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Long-term results of major upper extremity replantations

Üst ekstremitede majör replantasyonların uzun dönem izlem sonuçları

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Amaç: Üst ekstremitede majör replantasyon uygulanan olguların uzun dönem izlemlerinde elde edilen klinik ve fonksiyonel sonuçlar değerlendirildi.

Çalışma planı: 1987-2003 yılları arasında 26 erkek hastaya (ort. yaş 27; dağılım 3-69) uygulanan üst ekstremite majör replantasyon cerrahisi sonuçları, ortalama 11.3 yıl (dağılım 5-19 yıl) izlem süresi sonunda geriye dönük olarak değerlendirildi. Replantasyonlar transmetakarpal (n=6), el bileği (n=4), önkol (n=5), dirsek (n=4) ve kol (n=7) seviyesinden yapıldı. Yaralanma, yedi hastada keskin sınırlı, sekiz hastada ezilme, 11 hastada sıyrılma şeklindeydi. Ondokuz hastaya ikincil cerrahi uygulandı. Fonksiyonel sonuçların yorumlanmasında Chen ölçütleri ve DASH-T (Kol, Omuz ve El Sorunları Anketi-Türkçe) kullanıldı.

Sonuçlar: Ameliyat sırasındaki kısaltma miktarı ortalama 37.2 mm, takip sonundaki radyografik kısalma miktarı ortalama 52.2 mm idi. Yaralı tarafta ortalama kavrama gücü 12.3 kg, çimdik gücü 3.6 kg (sağlam tarafta sırasıyla 37.6 kg ve 8.7 kg) bulundu. Monofilaman testinde duyunun 20 hastada geri döndüğü görüldü. İki nokta ayrım testinde 18 hastanın median sinir için, 17 hastanın ulnar sinir için iki nokta ayrımı yapabildiği görüldü. Chen ölçütlerine göre 17 hastada (%65.4) çok iyi veya iyi, üç hastada (%11.5) orta, altı hastada (%23.1) kötü sonuç elde edildi. Yaralanma seviyesi (r=0.71) ve yaralanma türüyle (r=0.65) Chen ölçütleri arasında korelasyon saptandı. Dirsek seviyesindeki yaralanmaların ve sıyrılma tarzındaki yaralanmaların sonucu olumsuz etkilediği görüldü. DASH-T skoru ortalaması 6.7 (dağılım 0-32.5) olarak hesaplandı. Chen I-II grubu ile III-IV grubu hastaların ortalama DASH-T skorları arasında anlamlı fark bulundu ($p<0.05$).

Çıkarımlar: DAST-T skorlarının düşük olması, hasta memnuniyetinin ve replantasyon uygulanan ekstremitenin yardımcı kol olarak kullanımının iyi olduğunu, bu şekilde fonksiyonel eksikliğin hafifletildiğini göstermektedir.

Anahtar sözcükler: Amputasyon; kol yaralanması; replantasyon/yöntem.

Objectives: The aim of this study was to evaluate long-term clinical and functional results of major upper extremity replantations.

Methods: We retrospectively evaluated 26 male patients (mean age 27 years; range 3 to 69 years) who underwent major upper extremity replantations and had a mean follow-up of 11.3 years (range 5 to 19 years). The levels of the replantations were transmetacarpal (n=6), wrist (n=4), forearm (n=5), elbow (n=4), and arm (n=7). Amputations were of clean-cut, crush, and avulsion types in seven, eight, and 11 patients, respectively. Secondary operations were performed in 19 patients. Functional results were assessed using the Chen's criteria and the Turkish version of the DASH questionnaire (Disabilities of the Arm, Shoulder and Hand) was administered.

Results: The mean surgical shortening was 37.2 mm, and the final mean radiographic shortening was 52.2 mm. The mean grip and pinch strengths on the affected side were 12.3 kg and 3.6 kg, compared to the strengths of 37.6 kg and 8.7 kg on the normal side, respectively. Monofilament testing showed sensory recovery in 20 patients. Two-point discrimination could be made by 18 patients for the median nerve, and by 17 patients for the ulnar nerve. According to the Chen's criteria, the results were very good or good in 17 patients (65.4%), moderate in three patients (11.5%), and poor in six patients (23.1%). Functional results were correlated with the level (r=0.71) and type (r=0.65) of injury, with injuries at the elbow level and avulsion injuries being associated with a worse outcome. The mean DASH score was 6.7 (range 0 to 32.5) and the mean scores of Chen's grade I-II and grade III-IV patients differed significantly ($p<0.05$).

Conclusion: Lower DASH scores show increased satisfaction of the patients and improved use of their replanted extremities as the helper arm whereby functional deficiency is somewhat compensated.

Key words: Amputation; arm injuries/surgery; replantation/methods.

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By means of advancement with microsurgical techniques and equipments, functional results of major replantations improved. Developing industry made guillotine type injuries turn into crush and avulsion type injuries which have been reported not suitable for replantations before. Successful replantation rates of today's injuries reported as 90 %.[1-15] Goal of treatment is to obtain a nearly normal functioning extremity with an acceptable cosmetic result. Crush and avulsion type injury classification and treatment results have been reported in different series. [1,4,6-12] Definition of major replantation levels is still a debate.[4]

In our study, long term clinical and functional results of major upper extremity replatations were evaluated with different types and levels of amputations.

Patients and methods

A total of 26 male patients were operated between 1987 and 2003. The mean age was 27 years (range, 3–69 years). All patients were evaluated retrospectively.

Types and levels of amputation injuries are illustrated in Table 1. The dominant hands were injured in 8 cases.

Three forearm fractures, one tendon injury in the palmar region, one finger amputation, and one elbow luxation were detected in amputated parts. Bone fixation of the amputated parts was performed with plating in 13 patients, K-wire fixation in 12 patients, and external fixation in one patient. The mean amount of bone shortening was 37.2 mm. (range: 0-75 mm.) (Figure 1a.)

During the revascularization vein grafts were used for eight arterial reconstruction and for two vein reconstructions, mean ischemia time was 6,5 hours (range: 3-10 hours) (Figure 1b). Forearm fasciotomies were performed totally in seven patients, in five at arm level and in two at the elbow level. Nerve graft reconstruction was required for one patient and it is tried to finish all procedures in the first step. In one patient at the level of the elbow replantation of avulsion amputation had performed arterial reconstruction using vein graft, postoperative vein graft thrombosis required immediate exploration with further revision of the artery. The following secondary operations were carried out as; tenolysis and arthrolysis (n= 6), arthrodesis (n=3), pseudoarthrosis surgery (n=1), tendon transfer (n=7), corrective osteotomy (n=1), flap (n=4), functional muscle transfer for restoration of elbow flexion (n=2) and skin graft (n=14). (Figure 1c, d). The physiotherapy program was applied for all patients.

The final results were assessed at a mean follow-up time of 11.3 years (range 5-19 years). Arm length discrepancy measurements were made on x-rays. All patients were evaluated for vascular patency as determined by Doppler ultrasound. Range of motion of the joints was assessed with the standard goniometry. The grip and pinch strengths of all cases were measured using computerized systems (E-LINK Evaluation & Exercise Systems, Version 6 Software, Biometrics Ltd., Gwent, England). All fingers sensibility evaluated by the static and dynamic two-point discrimination (s2PD and m2PD) and the Semmes-Weinstein (SW) monofilament tests. Cold intolerance, pain, activity of daily life and ability to work were rated subjectively by the patients. Functional results were evaluated using Chen's criteria (22) and DASH-T Scoring system. Statistical analysis performed by use of t test and Sperman's correlation test. All data was analyzed by using SPSS 10 program.

Results

Last X ray examinations showed an average shortening 52.2 mm in operated extremities. Difference with the normal sides were significant statically ($p<0.001$; (Figure 1e). Length discrepancies are grouped in injury levels with Table 2.

Table 1. Injury types and levels

	Transmetacarpal	Wrist	Forearm	Elbow	Arm	*Total*
Clean cut	4	1	2	–	–	7
Crush	2	2	2	–	2	8
Avulsion	–	1	1	4	5	11
Total	6	4	5	4	7	

Figure 1. (a) Bone shortening and operative view of an avulsion type injury in arm level. **(b)** Post operative view. **(c)** Secondary latissimus dorsi muscle transfer for elbow flexion. **(d)** Gained elbow flexion in follow-up. **(e)** Length discrepancy and volumetric loss of operated extremity.

Doppler ultrasound has not shown an aneurysm formation or late thrombosis with the arterial anastomosis. Average volumetric loss of operated side were 70 cm3 and significant ($p<0.001$).

Ranges of joint motions were grouped according to the level of replantations in Table 3. It was noticed that wrist, elbow, forearm and proximal interphalangeal joints were more restricted in elbow level injuries.

Dynamometric mean grip strength was 37.6 kg (range 32-51.7 kg) for normal side and 12.3 kg (range 1.7-28 kg) for the operated side. Pinch mean was 8 kg (range 4.4-11 kg) for normal side and 3.6 kg (range 0.5-7.6 kg) for the operated side.

Re sensibility of median and ulnar nerve was gained in 20 patients with monofilament tests. Two-point discrimination could be made by 18 patients for the median nerve and 17 patients for the ulnar nerve (Figure 2).

Cold intolerance and pain was evaluated as subjectively. None of the patients complained of intolerable margins (Table 4). Twenty three patients were

Table 2. . Injury levels, ages, surgical shortenings and length discrepancy averages with normal sides.

				Average follow up limb lengths	
Injury levels	Patient Number	Average ages when operated	Average surgical shortenings (mm)	Operated (cm)	Normal Side (cm)
Metacarpal	6	29.0	15.0	72.3	73.8
Wrist	4	34.8	32.5	74.7	77.0
Forearm	5	27.2	34.0	69.4	74.8
Elbow	4	27.3	48.8	69.3	74.0
Arm	7	18.7	42.7	70.9	78.2

independent during daily activities of life while 3 patients needed a little support for completing a day. One of them was arm leveled and two were forearm leveled injuries.

Eight patients could return at pre injury occupations. Two of them were wrist level, two were transmetacarpal level, three were arm level, and one was forearm level injuries. Two of the arm level amputations were 3 and 10 years old patients when operated. They were working without complaints as a shoe maker and computer technician. Four patients were able to return their pre injury work levels with some modifications. Eight patients had to change their working status. Three of them were transmetacarpal, two were forearm, one was wrist, and two of them were arm level injuries. Unemployed four patients were grouped as two elbow level, one arm level and the other forearm level injuries. Patients' satisfactions were self evaluated as 1 point (the least) and 5 points (the most). Sixteen patients were most satisfied, while 4 gave 4 points, one gave 3 points, three gave 2 points, and two gave 1 point for satisfaction. Twenty five patients told that they would have had the same operation if they were able to return to the injury date.

According to Chen's criteria eight (30.8%) patients were very good, nine (34.6%) patients were good, three (11.5%) patients were moderate, and six

Table 3. Range of motion averages in replantation levels (°)

	Transmetacarpal	Wrist	Forearm	Elbow	Arm	*Average*
Wrist, elbow and arm						
Wrist flexion	67.5	36.2	51.0	3.3	18.5	38.8
Wrist extension	58.3	15.0	52.5	18.3	47.8	43.0
Elbow	130.8	122.5	119.0	72.5	88.7	109.0
Forearm pronation	88.3	80.0	70.0	5.0	36.8	58.0
Forearm supination	85.8	87.0	76.2	43.0	54.3	69.0
Metocarpophalangeal joint						
1. digit	50.8	25.0	25.0	10.0	10.0	24.6
2. digit	54.0	22.5	23.0	45.0	56.5	41.7
3. digit	71.6	32.5	15.0	55.0	56.4	47.8
4. digit	75.0	25.0	8.3	41.6	52.1	45.0
5. digit	76.6	27.5	15.0	31.6	44.3	43.8
Proximal interphalnageal joint						
1. digit	60.0	48.7	50.0	13.3	17.5	37.8
2. digit	80.0	28.7	68.0	16.6	31.8	46.4
3. digit	58.3	33.7	68.0	20.0	38.1	45.7
4. digit	68.3	57.5	70.0	15.0	44.3	53.1
5. digit	77.0	36.6	64.0	16.0	31.2	46.4

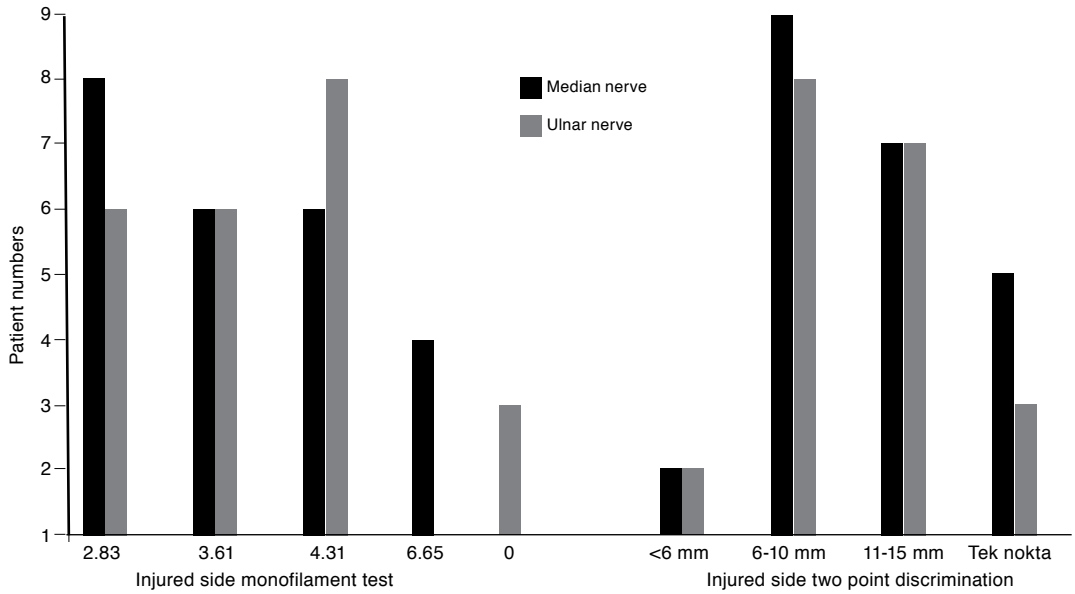

Figure 2. Patient numbers with monofilament and two point discrimination results in median and ulnar nerves.

(23.1%) patients were poor results. Seventeen (65.4%) patient results were functionally good (Table 5).

DASH-T score average was 6.70 (range 0-32.5). Correlation was significant between Chen's criteria and DASH-T scores (r=0.48). Chen I-II groups' DASH-T scores and Chen III-IV groups' DASH-T scores were significantly different ($p<0.05$).

Patients were grouped in injury levels and injury types in Chen's criteria (Table 6). Elbow level injuries and avulsion type injuries were worse prognostic factors. Injury level was correlated (r=0.71) and injury type was correlated (r=0.65) with Chen's criteria.

Discussion

Upper extremity major amputations are life threatening serious injuries. The initial examination of the patient is very important for medical and legal issues. Centers dealing with such injuries should be well equipped and capable of handling these serious cases. The patients' life should have the priority compared to the salvaging of the limb. The overall results were argued when high energy lacerations were treated. Long and tiring treatment protocols brought secondary operations in order to facilitate the functional results. The concept of 'helper arm' found place in the major replantation literature and a stable shoulder joint, active elbow flexion, and a sensate hand became the major aims of surgery.[3,6,7]

Amputations located at the elbow joint had the most limited ROM of all upper extremity amputations because of the disintegration of the elbow joint added to the soft tissue lacerations at this level. Such results were published in the literature.[7,11,12] Chuang et al.[11] proposed a classification system for avulsion amputations and declared that they can predict the functional results of such injuries.

Table 4. Subjective evaluation of cold intolerance and pain

	Cold intolerance	Pain
No	13	20
Little	6	2
Intermediate	6	4
Severe	1	–
Intolerable	–	–

Table 5. Patients groups in Chen's criteria and DASH-T averages.

Chen	Patient no	%	DASH-T score average
I	8	30.8	2.78
II	9	34.6	6.07
III	3	11.5	17.5
IV	6	23.1	7.4

Table 6. Chen groups according to injury levels and injury types

	Injury level						Injury type			
Chen	Transmetacarpal	Wrist	Forearm	Elbow	Arm	*Total*	Clean cut	Crush	Avulsion	*Total*
I	4	2	2	–	–	8	5	3	–	8
II	2	2	2	1	2	9	2	4	3	9
III	–	–	–	–	3	3	–	–	3	3
IV	–	–	1	3	2	6	–	1	5	6
Total	6	4	5	4	7	26	7	8	11	26

In our patient group, bone shortening facilitated the nerve, vessel and soft tissue repairs. This approach decreased the need of grafting for vessel repairs, and revascularization period was kept in minimum, and the complications of multiple anastomosis sites were avoided. The quality of nerve repair was kept in maximum by avoiding grafting and stretching the repaired nerves. Grafting of the nerves and vessels were performed in cases to overcome functional joint losses. The average bone shortening was 37.2 mm at the operation. The final result of 52.2 mm shortening was due to the young age of some patients with growing bones at the time of the injury. The importance and quantity of bone shortening was discussed in the literature. [1-3,8,11]

The importance of ischemia is related to the conditions rather than the time elapsed. The application of proper conditions for preservation of the extremity increased the time limit for revascularization.[13-16] In this study, the mean vascularisation time was 6.5 hours (range 3-10 hours).

In three patients, there was no sensation on the ulnar nerve innervated area when tested with Semmes-Weinstein monofilament test. These patients had long defects on the ulnar nerve which prevented primary or secondary repair. The failures of achieving protective sensation of the median nerve in some patients were due to the location and type of the nerve injury. The results of median and ulnar nerve injuries were assessed as one point sensation in two point discrimination test. Cold intolerance was attributed to revascularization and nerve regeneration.[17-18] In none of our patients, intolerable symptoms were documented subjectively.

When evaluating daily activities, independence of the patients during routine activities were assessed. Only 3 patients declared that they rarely needed help. The extremity, which was replanted as a 'helper arm' had superior results compared to amputation or prosthesis.[6,12,19-21]

Return to work or performing the pre injured tasks is vague in description in our country. The privileges that Turkish Social Security System offers to such patients and the decision to ease at retirement protocols affect the work that these patients perform. Also the characteristics of works that these patients perform before the injury is another important concern. For example, one of our non-working patients was a construction laborer before the injury. Another one was not working before the amputation. Two others were retired due to the incapacity of their arm according to their own will. The marked difference between the satisfaction of the patients and their ability to perform daily activities and the results of returning to work and Chen criteria are due to such cultural and social security privileges that are given to these patients. When evaluating Chen criteria, these patients adversely affect the results. According to Chen scoring system we had very good results in 8 patients (30.8%), good in 9 patients (34.6%), fair in 3 patients (11.5%), and poor in 6 patients (23.1%). The functional result was good in 17 patients (65.4%). Other reports in the literature gave good results as 56% and 82.6% respectively. [3-22]

When our results were evaluated according to the Chen criteria, we noticed that injuries around the elbow joint and avulsion injuries negatively affect the results, as it is reported in the literature. This is the result of the loss of integrity of the elbow joint at the time of injury and avulsion injuries that occurred. [1,4,7,11,12,23]

The average DASH-T score was 6.70 (range 0-32.5) in this study. The results of major replantation surgery are generally evaluated according to the Chen criteria in the literature. We did not find any reports using DASH evaluation system in such inju-

ries in the literature. When the functional results of other upper extremity injuries were assessed using the DASH system, poorer results were reported in less significant injuries compared to amputations. In our study, the correlation between DASH and Chen results, and better DASH-T scores than expected relates to the subjectivity of the evaluation, the dominance of the non-injured extremity, and compensation of the disability of the injured limb with the non injured extremity. The high ranked patient according to the Chen criteria with low DASH-T scores is a good proof that these patients were satisfied with their extremity.

The arguments about functional evaluation of major upper extremity amputation results are still on debate. Although Chen system is the most widely used evaluation system, it gives limited information about the functional results. The DASH evaluation system is not used routinely in the literature, except in few case reports. The low DASH-T scores in patients with at least 5 years of post-op, with an average evaluation of 11.3 years shows that patient satisfaction and the dexterity of the replanted arm as a helper arm is sufficient. We believe that the functional results will be even higher if such reports compare the functional results of these patients with patients having amputated arms or prosthetic arms.

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