Eur J Plast Surg (2001) 24:12–17
DOI 10.1007/s002380000219

ORIGINAL PAPER

B.E. Impelmans · J. Miles · F.D. Burke

The use of free fat grafts in recalcitrant carpal tunnel: a retrospective study

Received: 27 January 2000 / Accepted: 14 March 2000 / Published online: 2 February 2001

Abstract We present a retrospective study evaluating the proclaimed beneficial effect of the use of fat grafts in patients with recalcitrant carpal tunnel syndrome. Twenty-one re-decompression operations with fat grafting (group I) and 20 routine re-decompressions (group II) were assessed postoperatively with a questionnaire, physical examination, and nerve conduction studies. Both groups were improved by the operative intervention, but no significant differences were found between the two surgical techniques for postoperative severity of symptoms, threshold sensation, pain assessment, nerve conduction velocities, or patients' satisfaction with the postoperative result. Only the postoperative functional status score of the fat grafted patients revealed a trend to a significantly worse outcome. The fat grafted patients sustained more problems with a hypersensitive scar at the wrist level immediately after surgery, although on long-term review there was no significant difference in scar tenderness between the two groups. We concluded that implantation of free fat grafts has not proved to be of additional benefit in patients with recalcitrant carpal tunnel syndrome.

Keywords Recalcitrant carpal tunnel syndrome · Re-decompression · Free fat graft · Postoperative results

Introduction

Recalcitrant carpal tunnel syndrome after carpal tunnel decompression is a well-recognized problem. The incidence in the literature varies between 1.7 and 20% [10, 16,19]. According to Cobb and Amadio [5], 0.3–3% of the primary decompressed patients will need a re-decompression operation. The predominant causes of recalcitrant symptoms are incomplete sectioning of the flexor retinaculum [5, 6, 17, 19,27], reformation of the flexor retinaculum [23], tenosynovitis of the flexor tendons [19, 35,39], more proximal or secondary neuropathies [5, 10,23], and fibrous proliferation within the carpal tunnel [19, 35,39].

Fibrous proliferation creates adhesions between the epineurium of the median nerve and the surrounding tissues, predominantly the flexor tendon synovial lining or the edges of the divided flexor retinaculum [10, 11, 28,39]. The median nerve glides an average of 14.5 mm (range 11–17 mm) within the carpal tunnel during normal wrist flexion/extension [36]. Nerve excursion through the carpal canal will be inhibited by fibrous proliferation resulting in a longitudinal traction force [36]. This force disturbs the intraneural and extraneural microcirculation, causing ischemic damage [22]. Additionally, the diffusion properties of the perineurium are disturbed, after which proteins enter the fascicles producing intrafascicular edema which leads to fibrosis [8].

A variety of techniques to restore the movement of the median nerve have been reported. Several muscle flaps have been developed, the abductor digiti minimi muscle flap [23,33], the pronator quadratus muscle flap [23], the palmaris brevis flap, preferred by Rose [29], and the lumbrical muscle flap of Koncilia et al. [15]. Other techniques include the reverse radial artery fascial flap [35], the synovial flap recommended by Wulle [39], and reconstruction of the transverse carpal ligament, as described by Hunter [11]. Fat as an interposing material has been advocated by Eden and Rehn [7]; they recommended a free fat graft around traumatized nerves. Plancher [28] used a hypothenar fat pad flap, whilst McClinton [24] suggested a dermal fat graft for patients with recalcitrant carpal tunnel syndrome.

Fat grafting can be considered to be of benefit in two ways. The graft can reduce the risk of adhesive neuritis by interposing fat between the posterior surface of the retinaculum and the median nerve. The graft can also act as a spacer that maintains maximum volume in the car-

An invited commentary to this paper is available at http://dx.doi.org/10.1007/s002380000220

F.D. Burke (✉) · B.E. Impelmans · J. Miles
Pulvertaft Hand Surgery Centre, Derbyshire Royal Infirmary, Derby DE1 2QY, United Kingdom
Tel.: +44-1332-3471412363, Fax: +44-1332-254638

pal tunnel. The free fat graft is known to slowly reduce in size thereafter, thus ensuring a generous carpal tunnel with minimal risk of subsequent compression.

We retrospectively compared the effects of the routine re-decompression operation with additional implantation of free fat grafts associated with the routine re-decompression operation in patients with recalcitrant carpal tunnel syndrome.

Patients and methods

Patients

Between January 1990 and March 1998, 42 patients were operated on for recalcitrant carpal tunnel syndrome with a re-decompression and free fat graft, and 35 patients with routine re-decompression alone. All these patients were invited to visit a special research clinic for an assessment. Twenty-one patients treated with a free fat graft transplantation (group I) and 20 patients treated with the routine re-decompression operation (re-decompression and external neurolysis) for recalcitrant carpal tunnel syndrome (group II) responded.

The 21 patients (19 female, two male) in group I had 23 median nerves surrounded with an autologous fat graft (two bilateral, 19 unilateral) in addition to the routine decompression procedure. In the bilateral operated patients, only one side was included by randomization to avoid interference with the outcome. In this group 12 patients were unemployed, housewives or retired at the time of operation, one did office work, seven performed light manual labor, and one patient did heavy manual labor. The average age at the time of operation was 47.1 years (range 18–80 years). The average number of previous carpal tunnel release operations in group I was 1.3 per carpal tunnel. The mean time of follow-up was 36.1 months (range 2–100 months).

The 20 patients in group II (16 female, four male) had 21 carpal tunnels re-decompressed with the routine procedure (one bilateral, 19 unilateral). In the bilateral cases, only one side was randomly included to avoid interference with outcome. The average age at the time of the operation was 51.2 years (range 37–78 years). In group II, preoperatively eight patients were unemployed, housewives or retired, five performed office work, six light manual labor, and one heavy manual labor. The average number of previous carpal tunnel release operations in group II was 1.0 per carpal tunnel. Mean time of follow-up was 39.8 months (range 6–101 months).

Methods

Patients of both groups were assessed in a special research clinic. A questionnaire was given to all patients; it contained questions on general health and satisfaction with the outcome of operation (1=completely satisfied; 2=very satisfied; 3=somewhat satisfied; 4=unsatisfied; 5=very unsatisfied). Pain was assessed on a Visual Analogue Scale (10.0 cm). A standardized questionnaire [20] was used to determine the patients' Symptom Severity Scale (1=normal; 2=mild; 3=moderate; 4=severe; 5=very severe) and Functional Status Scale (1=normal; 2=mild; 3=moderate; 4=severe; 5=very severe) [20]. The preoperative Symptom Severity Scale (SSS), Functional Status Scale (FSS) and pain assessment (VAS) were retrospectively determined during the assessment. The postoperative physical parameters measured included: threshold sensation with the Semmes-Weinstein monofilament test, Phalen's test, Tinel's test, grip strength (JAMAR 2nd slot), lateral pinch strength (JAMAR pinch meter) and nerve conduction velocities of the median nerve at wrist level (0=unreliable/not done; 1=normal; 2=mildly reduced; 3=markedly reduced; 4=severely reduced). Preoperative and perioperative data were obtained from the patients' health record.

All data were statistically evaluated with one-way ANOVA (Analysis of Variance), adjusting for preoperative data in the postoperative Symptom Severity Scale, Functional Status Scale and nerve conduction velocities. Three patients of group I also underwent an MRI scan (T1). Two patients were respectively 2 months and 2.5 years postoperative, and one patient with bilateral fat grafts was 9 months (right hand) and 4.2 years (left hand) postoperative.

Surgical technique

The carpal tunnel release operation with implantation of an autologous free fat graft was usually carried out under general anaesthetic (17 cases) or (in four cases) local block. The routine re-decompression was done under a local block in half of the patients, the remainder under general anaesthesia. An extended incision was made incorporating the scar of the previous surgery. The median nerve was exposed from the lower forearm to the palm (Fig. 1 a). If there was evidence of scarring between the median nerve and the surrounding carpal tunnel, these adhesions were released.

The graft was predominantly taken from the medial side of the proximal forearm (12 patients) or the distal upper arm (four patients). In patients with an insufficient amount of fat in the arm, the fat was taken from the groin (four patients). A single patient had the fat graft taken from the lateral aspect of her right proximal lower leg. A straight skin incision of approximately 5 cm was made at the donor site reaching the level of subcutaneous fat, the wound was opened with skin retractors so that subcutaneous fat was exposed and a strip of approximately 5×2×1 cm was removed with a scalpel (Fig. 1b). Directly after harvesting, the fat graft was longitudinally incised (partial thickness) and placed under the median nerve allowing the nerve to sink into the trough of the graft (Fig. 1c). The two edges of the remains of the divided retinaculum were placed over the fat graft and both skin incisions were closed with #4–0 nylon (Fig. 1d). The skin edges of the incisions were infiltrated with 5 ml 1% Lidocaine to provide postoperative pain relief.

The wounds were covered with Vaseline impregnated gauze, a bulky dressing and a bandage. The wrists were immobilized by a volar slab for 10 days. After removal of the plaster the patients were allowed to gradually start using the hand, but were advised not to do heavy lifting for 6 weeks. The sutures were removed after 3 weeks in the case of the fat graft, because of the extra tissue bulk in the carpal tunnel.

The routine re-decompressions were simply dressed in crepe and cotton wool at the outset and sutures were removed at 10–14 days. In our study, eight fat grafted patients needed postoperative physiotherapy and four required desensitization therapy to the scar of the wrist. Eight routine re-decompressed patients required physiotherapy and three required treatment for a hypersensitive scar.

Results

The mean preoperative Symptom Severity Scale of group I was 3.7 (± 0.2) and in the routinely re-decompressed patients 3.3 (± 0.2). The preoperative symptoms of carpal tunnel syndrome in the fat implanted patients were significantly worse than those that were simply re-decompressed ($P<0.05$).

The assessed results are summarised in Table 1. The Functional Status Scale visualises a trend to a significantly worse functional status postoperatively in the fat implanted patients (group I) ($P<0.1$). All the other variables reveal no significant difference in outcome between group I and group II ($P>0.1$). Changes in grip strength, lateral pinch strength, Phalen's test and Tinel's test could not be evaluated, because insufficient preoper-

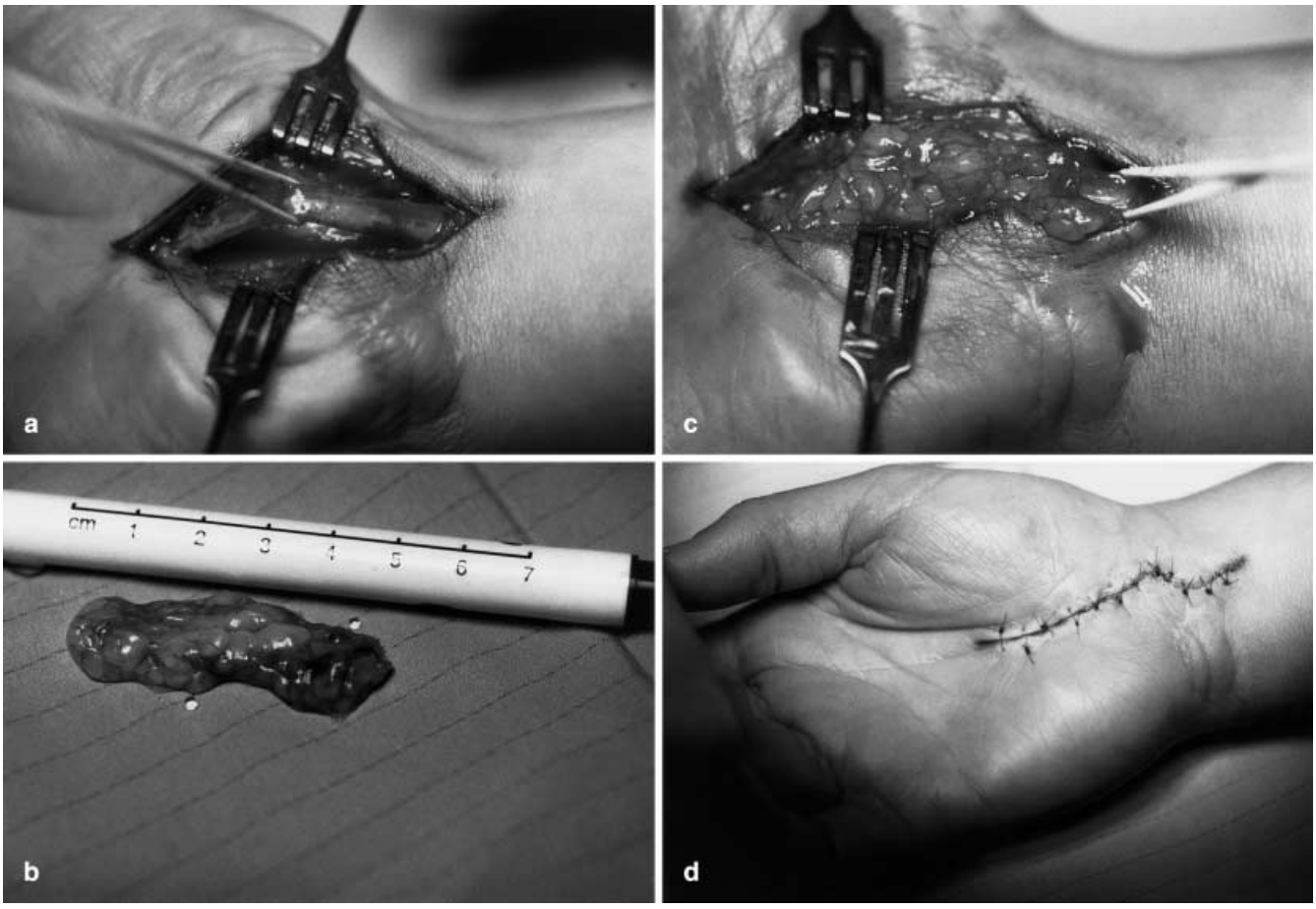

Fig. 1 **a** Exposed median nerve in the carpal tunnel. **b** Resected fat graft of approximately 2×5×1 cm. An incision (partial thickness) was made along the long axis of the graft. **c** The positioned graft in the carpal tunnel; the graft was first placed under the median nerve with the incised side towards the median nerve, thereafter the median nerve was embedded in the incision and the two side flaps were used to cover the palmar aspect of the nerve. **d** Final result of the operation after closure

ative data was available. The postoperative results of the Phalen's and Tinel's test are displayed in Table 2. Twenty of 21 fat grafted patients have a positive Phalen's and ten have a positive Tinel's test postoperatively.

The complications after surgery are summarised in Table 3. There is no significant difference in scar pain at the wrist level between group I and group II ($P>0.1$).

Overall there is no significant difference in patient satisfaction with the outcome of surgery between group I and group II ($P>0.1$).

Table 1 Postoperative results of fat grafted median nerves (group I) and routine re-decompressed carpal tunnels (group II)

Variable[a]	Group I Fat graft Mean±SE	Group II Routine re-decompressed Mean±SE	F	Df	*P*-value
SSS[b]	2.5±0.2	2.3±0.2	0.652	1	NS
FSS[b]	3.0±0.2	2.6±0.2	3.259	1	<0.1
Threshold sensation	3.0±0.3	2.2±0.3	2.687	1	NS
(SW test),[d] pain assessment in cm	–2.2±0.7	–2.7±0.7	0.333	1	NS
(VAS)[e] NCV[b,c]	1.9±0.2	1.8±0.2	0.264	1	NS
Scar pain to palm	2.3±0.2	1.9±0.2	2.160	1	NS
Satisfaction	2.8±0.3	3.0±0.3	0.294	1	NS

[a] All variables in group I, *n=21* (mean±SE); group II, *n=20* (mean±SE)
[b] Symptom Severity Scale (SSS), Functional Status Scale (FSS) and nerve conduction velocities (NCV) are adjusted for preoperative values
[c] Goup I, *n=19*; group II, *n=16*
[d] Semmes-Weinstein monofilament test
[e] Visual Analogue Scale

Table 2 Postoperative Phalen's and Tinel's test (*n*=41)

Test	Group I Fat graft *(n=21)*		Group II Routine re-decompressed (*n=20)*	
	Positive	Negative	Positive	Negative
Phalen's test	20	1	16	4
Tinel's test	10	11	8	12

Table 3 Complications in fat grafted and routine re-decompressed patients *(n=41)*

Complication	Group I Fat graft *(n=21)*	Group II Routine re-decompressed *(n=20)*
None	11	17
Superficial infection	3	2
Hypersensitive scar	7	1

Table 4 Results of different variables in groups I and II separated on temprorary improved and persistent symptoms after previous surgery

Variable	Group I Fat graft		Group II Routine re-decompressed		F	Df	*P* value
	Recurrent (*n*=8) Mean±SE	Persistent (*n*=13) Mean±SE	Recurrent (*n*=9) Mean±SE	Persistent (*n*=11) Mean±SE			
SSS[a]	2.4±0.3	2.6±0.3	1.9±0.3	2.6±0.3	1.553	3	NS
FSS[a]	3.1±0.2	2.9±0.2	2.4±0.2	2.9±0.2	2.221	3	NS
Threshold sensation	3.1±0.5	2.9±0.4	2.0±0.5	2.4±0.5	1.1015	3	NS
(SW-test)[c]							
Pain assessment in cm	–2.1±1.0	–2.2±0.8	–4.5±1.0	–1.3±0.9	2.121	3	NS
(VAS)[d]							
NCV[a,b]	1.6±0.2	2.2±0.2	2.1±0.2	1.6±0.2	2.142	3	NS
Scar pain palm	2.4±0.4	2.3±0.3	1.7±0.4	2.0±0.3	0.858	3	NS
Satisfaction	2.9±0.4	2.8±0.3	2.4±0.4	3.5±0.3	1.531	3	NS

[a] Symptom Severity Scale (SSS), Functional Status Scale (FSS) and nerve conduction velocities (NCV) are adjusted for preoperative values
[b] Group I recurrent *n*=7; group I persistent *n*=12; group II recurrent *n*=8; group II persietnet *n*=8
[c] Semmes-Weinstein monofilament test
[d] Visual Analogue Scale

Both groups consisted of patients with persistent and recurrent symptoms. Patients were defined as having recurrent symptoms if the period of temporary relief, occurring after previous decompression, was equal to or longer than 3 months. The results for subdividing into four groups are summarized in Table 4. No significant difference was found after subdividing into persistent and recurrent carpal tunnel syndrome.

Radiographic results

We were able to review the radiographic appearances of the fat grafts in three patients who had been operated on 2 months (Fig. 2 a), 9 months (Fig. 2b(R)), 2.5 years (Fig. 2c), and 4.2 years (Fig. 2b(L)) previously.

In general, the volume of the fat graft appears to diminish with the passage of time. The amount of fat graft in Fig. 2b(L) is less than in Fig. 2a. On the dorsal aspect of the median nerve in Fig. 2b(R) adhesions are visible between the epineurium of the median nerve and the flexor tendon sheaths (Fig. 2b(R)).

Discussion

Fat transplantation, as an option in various forms of surgery has been an issue since the last century. It has been used for filling facial depressions [25, 26,34] and to restore the contour of breasts [26,38]. It also has been used to stem haemorrhage in abdominal surgery [21], to fill bony defects [7], and to repair a mucosal defect of the urethra [7].

Fat transplantation has been used to prevent heterotopic bone formation (for example in temporomandibular joint replacement [37]). It was used to stem haemorrhage in the epidural space, thereby preventing scar tissue formation after laminectomy [1, 3,18]. Others have mentioned the use of fat grafts around tendons and nerves again to prevent scar tissue formation [7, 24,26].

A persistent disadvantage of free fat grafts is the tendency to resorb. Gurney [9] found that two-thirds of the fat graft resorbed in rats after autologous fat transplantations. In humans, the survival rate of the fat graft is considered to be between 30 and 50% [1, 3, 4, 26,32]. There are two views on the survival of fat grafts [2,26]. The first, "host replacement theory", postulates that none of the transplanted adipocytes survive and that the graft is

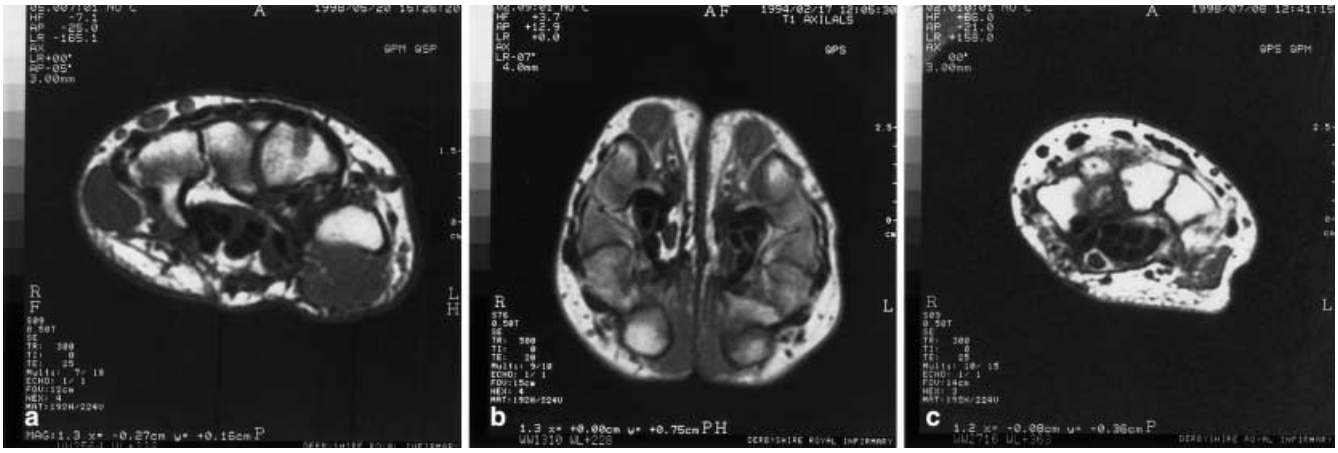

Fig. 2 **a** The fat graft (2 months postoperative) is visible on the volar/ulnar aspect of the median nerve and on the superficial flexor tendons. The fat graft has slipped off the median nerve, causing an area of potential adhesion (between the flexor tendon sheath and the epineurium) which is not protected by interposed fat. **b** *Right*: The fat graft (9 months postoperative) is surrounding approximately 80% of the median nerve, except (as in **a**) in the area the flexor tendon sheath/synovial lining. The graft is diminished in volume and adhesions are visible on the unprotected side of the median nerve. *Left*: 4.2 years postoperative the fat graft is almost completely resorbed and adhesions are visible between the whole epineurium of the median nerve and the surrounding tissues **c** 2.5 years postoperatively the reduced fat graft is visible surrounding the median nerve. The dorsal side of the median nerve is still protected by the fat graft

replaced by histiocytes. The second, "fat survival theory", states that only part of the transplanted adipocytes necrose and the residue forms the remaining graft. The fat survival theory is the more widely supported [2, 4, 9, 26,30].

The fat graft resorption is the consequence of a number of histological changes that occur in the fat graft after transplantation, and the general intolerance to ischemia of the adipocytes.

The fat graft is infiltrated by macrophages and neutrophils and a collagen layer is formed on the boundaries of the graft during the first week after transplantation [4, 7, 9, 14, 26, 30,32]. By the end of the first week a central zone can be identified, containing non-inflammatory denucleated adipocytes with an inflammatory peripheral zone [4]. After 3 weeks, three layers can be identified in the fat graft; a central, necrotic zone [4,32], an intermediate, densely inflamed zone containing collagen fibres and pseudocysts, and a peripheral zone with viable adipocytes. By 1 month, the viable fraction of the peripheral zone becomes larger and the intermediate zone denser. One month later, the peripheral zone is twice as wide and the central zone still shows an inflammatory response, pseudocysts, and collagen condensation [4]. Šmahel [31] supports the view that there is an acute degradation when the invading macrophages remove the necrotic cells in the central part. He states that this is followed by a chronic degradation process of dead cells in the pseudocysts, which can last for months or years. This explains how the fat graft reduces in volume over several years, as demonstrated on the MRI scans.

Peer [26] stated that larger free fat grafts survive better than multiple small ones because of improved revascularisation [9]. Others felt that using small fragmented grafts would give a better revascularization, because of close contact between graft and host tissue [12,21]. McClinton [24] believes transplanting dermis with the fat restores the vascularisation in the fat graft faster.

Peer [26] considered the use of fat grafts to reduce the formation of adhesions around nerves and tendons to be disadvantageous, because the graft interferes with the blood supply of the nerve or tendon. However, Eden and Rehn [7] reported positive results in their patients. They noted that adhesions between the epineurium and the fat graft were visible at 19 days postoperatively, but that these were reduced 6 months later. Jones [13] states that small, nonvascularized subcutaneous or muscle flaps may not survive or even produce more scar tissue. We confirm the occurrence of adhesions between the fat graft and the surrounding tissues, which in our study did not seem to disappear with the passage of time.

McClinton [24] reported in a non-comparative study that in some cases of recurrent carpal tunnel syndrome re-exploration of the median nerve, neurolysis, and implantation of a dermal fat graft could be beneficial. Our results, comparing the overall effects of the routine re-decompression of the carpal tunnel and the additional implantation of a free fat transplant, reveal that both procedures are effective, but do not support the view that fat-grafting is of additional benefit to re-decompression alone.

Acknowledgements We would like to express special thanks to Pieksma Medical Supplies B.V., Amsterdam, for donating a Semmes-Weinstein monofilament test.

References

1. Akkerveeken van PF, Kraan van de W, Muller JWT (1986) The fate of the free fat graft. A prospective clinical study using CT scanning. Spine 11:501–504.
2. Billings E, May JW (1989) Historical review and present status of free fat graft autotransplantation in plastic and reconstructive surgery. Plast Reconstr Surg 83:368–381

3. Bryant MS, Bremer AM, Nguyen TQ (1983). Autogenic fat transplants in the epidural space in routine lumbar spine surgery. Neurosurgery 13:367–370
4. Carpanedo CA, Ribeiro MT (1993) Study of the histological alterations and viability of the adipose graft in humans. Aesthetic Plast Surg 1:43–47
5. Cobb TK, Amadio PC (1996) Reoperation for carpal tunnel syndrome. Hand Clin 12:313–323
6. Dawson DM (1993) Current concepts: Entrapment neuropathies of the upper extremities. N Engl J Med 329:2013–2018
7. Eden R, Rehn E (1914) Die Autoplastische Fettransplantation zur Neurolysis und Tendolysis. Langenbecks Arch Klin Chir 104:65–83
8. Grewal R, Xu J, Sotereanos DG, Woo S (1996) Biomechanical properties of peripheral nerves. Hand Clin 12:195–204
9. Gurney CE (1938) Experimental study of the behaviour of free fat transplants. Surgery 3:679–692
10. Hunter JM (1991) Recurrent carpal tunnel syndrome, epineural fibrous fixation, and traction neuropathy. Hand Clin 7:491–504
11. Hunter JM (1996) Reconstruction of the transverse carpal ligament to restore median nerve gliding: The rationale of a new technique for revision of recurrent median nerve neuropathy. Hand Clin 12:365–378
12. Illouz, GY (1986) The fat cell “graft”: a new technique to fill depressions. Letter to the Editor. Plast Reconstr Surg 78:122
13. Jones NF, Shaw WW, Katz RG (1997) Circumferential wrapping of a flap around a scarred peripheral nerve for salvage of end-stage traction neuritis. J Hand Surg 22A:527–535
14. Kiviluoto O (1976) Use of free fat transplants to prevent epidural scar formation. An experimental study. Acta Orthop Scand Suppl 164:1–75
15. Koncilia H, Kuzbari R, Worseg A, Tschabitscher M, Holle J (1998) The lumbrical muscle flap: anatomic study and clinical application. J Hand Surg 23A:111–119
16. Kulick MI, Gordillo G, Javadi T, Kilgore ES, Newmeyer III WL (1986) Long-term analysis of patients having surgical treatment for carpal tunnel syndrome. J Hand Surg 11A:59–66
17. Kuschner SH, Brien WW, Johnson D, Gellman H (1991) Complications associated with carpal tunnel release. Ortho Rev 20:346–352
18. Langenskiöld A, Kiviluoto O (1976) Prevention of epidural scar formation after operations on the lumbar spine by means of free fat transplants. A preliminary report. Clin Ortho Rel Res 115:92–95
19. Langloh ND, Linscheid RL (1972) Recurrent and unrelieved carpal-tunnel syndrome. Clin Ortho Rel Res 83:41–47
20. Levine DW, Simmons BP, Koris MJ et al (1993) A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. J Bone Joint Surg 75A:1585–1592
21. Lexer E (1925) Zwanzig Jahre Transplantations Furschung in der Chirurgie. Langenbecks Arch Klin Chir 138:294–297
22. Lundborg G, Dahlin LB (1992) The pathophysiology of nerve compression. Hand Clin 8:215–227
23. Mackinnon SE (1991) Secondary carpal tunnel surgery. Neurosurg Clin N Am 2(1):75–91
24. McClinton MA (1996) The use of dermal fat grafts. Hand Clin 12:357–364
25. Neuber G (1893) Fettransplantation. Verh Deutsch Ges Chir Kong Verh, 22:66
26. Peer LA (1956) The neglected free fat graft. Plast Reconstr Surg 18:233–250
27. Phalen GS (1966) The carpal tunnel syndrome. Seventeen years’ experience in diagnosis and treatment of six hundred fifty-four hands. J Bone Joint Surg Am 48:211–228
28. Plancher KD, Idler RS, Lourie GM, Strickland JW (1996) Recalcitrant carpal tunnel: the hypothenar fat pad flap. Hand Clin 12:337–350
29. Rose EH (1996). The use of the palmaris brevis flap in recurrent carpal tunnel syndrome. Hand Clin 12:389–396
30. Saunders MC, Keller JT, Dunsker B, Mayfield FH (1981) Survival of autologous fat grafts in humans and mice. Connect Tissue Res 8:85–91
31. Šmahel J (1986) Adipose tissue in plastic surgery. Ann Plast Surg 16:444–453
32. Šmahel J (1989) Experimental implantation of adipose tissue fragments. J Plast Surg Br 42:207–211
33. Špokevicius S, Kleinert HE (1996) The abductor digiti minimi flap: its use in revision carpal tunnel surgery. Hand Clin 12: 351–356
34. Stevenson TW (1949) Fat grafts to the face. Plast Reconstr Surg 4:458–468
35. Tham SKY, Ireland DCR, Riccio M, Morrison WA (1996) Reverse radial artery fascial flap: a treatment for the chronically scarred median nerve in recurrent carpal tunnel syndrome. J Hand Surg [Am] 21:849–854
36. Wilgis EFS, Murphy R (1986) The significance of longitudinal excursion in peripheral nerves. Hand Clin 2:761–766
37. Wolford LM, Karras SC (1997) Autologous fat transplantation around temporomandibular joint total joint prostheses: preliminary treatment outcomes. J Oral Maxillofac Surg 55:245–251
38. Wrede L (1927) Einige Spätergebnisse der Mamma- und Gelenkplastik mittelst frei transplantierten Fettgewebes. Dtsch Z Chir 203–204:672–685
39. Wulle C (1996) The synovial flap as treatment of the recurrent carpal tunnel syndrome. Hand Clin 12:379–388