Hiroshima Journal of Medical Sciences
Vol. 33, No. 4, 643~648, December, 1984
HIJM 33-90

Long Term Follow Up and Evaluation of Free Muscle Graft in the Upper Extremity*)

Yoshikazu IKUTA, Eiji HATANO and Kaoru YOSHIOKA

Department of Orthopedic Surgery, Hiroshima University School of Medicine, 1-2-3, Kasumi, Minami-ku, Hiroshima 734, Japan

(Received September 13, 1984)

Key words: Free Muscle Graft, Microsurgery

ABSTRUCT

A summary of the experimental and clinical evaluation of the long follow up cases which we have been doing from the past 8 years is reported.

In experimental study, it was demonstrated that in the muscle graft which includes vessel and nerve anastomoses, the recovery of muscular power can be achieved up to 60 to 80% to that of normal, and thus its application in treatment of Volkmann's contracture and paralysis of brachial plexus has been increased.

In clinical study, our conclusion is based on evaluation of the 5 successful cases in whom it was possible to make follow up examination for more than 2 years after operation. On clinical examinations, the contraction power of the grafted muscle were regained 30 to 75% to that of normal; the total active motion of the fingers was increased on the average by 60 to 90%, the grasping power for large objects increased much and it was used well in daily activities. However, as the fine delicate motion was not possible to achieve, this procedure is only one segment in the overall treatment of dysfunction of the limb. But it is felt that the procedure should be highly evaluated as a means for restoration of motion in those cases where all the measures had totaly failed in the past.

INTRODUCTION

After report of free flap transfer, many different types of free tissue grafts are attempted and applied to clinical field. Almost all of them are quite important for reconstruction of severely injured limb, but there is no such attractive procedure as free muscle graft to restore the motor function of the upper limb. I would like to report a summary of the experimental and one of our clinical case to clarify the surgical procedures and clinical evaluation of the long follow up cases which I have been doing from the past 8 years.

Experimental Study

The first attempt of free muscle graft in the world was reported by Zielonko (1874), a Russian pathologist in Strassbourg, who grafted the femoral muscle of a frog to a lymph sac, but this ended in failure. Later many others carried out experiments using muscles of dogs, rabbits and chicken, but none of the efforts were successful. However, Hildebrachd (1906) in his experiment observed that part of the grafted muscle along the edges had not become necrotic, and Studitsky (1964), and others succeeded in muscle graft by using thin sections of muscle.

Experimental success of free muscle graft using microsurgical techniques were reported by Tamai[13] and Kubo[7], and its clinical application were made by Chinese group[11], Harii[1] and Ikuta[4]. Subsequently, Terzis[13] carried out tests to determine the degree of functional restoration of the grafted muscle using the rectus femoris muscle of rabbits, and reported that at best only 1/4 of the original muscle power could be regained, but on the basis of our clinical experience, we feel that the muscle power recovery is better than her experimental

*) 生田義和，畑野栄治，吉岡　薫：上肢における遊離筋肉移植の長期観察と評価

results. As there were many other questionable points, we repeated the experiment from the begining, and attained definite answer to the following points. That is 1) the possibility of survival by the free graft procedure as performed by Thompson[14], 2)denervation of grafted muscle and changes during course of regeneration, 3) changes in motor end plate during the course of reinnervation, 4) relationship between tension of the grafted muscle and restoration of muscular power and 5) effects of low frequency stimulation on denervated muscle.

The anterior tibial muscle of a rat and rectus femoris muscle of a rabbit were used to prepare the experimental model. The Thompson's technique lacks reliability because it was sectioned traversely in the middle of the muscle belly, so, it could not be applied clinically, but it was found that there were several layers of muscle along the margin which had not become necrotic. Further, it was noted that when thce middle of the long muscle fibers were transected, the distal portion became necrotic, but there was little effect upon the proximal portion. The observation on the effect of denervation using only the wet weight of muscle as the index revealed that the weight decreased to 20% of the normal within 10 weeks after nerve severing, while on the other hand, in muscles where the nerve had been sutured although the weight dereased once to 40% of the normal within 5 weeks after surgery and it was restored to 80% on the 10th week[15]. Interesting findings regarding changes in distribution of red, white and intermediate muscles were observed during this time by staining for succinic dehydrogenase[3]. Also the methods of observation for changes in the distribution of muscle fibers changed from manual operation to computer by graphic pen, and by changing the method of analysis, it became possible to express the degree of reinnervation digitally[2]. It is felt this will become a useful means for evaluating postoperative regeneration and recovery.

Normal end plates as can be seen by Wachstein stain which are round or ellipse, and a synaptic fold can be observed inside the edges distinctly and the stainability is good. But when there is denervation, deformation and disruption, the indistinctness and disappearance of the synaptic fold occurs and stainability decreases. These changes are most prominent at 3 weeks after surgery[3].

Study of the relationship between tension of the grafted muscle and recovery of muscular power showed that due to the nature of the experimental model, hypertonic muscles could not be achieved, and only the effects of reduced tension could be observed. Temporarily the muscular atrophy occurs, but ultimately there is no difference from the normal tension group. It is felt that there is no need to be over concerned clinically. However, ideally it would be better to arrange the limb position by adjusting the joint so that the grafted muscle would have normal tension. It was found at the last that the effects of low frequency stimulation on denervated muscle showed progression of atrophy which was delayed for about one week when compared with unstimulated muscle.

In summary, it was demonstrated experimentally that in the muscle graft which includes vessel and nerve anastomoses, the recovery of mucular power can be achieved up to 60 to 80% to that of normal, and thus its application in treatment of Volkmann's contracture[6,8] and paralysis of brachial plexus has been increased[5]. Morever the advancement of knowledge about haemodynamics between muscle and skin, gives a possibity of clinical use of musculo-cutaneous free graft[9,10].

CLINICAL STUDY

On the basis of experimental results using the rectus femoris muscle of dogs, it was deemed that the clinical application of free muscle graft would be possible, and on May 23, 1975 the proceduse was performed by me for the first time on Volkmann's contracture. I would like to report a case of free musculo-cutanecous flap transfer in this paper and to discuss the general concepts of this procedurs.

A CASE REPORT

A 11-year-old boy who fell down on his left elbow when he was playing baseball game. The left upper limb was immobilized with a plaster slab by a near local doctor with a diagnosis of supracondylar fracture. As three days after injury, the patient conplained sensory and motor disturbance of his left hand, open reduction was done 4 days after injury.

The patient was referred to our clinic because the movement and sensation of the left hand

and digits did not change 3 months after injury but the fracture site has united completely. His left hand showed a typical Volkmann's ischemic contracture, that is, the sensory disturbance of median and ulnar nerve teritories with claw deformity of all fingers and the thumb in reposition.

Since the significant recovery could not be seen in 5 months by conservative treatments, the muscle release and neurolysis was carried out 6th month after injury. This surgery was effective for the sensory recovery of the hand and digits and also the intrinsic muscles regained its function, but there was no change of the extrinsic flexor muscles power. All MP joints can be flexed by intrinsic muscle power but active flexion of PIP and DIP joints were impossible (Fig. 1). To reconstruct the

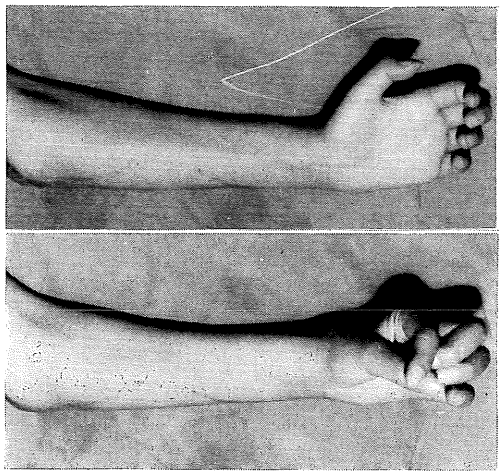

Fig. 1. Preoperative findings. Typical claw deformity and intrinsic muscle atrophy can be seen. Active movement of MP joints is possible but movement of IP joints is impossible. Sensory of the hand and digits is recovered to almost normal by neurolysis which was performed 6 months ago.

powerful flexion of digits, a muscle graft was carried out at 1 year after injury.

Using the zig-zag skin incision just like as the previous procedure, the left forearm was opened and all scared sublimis and profundus muscles were resected out.

The palmaris longus muscle was transfered to the extensor pollicis longus which was functioning for opposition of the thumb. The procedures such as tendon graft, tendon transfer,

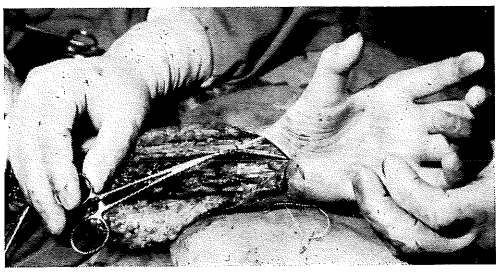

Fig. 2. Palmaris longus muscle was transfered to the extensor pollicis longus to reconstruct opposition of the thumb.

tenodesis are essential manuever to reconstruct total function of the Volkmann's contracture (Fig. 2).

The ulnar artery with concomit ant veins and anterior interosseous nerve, that is a motor branch of the median nerve, were isolated for anastomosis with a neurovascular bundle of the muscle graft. After preparation of the r-cipient site, the left gracilis muscle was taken as the following procedures. At first, a skin incision of 5 cm length on the medial side and just proximal to the left knee joint and the another skin incision of 3 cm length slightly distal to the pubic symphysis were given and then the proximal and distal portions of the gracilis muscle were exposed. Pulling these two ends with strings, the location of the muscle and overlying skin were cofirmed and a shape of the flap was drawn on the skin (Fig. 3). After measuring the length of the muscle which is needed for the recipient site, exactly the same length of gracilis muscle combined with over-

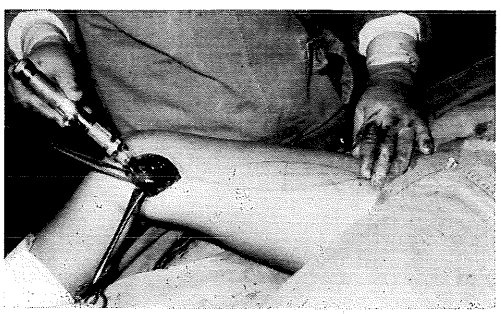

Fig. 3. The insertion of right gracilis muscle was identified by a small skin incision on the medial side of the knee joint. Then, the direction of the muscle and the overlying skin flap was designed by pulling the muscle insertion and stimulating with electric stimulator.

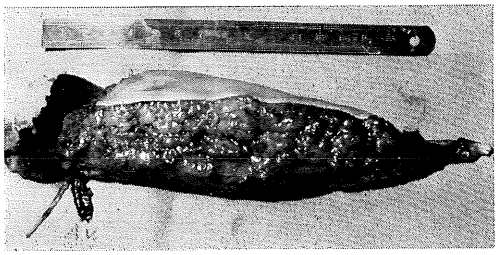

Fig. 4. The right gracilis muscle with skin flap of 16×4 cm was taken out. A neuro-vascluar bundle can be seen on the left side. The constricted muscle length was about 19 cm in length.

lying skin flap was isolated and taken out preserving a neurovascular bundle (Fig. 4). The muscle graft was not too long nor too short because the tension of the muscle was quite important for functional recovery. This was cofirmed by our experimental study.

At the recipient site, after fixing of the proximal end of the gracilis muscle to the medial epicondyle, the motor nerve and vessels of the gracilis muscle were anastomosed to anterior interosseous nerve and ulnar artery and the two concomitant veins under a microscope (Fig. 5). General speaking, the order of suturing is the artery first then veins and followed by nerve suture. When the special double vascular

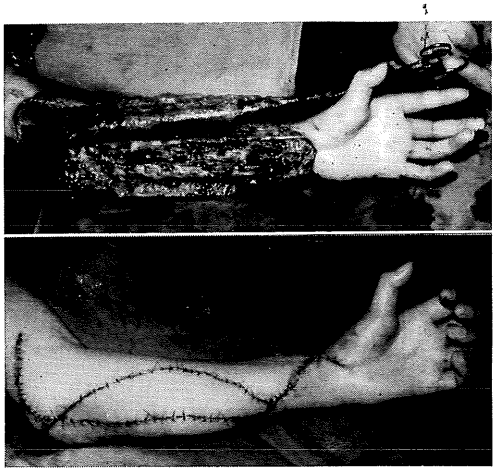

Fig. 5. The proximal edge of the muscle was fixed to the medial epicondyle and anastomoses of neuro-vascular bundle were performed. After that, the distal end of the grafted muscle were sutured with all flexor profundus tendons (above). Findings just after skin closure. The elbow joint is slightly in flexed position and all fingers are in funcional position.

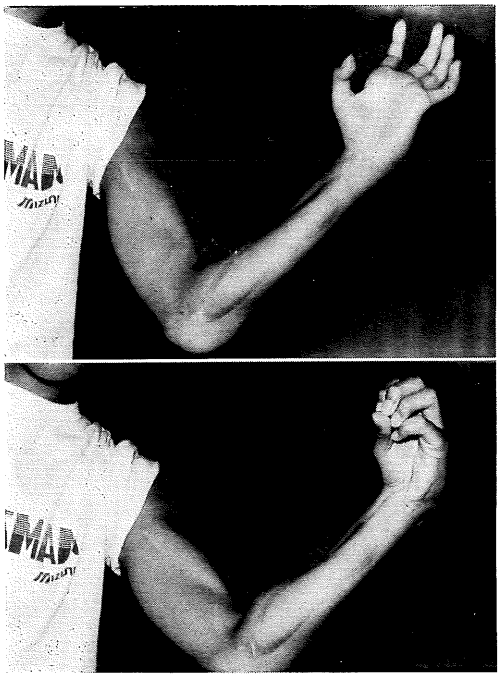

Fig. 6. Post-operative findings about one and half year. The movement of the elbow joint is almost normal and powerful extension and flexion of all fingers are possible. Contraction of the grafted muscle can be palpated and seen in the forearm.

clamp which I developed is used to stabilize the vessel, the artery and concomitant veins can be clamped together which is shown in Fig. 6, the anterior wall of artery and veins are sutured first, and then the clamp is turned over, and the posterior walls are sutured. This method has two advantages, 1) there is no need to isolate three vessels separately from each other and 2) to consume the time for clamping the vessels three times. Then, the distal stump of the gracilis muscle was sutured to the flexor digitorum tendons of the four fingers under normal tension.

Circulation of the flap was very good and it took up completely. The skin flap of the musculo-cutaneous flap is used as a good monitor of the circulation of the grafted muscle. The active flexion of all fingers were possible after the 5th month of this surgery. Figure 7 shows the state one year and 6 months postoperatively.

During the past 8 years period till 1984 we have performed 10 cases (8 males and 2 females) of free muscle graft whose ages ranged from 6 to 21 years (a mean of 12). The conditions

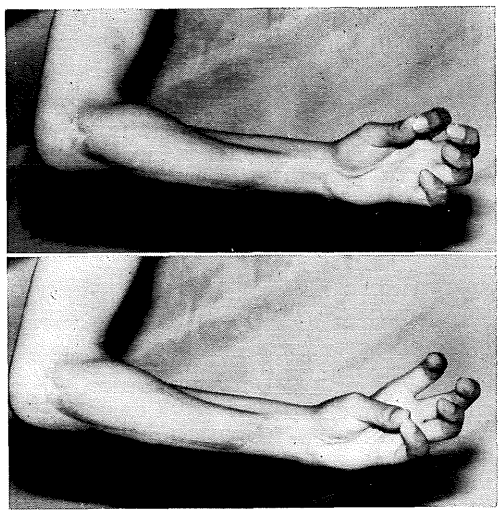

Fig. 7. Powerful opposion of the thumb and pich with all fingers are possible.

for which the operation was performed were Volkmann's contracture 7, polio 2 and old traumatic brachial plexus paralysis 1. All the 8 traumatic cases underwent multiple operations for functional reconstruction such as fasciectomy, necrotomy, neurolysis and tendon transfer, but still residual motor disturbance persisted. The purpose of functional reconstruction was the flexion of elbow in 2 polio and 1 brachial plexus palsy cases, while for others it was the flexion of fingers. Therefore, in the former three cases the grafted muscle was positioned parallel to the biceps muscle of the arm and the proximal and distal ends were sutured with biceps, while the intercostal nerve was transfered to serve as the motor nerve. In the latter cases, proximal part of the muscle graft was sutured to the medial condlyle of the humerus on the flexor aspect, and the distal part was sutured to the flexor digitorm profundus tendon of all five digits in 4 cases; to the same tendon of the four fingers in 2 cases; and to flexor pollicis longus muscle in one case, while for the motor nerve functions the anterior interosseous nerve or nerve bundle considered to be the motor branch of the median nerve was used. In general, one artery and 2 veins were anastomosed under the microscope.

The muscles used for grafting were the pectralis major muscle in 1 case, semitendinosus muscle in 1 case and gracilis muscle in 8 cases. It was important that the muscle to be taken should not cause any residual deformity or motor disturbance in any patients after excision, and also due consideration was given to the postsurgical cosmetic appearance. After the experimental introduction of muscle-skin flap or musclo-cutaneous flap it was used clinically in 1979. I used in 5 out of 6 cases, that is, the gracilis muscle flap was grafted in 4 cases and the semitendinosus muscle flap in 1 case.

The 8 cases in whom strong spontaneous flexion could be achieved after surgery were considered successful cases, while in 2 in whom we could not achieve enough muscle power were considered failure cases. The latter 2 were polio cases.

Practically, in all of the successful cases, the signs of recovery in the grafted muscle began to appear on electromyograms after 2 to 5 months, and following 6 to 7 months, spontaneous contraction could be observed macroscopically in our cases. As no signs of recovery were seen during 6 months after surgery in 1 case of Volkmann's contracture of the forearm, the nerve suture site was excised after the 8th month and cable nerve graft was done (Case 2).

Our conclusion is based on evaluation of the 5 successful cases in whom it was possible to make follow up examination for more than 2 years after operation. On clinical examinations, the contraction power of the grafted muscle was regained 30 to 75% to that of normal; the total active motion of the fingers was increased on the average by 60 to 90%, the grasping power for large objects inceased much and it was used well in daily activities. However, as the fine delicate motion was not possible to achieve, it necessitated the patient to switch over on the dominant hand. Further, in another case of brachial plexus palsy (Case 3), the limb could hardly be used because of instability of the shoulder joint and disturbance of sensation in the fingers, which indicates that this procedure is only one segment in the overall treatment of dysfunction of the limb. However, it is felt that the procedure should be highly evaluated as a means for restoration of motion in those cases where all the measures had totaly failed in the past.

REFERENCES

1. **Harii, K., Ohmori, K. and Torii, S.** 1976. Free gracilis muscle transplantation with microneuro-

vascular anastomoses for the treatment of facial paralysis. A preliminary report. Plast. and Reconstr. Surg. 57 : 133-143.

2. **Hatano, E., Arita, S., Hori, Y., Miyamoto, Y., Tsuge, K., Ikuta, Y., Yoshioka, K. and Hiramatsu, N.** 1981. Application of computer system to analysis of muscle morphology. Sogo Rehabiriteshon 9 : 805-810.
3. **Hatano, E., Tsuge, K., Ikuta, Y., Miyamoto, Y., Yoshioka, K. and Hiramatsu, N.** 1981. Denervated changes in muscle fibers and motor end-plates. Hiroshima J. Med. Sci. 30 : 293-299.
4. **Ikuta, Y., Kubo, T. and Tsuge, K.** 1976. Free muscle transplantation by microsurgical technique to treat severe Volkmann's contracture. Plast. and Reconstr. Surg. 58 : 407-411.
5. **Ikuta, Y., Yoshioka, K. and Tsuge, K.** 1979. Free muscle grafts as applied to brachial plexus injury-case report and experimental study. Ann. Acad. Med. 8 : 454-458.
6. **Ikuta, Y., Hatano, E. and Yoshioka, K.** 1984. Free muscle graft: clinical and experimental studies. Symposium on fronties in reconstructive microsurgery. p. 315-329, St. Louis, C. V. Mosby.
7. **Kubo, T., Ikuta, Y. and Tsuge, K.** 1976. Free muscle transplantation in dogs by microneurovascular anastomoses. Plast. and Reconstr. Surg. 57 : 495-501.
8. **Manktelow, R. T. and Mckee, N. H.** 1978. Free muscle transplantation to provide active finger flexion. Jr. Hand Surg. 3 : 416-426.
9. **Maxwell, G. P., Stueber, K. and Hoopes, J. E.** 1978. A free latissimus dorsi myocutaneous flap. Case report. Plast. and Reconstr. Surg. 62 : 462-466.
10. **Schenck. R. R.** 1978. Rectus femoris muscle and composite skin transplantation by microneurovascular anastomoses for avulsion of forearm muscles. Aa case rese report. J. Hand Surg. 3 : 60-69.
11. **Six Peoples Hospital, Microvascular service, Shanghai.** 1976. Free muscle transplantation by microsurgical neurovascular anastomoses. Chinese Med. Jr. 2 : 47-50.
12. **Tamai, S., Komatsu, S., Sakamoto, H.,** Sano, **S., Sasauchi, N., Hori, Y., Tatsumi, Y. and Okuda, H.** 1970. Free muscle transplants in dogs, with microsurgaical neurovascular anastomoses. Plast. and Reconster. Surg. 46 : 219-225.
13. **Terzis, J. K., Sweet, R. C., Dykes, R. W. and Williams, H. B.** 1978. Recovery of function in free muscle transplants using microneurovascular anastomoses. Jr. Hand Surg. 3 : 37-59.
14. **Thompson, N.** 1971. Autogenous free grafts of skeletal muscle; A preliminary experimental and clinical study. Plast. Reconstr. Surg. 48 : 11-27.
15. **Yoshioka, K.** 1984. Experimental and clinical studies on results of free muscle transplantation. Hiroshima M. J. 32 : 785-825.