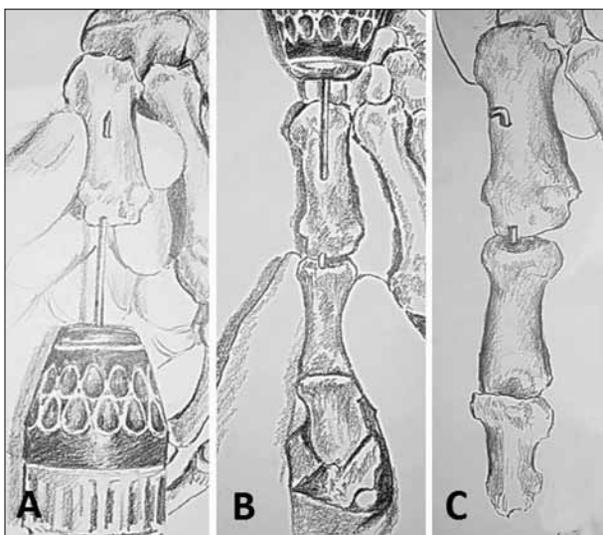


Figure 1. Review of surgical technique on model: a) introducing the K-wire into the proximal part of the bone; b) leaving the top of the K-wire in the cortex; c) cut and curved proximal part of the K-wire.

the top of the wire was stopped (Figure 1B). There are two ways showing the end of passing the wire into the amputated part: when the wire enters the cortex, it is possible to feel higher resistance (so after few seconds of drilling in cortex, further introduction of wire into the amputated part is stopped). Another solution means that the wire passes through the cortex and at the moment when the wire gets out of the cortex, the small vibration can be noticed in the part of the digit where the wire is expected to get out. This technique saves the neurovascular structures, which is very important because of their great significance for the success of replantation. After the fixation was completed, the proximal part of the wire should be curved for 90° at the point where the wire got out of the skin and it should be also shortened (Figure 1C). When the fracture is healed, the wires should be pulled out proximally.

Standard descriptive statistical methods and the appropriate tests were used for statistics (χ^2 test and Kruskal-Wallis test).

RESULTS

The technique of osteofixation using K-wires was applied in 103 replanted fingers (Figures 2-7). There were 47 (45.6%) replantations in the first group of replanted fingers, and standard technique was used for fixation. Among them, fixation using single K-wire was done in 11 (10.7%) cases and fixation using two K-wires in 36 (34.6%) cases. In the second group with reversal positioning of K-wires, there were 56 replantations (54.4%). Among them, the fixation using the single K-wire was done in 21 (21.4%) cases and the fixation using two K-wires in 35 cases (33.9%) (Table 1).

Average bone shortening among followed up replantations was 7 mm. Shortening from 0 mm to 31 mm was presented in Table 2. There was no shortening in 8 replantations. In case of 26-year old male patient, the proximal phalanx was 2 mm longer, compared to the opposite side.

In bone shortening, the difference between the standard and reversible group was not statistically significant ($\chi^2=0.366$, $p>0.05$).

Post-traumatic arthritis after the replantation was found in 24 (27.6%) cases. It was most frequently single and localized in distal and injured joints. Five replantations in two patients were followed by arthritis which affected all hand joints. The patients were between 30 and 56 years old. Arthrodesis in functional position was performed in 25 cases (28.7%) with joint lesions.

In digital replantation after the osteofixation with K-wires, fracture healing was assessed as excellent in 56 cases (54.4%), good in 35 cases (34.4%), malposition in 10 cases (9.7%) and nonunion in 3 cases (2.9%) (Table 3). Comparison of fracture healing between two analyzed groups showed no significant difference ($\chi^2=1.09$, $p>0.05$), although slightly bigger number of replantations with excellent and good results was recorded in the group where reversal technique was applied.

Average time of bone healing in digital replantation after the osteofixation using K-wires with standard and



Figure 2. A male, 51 years, complete amputation of three fingers with saw



Figure 3. The condition just after the replantation of three fingers. K-wires fixation, reversal technique. The ends of the wires are easily seen in metacarpus.



Figure 4. X-ray five weeks after operation, following the placement of reversal K-wires



Figure 5. X-ray five months after operation



Figure 6. Finger extension function after five months



Figure 7. Finger flexion function after five months

reversal bone technique was 7.5 and 7.2 weeks, respectively. The wires were pulled out within 6-9 weeks. In 39.8% (41) of replantations with osteofixation using standard or reversal technique, the fracture healing was achieved after 7-8 weeks. A bigger number of healings achieved in 6 weeks (or 7 weeks) (Table 4) was noticed after the use of reversal technique. Statistically significant difference in time of healing between these two analyzed groups was not found ($\chi^2=1.28$, $p>0.05$).

Type of injury was the major factor for indication of digital replantation. It also had the highest impact on the entire functional recovery. The analysis of functional outcomes in digital replantation according the type of injury

using Tamai criteria showed that the functional outcome was worse as the injury was wider. Every case of clean cut produced excellent or good result. In cases of avulsions and local crushes, the functional recovery was significantly worse. In cases of crushes, recovery was satisfactory and poor, according to Tamai criteria (Table 5).

There was a significant difference between the groups considering the type of injury and final functional outcome (Kruskal-Wallis $H=33.8623$, $p<0.01$). Clean cuts and avulsions were the exception, meaning that there was no significant difference between these two types of injury. The data obtained in this series showed that there was no excellent functional outcome if bone healing was not excellent.

Table 1. Osteofixation type in replanted fingers of the analyzed group

Fixation type	Reversal technique			Standard technique			Total
	1K-wire	2K-wires	Total	1K-wire	2K-wires	Total	
Number of fingers (%)	21 (20.4)	35 (33.9)	56 (54.4)	11 (10.7)	36 (34.6)	47 (45.6)	103 (100.0)

Table 2. Bone shortening in digital replantation – number of fingers (%)

Replantations	Bone shortening (mm)				Total
	0	1–10	11–20	21–30	
Standard technique	3 (2.9)	26 (25.2)	17 (16.5)	1 (1.0)	47 (45.6)
Reversal technique	5 (4.9)	32 (31.1)	18 (17.5)	1 (0.9)	56 (54.4)
Total	8 (7.8)	58 (56.3)	35 (33.9)	2 (2.0)	103 (100.0)

Table 3. Fracture healing after the bone fixation with K-wires – number of fingers (%)

Technique of fixation using K-wires	Fracture healing				Total
	Excellent	Good	Malposition	Nonunion	
Standard technique	27 (26.2)	14 (13.6)	4 (3.9)	2 (1.9)	47 (45.6)
Reversal technique	29 (28.1)	20 (19.4)	6 (5.8)	1 (0.9)	56 (54.4)
Total	56 (54.4)	34 (33.0)	10 (9.7)	3 (2.9)	103 (100.0)

Table 4. Bone healing duration in digital replantations – number of fingers (%)

Technique of fixation using K-wires	Bone healing duration (weeks)				Total	Average (weeks)
	6	7	8	9		
Standard technique	7 (6.8)	12 (11.6)	29 (28.2)	2 (1.9)	50 (48.5)	7.5
Reversal technique	11 (10.7)	19 (18.4)	22 (21.4)	1 (1)	53 (51.5%)	7.2
Total	18 (17.5)	31 (30.1)	51 (49.5)	3 (2.9)	103 (100.0)	7.4

Table 5. Functional outcome using Tamai criteria – number of fingers (%)

Functional outcome	Tamai score				Total
	Excellent	Good	Satisfactory	Bad	
Clean cut	15 (14.6)	5 (4.8)	/	/	20 (19.4)
Local crush	15 (14.6)	31 (30.1)	18 (17.5)	2 (1.9)	66 (64.1)
Avulsion	/	9 (8.7)	1 (1.0)	/	10 (9.7)
Crush	/	/	5 (4.8)	2 (1.9)	7 (6.8)
Total	30 (29.2)	45 (43.6)	24 (23.3)	4 (3.8)	103 (100.0)

Table 6. Functional outcome according to the type of osteofixation using K-wires – number of fingers (%)

Type of fixation	Tamai score				Total
	Excellent	Good	Satisfactory	Bad	
Standard technique	14 (13.6)	22 (21.4)	10 (9.7)	1 (0.97)	47 (45.6)
Reversal technique	16 (15.5)	23 (22.3)	14 (13.6)	3 (2.9)	56 (54.4)
Total	30 (29.1)	45 (43.7)	24 (23.3)	4 (3.9)	103 (100.0)

Functional outcome of replantations by Tamai criteria (Table 6) showed that there was no statistically significant difference between standard and reversal osteofixation technique using K-wires (Kruskall-Wallis $H=33.8623$, $p<0.01$).

DISCUSSION

For successful replantation, type of the injury and possibility for structural reconstruction are most important factors. Many factors may have significant influence. Bone fixation requires the best choice of method, taking into account the level of amputation and type of injury. In addition, the precise use of technique is required. Fracture healing in digital replantation takes 4-12 weeks [8]. Depending on the osteofixation type, an average duration of fracture healing is 9 weeks in osteofixation with two parallel K-wires. Fixation with interosseous wire takes 8.1 weeks and fixation with

combination of oblique K-wire and interosseous wire takes 7.9 weeks [8]. The type of phalanx fixation in digital replantation has influence on: operation duration, possibility of early movements and functional recovery of replanted finger [3-7]. Meta-analysis of various series of digital replantation and revascularization shows variable success, 35%-100% [7]. Functional evaluation in presented series reveals success in 67%, presenting the score of group I and II according to Tamai criteria. Postreplantation surgery ranged from 2.9-93.2%, and an average number of secondary procedures per patient was 1-4.5. Joint procedures and skeletal stabilization accounted for 18.9% and 12%, respectively [2]. Later bone interventions were not performed in the presented series. Bone complications of replantations may be as high as 20.45% and they include nonunion of bone fragments, K-wires migration and infection [9].

Complications of bone healing in presented series were recorded in 12.6%, including the nonunion and malposition.

The technique of reversal phalanges fixation using K-wires was applied among patients with digital replantation, at the level of phalanges, metacarpal and carpal bones. The technique is simple and makes no harm to soft tissue of replanted finger in any way. The success would be the same if one wire intramedullary, two wires intramedullary, two wires intramedullary and parallel or two crossed wires were applied. If one K-wire was inserted, the unstable rotational condition of the bone would be corrected by suturing the joint capsula, tendons, extensors and, finally, the skin (operative wound).

The longest bone shortening was 31 mm. There was only one patient who had shortening longer than 20 mm. Literature reports shortenings up to 40 mm in some cases of replantation. There are only minor disturbances in digital growth after the replantation; reduction of 14%, compared to the normal growth, has been reported. There were few cases where replanted finger grew so much, that it was longer than healthy fingers on the opposite hand [10]. In our series, only one case of excessive growth after the replantation was documented. The proper skeletal fixation of fragments in functional position is important for successful functional recovery and also for successful revascularization and reconstruction [1, 10, 11, 12]. Many authors think that the K-wires technique is an optimal solution for phalangeal fixation in digital replantation [3, 13-16]. Oblique K-wire with interosseous wire is also a frequent method [6].

Our research shows that, although slightly bigger number of good results is seen in the group of replantations with reversal phalanges fixation, this difference is not statistically significant. Modified-reversal technique of fixation using K-wires is a valid alternative to standard technique of placing K-wires in bone fixation during the digit replantation, from the aspect of duration of fragment healing and final functional outcome.

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CONCLUSION

Osteofixation using K-wires in digital replantation, with the use of reversal, modified technique (where the tops of the wires are pulled out proximally) is not different in comparison to standard technique (where the tops of the wires are drawn out from the distal part of the finger), from the aspect of bone healing, fragments fixation and the healing duration.

With standard technique, during pulling out the K-wires through the skin in replanted part of the finger, surgeon cannot avoid even the slightest injury of the soft tissues and it certainly has effect on postoperative period and outcome of replantation. Reversal technique means that the wires are pulled out of the skin in proximal part of the stump through the tissue which does not suffer the consequences of hypoxia and traumatic soft-tissue damage. Reversal technique completely prevents potential iatrogenic damage of soft tissues and, in particular, of the veins in distal, replanted part.

Based on presented results and our previous results of the use of both techniques, we find that reversal-modified technique has a conceptual advantage compared to the standard technique of bone fixation using K-wires, which enables a valuable alternative choice in operative techniques for fixation of hand bones during the replantations.

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Процена реверзне остеофиксације применом К-игала у реплантацији прста

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КРАТАК САДРЖАЈ

Увод Анализирана је реверзна техника фиксације употребом К-игала код реплантације прста. Упоредивани су резултати примене стандардне и реверзне технике фиксације К-иглама.

Циљ рада Циљ рада је био да се упореде резултати остеофиксације К-иглама код реплантација прстију применом стандардне технике и реверзне – модификоване технике.

Методе рада Ретроспективна студија је обухватила 103 реплантирана прста код 72 пацијента. Прва група обухватала је стандардну фиксацију К-иглама, а друга фиксацију К-иглама применом модификоване технике. Модификација се састојала у обрнутом редоследу потеза током фиксације фаланги у поређењу са стандардном техником. Прво, К-игла се уводи интрамедуларно у проксималну фалангу и врх игле се изводи кроз кожу у проксималном делу прста шаке. Друго, дистални део игле се интрамедуларно уводи у

фалангу ампутираног дела прста док игла не уђе у кортекс. Пошто К-игла не излази из кости ампутираног дела прста, не повређује мека ткива реплантираног прста и због тога се очекује бољи резултат реплантације.

Резултат Време срастања кости након реплантације прста било је краће након примене реверзне технике у поређењу с применом стандардне технике (7,2 недеље у поређењу са 7,5 недеља), али ова разлика није била статистички значајна.

Закључак Поређење стандардне и реверзне технике фиксације фаланги К-иглама код реплантације прстију показује применљивост обе технике. Реверзна техника је опција при избору хируршке технике за фиксацију костију током реплантације. Показује извесне предности и претпостављено избегавање повређивања вена.

Кључне речи: реплантација прстију; остеофиксација К-иглама; срастање кости