Carbon fiber for repair of the rotator cuff

A 4-year follow-up of 14 cases

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Thirteen patients with 14 large rotator cuff tears were operated on using carbon fiber to cover the defect. The median follow-up time was 4 years. In 11, 1, and 2 cases the results were respectively excellent or good, fair, and poor. In 2 cases where the carbon fiber was anchored to the major tuberosity, a bone cyst was seen, but it did not influence the result. A carbon fiber tow application combined with Neer's anterior acromioplasty seems useful in the reconstruction of large tears of the rotator cuff.

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Since 1983, we have used carbon fiber tow in the reconstruction of large tears of the rotator cuff. This practice was initiated by the observation, at a reoperation, of a broken carbon fiber ligament in a knee where the carbon fiber tow was strongly hypertrophied because of connective tissue ingrowth. We hoped that this hypertrophied tissue could cover even massive rotator cuff ruptures. We report 14 cases operated on with this method.

Patients and methods

Thirteen patients with 14 complete rotator cuff tears were reconstructed with carbon fiber between 1983 and 1987. The median age of the patients was 54 (48–77) years, and the median follow-up time 4 (2–7) years. The duration of symptoms varied from 3 to 120 months before surgery. The tear of the rotator cuff was confirmed by arthrography in all the cases.

The size of the tear (longest diameter) was classified according to Post et al. (1983): small tear, up to 1 cm; medium tear, 1–3 cm: large tear, 3–5 cm; and massive tear, more than 5 cm.

At follow-up, preoperative and postoperative radiographs were analyzed; the appearance of the reconstructed tendon was examined by ultrasound (Mack et al. 1985).

We regarded the clinical result as excellent when there was no pain, the active movements of the shoulder were within the normal limits, and the deltoid and external rotation muscle strengths were 4–5 on the scale of ordinary muscle strength testing. The results were good if the shoulder was still painless, the muscle strengths were 3–4, or the abduction was limited no more than 60°. The results were fair if there was pain during effort (painful arch); but the patient could abduct over 90°, and the muscle strengths were 3–4. In the poor results the patient still suffered from pain at rest or the patient could not abduct over 90° and the muscle strengths were clearly weakened (2–3).

Operative methods and postoperative care

An anterosuperior saber-cut incision was used in all the cases (except in Case 2, in which a longitudinal incision was used) because the lateral part of the clavicle was resected for the osteoarthrosis of the acromioclavicular joint. Both the anterior and the lateral part of the deltoid were subperiosteally detached from the acromion, and the lateral part of the deltoid was split to reveal the major tuberosity. Then, Neer's anterior acromioplasty was performed (Neer et al. 1983). The tear was closed with the "shoe-laced" sutures starting from the medial edge of the tear. Only in the first 4 cases (Cases 1–4) were the avascular rims of the tears sparingly resected. During the application of the carbon fiber, the arm was strongly pulled down to relieve the tension of the teared rims of the supraspinous tendon. The friction between the carbon fiber and the rotator cuff helped to maintain the achieved position during the closure.

In Case 1, a Strover carbon fiber was used, and the ends of the tow were fixed to the major tuberosity with the Strover rivet. In Case 2, a Jenkins carbon fiber tow was used, and it was fixed to the major tuberosity with two parallel 4-mm holes, and the tails of the tow were tied together. In the other cases the Integraft® carbon fiber with curved needles on both the tails was used, and the fixation to the major tuberosity was performed

Table 1. Clinical and radiographic findings

Case	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	M	48	1	5	3/83	1	1	1	1	85	90/180	E	3	0	0	0.4	1	1	1
2	M	60	0	120	3/84	2	0	1	1	75	90/160	G	9	0	2	0.4	1	1	2
3	M	52	1	3	12/84	3	0	0	1	64	80/180	E	3	1	2	0.4	1	1	
4	M	52	1	4	3/85	3	0	1	1	61	30/180	E	R	1	1	0.5 sin	1	2	
5	F	62	0	36	4/85	1	0	0	1	60	80/180	G	R	1	1	0.7	1	1	
6	M	57	0	96	6/85	2	0	1	1	56	80/180	E	R	1	1	0.4	1	1	
7	F	53	1	8	7/85	2	0	1	1	55	80/180	E	3	1	2	0.6	1	2	2
8	M	49	0	60	2/87	2	0	1	0	36	90/180	E	3	1	1	0.4	1	1	
9	M	54	0	24	2/87	1	0	1	0	36	90/180	E	R	1	1	0.6 dx	1	1	
10	M	49	1	3	2/87	2	0	0	0	25	80/60	P	2	1	1	–	–	–	
11	M	58	1	8	2/87	1	1	1	0	43	80/110	F	3	0	0	0.5	1	1	
12	M	51	0	18	2/82	1	0	0	0	36	30/180	E	4	1	1	0.7	1	1	
13	M	54	0	120	12/87	1	1	0	0	28	70/70	P	R	1	1	0.4	1	2	
14	M	77	1	4	7/88	1	1	0	0	25	50/180	G	R	1	1	0.7	1	1	

A Case
A Sex
B Age
C Previous trauma: 0 no, 1 yes
D Duration of symptoms, months
E Date of surgery, month/year
F Size of the tear
  1 medium, 1–3 cm
  2 large, 3–5 cm
  3 massive, > 5 cm
G Closure of the tear
  0 partial
  1 complete
H Bony fixation
  0 no bony fixation
  1 bony fixation
I Abduction splint
  0 no splint
  1 splint
J Follow-up time, months
K Pre-/postoperative abduction
L Clinical results
  E excellent
  G good
  F fair
  P poor
M Sick leave, months
  R retired because of age or other reason than shoulder
N Preop. radiographic findings
  0 normal
  1 degenerative changes
O Postop. radiographic findings
  0 normal
  1 no progression of degeneration
  2 progression of degeneration

Postop. ultrasound findings:
P Thickness of supraspinous tendon, cm
Q Signal intensity
  0 normal
  1 increased
R Margins of supraspinous tendon
  1 even
  2 uneven
S Remarks
  1 regular hole of Strover's bolt
  2 postop. cystic degeneration of major tuberosity

through one horizontal 3–4-mm hole, the edges of which were rounded. In 5 cases, bony fixation was not regarded as necessary (Table 1).

In 4 cases, the tear could be completely closed; and in 10 cases of massive or large tears, only a partial closure was possible, leaving a defect of up to 1 × 3–4 cm (Table 1).

An abduction splint set at 70° for 6 weeks was used in 7 cases; and in 7 cases, the shoulder was also immobilized for 6 weeks with the Camp shoulder immobilizer (Table 1).

Results

Good or excellent results were obtained in 11 cases (Table 1). These cases included two massive tears in which only a partial closure was possible, with a defect of 1 × 4 cm (Cases 3 and 4). In 5 cases the good results had been maintained for more than 5 years, indicating that a permanent improvement is possible. Two of these patients were able to participate in strenuous sports. Two of the cases were classified as poor. In 1 of the poor cases (Case 10), the primary result was excellent, and the patient returned to his previous occupation after only 2 months' sick leave. During heavy factory work, the condition of the shoulder deteriorated again: the patient sustained pain at rest, and the good mobility after surgery was reduced. A recurrent rotator cuff tear was diagnosed by arthrography. At the reoperation 25 months after the primary operation, the supraspinous tendon was observed to be partly replaced by an abundant, carbon-mixed connective tissue without any identifiable tendon. The histologic studies showed a fragmentation of the carbon fibers embedded in a loose connective tissue (Figure 1). None of the patients retired because of shoulder surgery. The postoperative sick-leave period varied from 2 to 9 months. Except Case 3, all the patients had perviously performed manual labor.

Eleven cases showed osteoarthrotic changes before surgery (Table 2). Generally, there was a slight increase in these changes during the follow-up period. In 2 cases (Cases 2 and 7) a cystic destruction of the major tuberosity, where the carbon fiber was fixed, was seen (Figure 2). The clinical results in these cases were good. The postoperative ultrasound examination demonstrated an intact supraspinous tendon with uniform boundaries, but with increased signal intensity in most of the cases (Table 1, Figure 3). However, there was no correlation between the ultrasound findings and the clinical results.

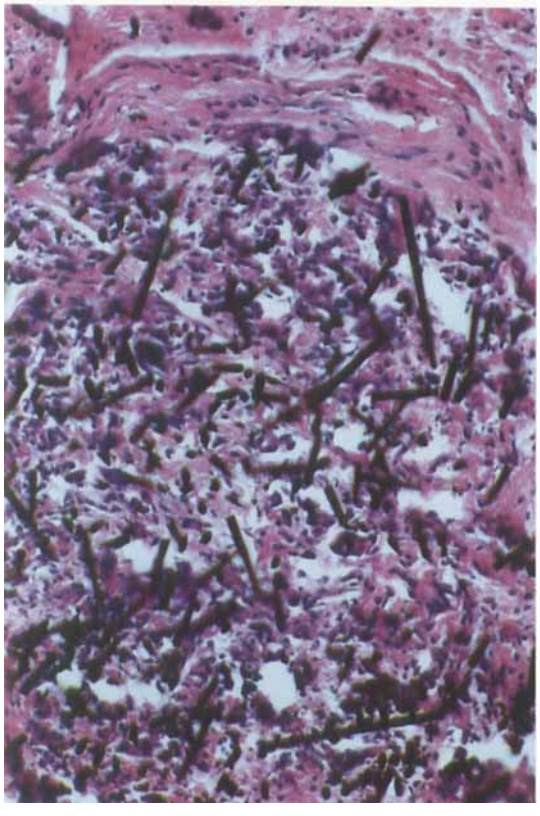

Figure 1. Case 10. Histologic section of the carbon-fiber reinforced supraspinous tendon 25 months after surgery. Fragmented carbon fibers are embedded in dense fibrous tissue. No foreign-body reaction is seen. Capsular tissue in the left part. H&E, ×100.

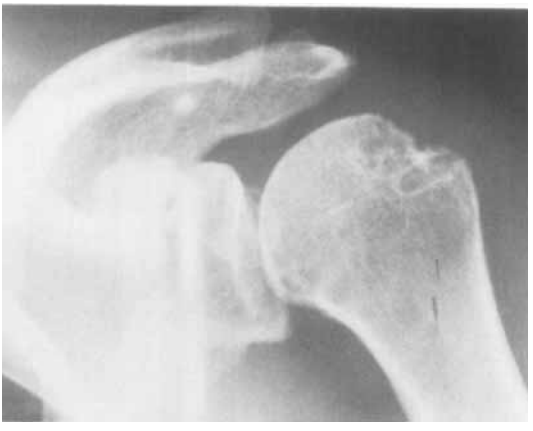

Figure 2. Case 7. Five years after surgery. There is a marked cystic degeneration of the major tuberosity in the area of the carbon fiber implantation. The clinical result is still excellent.

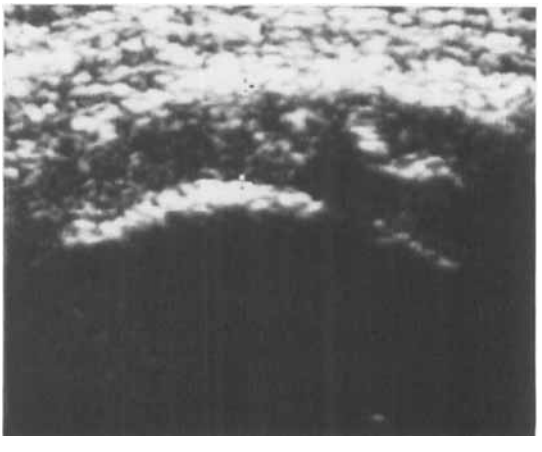

Figure 3. Case 12. Sonographic demonstration of the supraspinous tendon reconstructed with carbon fiber 36 months after the operation. Increased signal intensity inside the tendon, with uniform margins.

Discussion

Surgery seems to be indicated in a large proportion of the major tears of the rotator cuff, for good results were obtained only in half of the arthrographically confirmed tears using conservative treatment (Tagagishi 1978). The use of carbon fiber makes it possible to repair large tears. The collagenous tissue that is formed around the carbon fibers can result in a ligamentous structure that is biomechanically and physiologically compatible (Mendes et al. 1985). Collagen ingrowth causes a threefold or fourfold increase in the hypertrophy of the new structure (Mendes et al. 1985). Although carbon fiber debris can cause a synovitis of the synovial joint, it does not alter the mechanical properties of the cartilage (Parsons et al. 1985).

Our radiographic and histologic results show that the carbon fiber induces collagen ingrowth that covers large tears of the rotator cuff. Thus, the shoulder joint will be closed, allowing a normal synovial fluid mechanism (Neer et al. 1983). The newly formed tendon can conduct the power of the rotator muscles to the major tuberculum and act as a "tendinous glenoid" (Ozaki et al. 1986), and even tolerate high stresses, as some of our cases have shown.

Too early mobilization and heavy work resulted in deterioration of a primarily good result in 1 patient, with recurrence of the tear and fragmentation of the carbon fiber. A minimum of 3 months' sick leave seems to be needed after this operation.

In 2 cases, cystic destruction of the major tuberosity was seen; and both of these patients had been working with their arms extended above the shoulder level (a

barber and a storage worker) for 4–5 years after surgery, implying high forces in this area. According to experimental (Guiral et al. 1990) and clinical observations (Neugebauer and Burri 1985), the carbon fibers may be incorporated into bone as a result of bony ingrowth.

There are only two reports on the use of carbon fibers in the repair of the rotator cuff tears. Packer et al. (1983) reported 5 cases with promising results, and Post (1985) also reported 5 cases with good or excellent results in 3 cases and poor in 2 cases. In the poor cases, the application of the carbon filament was performed as a revision operation after total acromionectomy.

In half of the cases, an abduction splint was used after surgery. In all of these cases the clinical results were good or excellent, although the largest tears were included in this part of the series. The use of the abduction splint is obviously indicated in major tears to relieve tension on the reconstructed rotator cuff and to prevent the cutting through of the carbon fiber tow.

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