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Original article

Revision surgery for carpal tunnel syndrome: a retrospective study comparing the combination of Canaletto® and Dynavisc® gel *versus* Dynavisc® gel alone

Chirurgie de reprise du syndrome du canal carpien: étude rétrospective comparant l'implant Canaletto® plus gel Dynavisc® versus gel Dynavisc® seul

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ABSTRACT

The aim of this study was to assess the value of using a Canaletto® implant in combination with a gel composed of carboxymethylcellulose and polyethylene oxide in the surgical treatment of recurrent carpal tunnel syndrome (CTS). The case series included 31 patients with 32 hands operated for the second time for recurrent (22 cases) or recalcitrant (9 cases) CTS by neurolysis. The average patient age was 62 years. Dynavisc® gel alone was applied around the median nerve in the first 16 cases (Group I). The Canaletto® implant combined with Dynavisc® gel was used in the last 16 cases (group II). With an average follow up of 8 months (for group I) and 11 months (for group II), the pre/postoperative variation in pain assessed with a visual analog scale was 1.38/10 (group I) and 2.04/10 (group II), the QuickDASH score was 20.1/100 (Group I) and 20.48/100 (Group II), grip strength was 8% (Group I) and 20% (Group II), sensory nerve conduction speed was 23.20 m/s (group I) and 15.51 m/s (group II) and distal motor latency was 1.55 m/s (group I) and 1.21 m/s (group II). Ten patients recovered from hypoesthesia in both groups, 6 patients in group I and 2 patients in group II regained good trophicity of their superficial thenar muscles. Two patients from group II had not improved clinically although their electromyography had become normal. One patient from group II suffered a postoperative infection that required removal of the Canaletto® implant. He subsequently improved slightly. Our study found that for recurrent or recalcitrant CTS, the combination of Dynavisc® anti-adhesion gel around the median nerve and a Canaletto implant® after neurolysis results in outcomes that are as good as Dynavisc® alone, with a significant improvement of the QuickDASH score without the Canaletto®. In conclusion, the use of Dynavisc® gel alone around the median nerve after neurolysis seems to be as effective as other techniques described in literature but less invasive or time-consuming, and not associated with donor site morbidity such as the flexor tendon sheath.

Mots-clés:
Canal carpien
Canaletto
Nerf médian
Neurolyse
Récidive
Gel antiadhésion

RÉSUMÉ

Le but de ce travail était de tester l'intérêt d'associer un implant Canaletto® à un gel composé de carboxyméthylcellulose et de polyéthylène oxyde dans le traitement chirurgical des récidives de syndrome du canal carpien (SCC). La série comprenait 31 patients soit 32 mains opérées pour la deuxième fois d'un SCC récidivant (24 cas) ou récalcitrant (7 cas) par neurolyse. L'âge moyen était de 62 ans. Un gel Dynavisc® seul a été appliqué autour du nerf médian chez les 16 premiers cas (groupe I). L'implant Canaletto® plus gel Dynavisc® a été mis en place chez les 16 derniers cas (groupe II). Au recul moyen de 8 mois (groupe I) et 11 mois (groupe II), une variation pré/postopératoire des items suivant a

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été notée : douleur évaluée sur une échelle visuelle analogique 1,38/10 (groupe I) et 2,04/10 (groupe II), score QuickDASH 20,1/100 (groupe I) et 20,48/100 (groupe II), force de poigne 8,18% (groupe I) et 19,66% (groupe II), vitesse de conduction nerveuse sensitive 23,20 m/s (groupe I) et 15,51 m/s (groupe II), latence motrice distale 1,55 m/s (groupe I) et 1,21 m/s (groupe II). Dix patients avaient récupéré une sensibilité dans les 2 groupes, 6 patients avaient récupéré une bonne trophicité des muscles thénariens superficiels dans le groupe I et 2 patients dans le groupe II. Deux patients du groupe II n'étaient pas cliniquement améliorés alors que les signes électromyographiques étaient normalisés. Un patient du groupe II a présenté une infection qui a nécessité l'ablation de l'implant Canaletto® avec une légère amélioration finale. Nos résultats semblent montrer qu'en présence d'un SCC récidivant ou récalcitrant, l'association d'un gel anti-adhérant Dynavisc® autour du nerf médian à la mise en place d'un implant Canaletto® après neurolyse donne d'aussi bons résultats qu'avec gel anti-adhérant Dynavisc®, avec même une amélioration significative du score QuickDASH en l'absence de Canaletto®. En conclusion, l'utilisation seule de gel anti-adhérant Dynavisc® autour du nerf médian après neurolyse semble aussi efficace que les autres techniques de la littérature, mais moins invasive, plus rapide, et sans morbidité au site donneur comme la gaine des tendons fléchisseurs.

Introduction

Failures of surgical management for carpal tunnel syndrome (CTS) are not rare. The surgical revision rate varies from 0 to 19% [1,2]. In carpal tunnel revision procedures, some authors report good results by combining nerve release with application of a Canaletto® implant [3]. The Canaletto® implant, sutured to each of the two ends of the flexor neo-retinaculum, widens the cross-sectional area of the carpal tunnel and restores an exclusive gliding space for the palmar aspect of the median nerve. Other authors have demonstrated the value of using a gel composed of carboxymethylcellulose and polyethylene oxide to reduce epidural postoperative fibrosis and improve the clinical outcomes after discectomy or laminectomy in spine surgery [4].

The purpose of this work was to assess the value of combining the Canaletto® implant with a compound gel of carboxymethylcellulose and polyethylene oxide in the surgical treatment of recurrent CTS.

The main hypothesis was that the difference in pain levels before and after revision surgery, measured using a visual analog scale (VAS), in the group of patients operated with a Canaletto® implant and Dynavisc® anti-adhesion gel was lower than the pain difference achieved with Dynavisc® alone. The secondary hypothesis was that the preoperative to postoperative change in the clinical quantitative variables (strength, QuickDASH score), qualitative variables (paresthesia, atrophy) and electromyographic variables (sensory conduction speed and distal motor latency) in the Canaletto® and Dynavisc® gel group was lower than in the Dynavisc® alone group.

Patients and methods

The Local Committee for the Protection of Human Subjects approved this retrospective study. All the clinical records of patients who had undergone revision surgery in our unit between 2014 and 2016 for recurrence or persistence of CTS were reviewed. Exclusion criteria were complications without recurrence of acroparesthesia (complex regional pain syndrome type I, infection, iatrogenic nerve lesion, etc.), persistence of acroparesthesia due to cervical compression, less than 18 years old, pregnancy, patient lost to follow-up or patient with incomplete records (8 cases). All patients who had undergone revision surgery for recurrent or persistent CTS with the carboxymethylcellulose and polyethylene oxide compound gel (Dynavisc®, Fziomed™, San Luis Obispo, CA, USA) and the Canaletto® implant (Eurymed™, Nîmes, France) or Dynavisc® alone were included in the study. It should be noted that primary surgery had been carried out for all patients through a volar incision over the line crossing the third interosseous space.

The case series included 31 patients with 32 hands (1 bilateral case) who had undergone revision surgery for CTS due to recurrence or persistence of signs and symptoms (Tables 1 and 2). Twenty-two patients had a recurrence with an average symptom-free interval of 100 months and 9 patients had recalcitrant CTS, characterized by the persistence of the paresthesia after primary surgery. The average patient age was 62 years, ranging from 41 to 89. Seven patients had polyneuropathy. The decision to perform revision surgery was based on the results of the electromyography (EMG) in all cases.

All the patients of our case series were operated as outpatients, under regional anesthesia and with a tourniquet positioned at the base of the arm. The surgical incision was approximately 25 mm long and corresponded to the primary scar. The neo-flexor retinaculum appeared macroscopically thickened in all cases but one, mainly in its distal segment. An extensive longitudinal cut of the entire neo-retinaculum was made. The position of the median nerve in the carpal tunnel appeared normal in 4 cases and was deviated radially in 23 cases. The macroscopical appearance of the median nerve was normal in only one case, and purple, flattened or opaque in the remaining cases. In some cases, the flexor tendons had moderate synovitis (8/32). The next step was extrafascicular neurolysis of the median nerve, without flexor synovectomy.

In the first 16 cases (Group I), the Dynavisc® gel was applied circumferentially along the entire surface of the released median nerve from the entry point to the exit point of the carpal tunnel (Fig. 1). In the last 16 cases (Group II), the same Dynavisc® gel was applied circumferentially along the entire surface of the released median nerve from the entry point to the exit point of the carpal tunnel, then a Canaletto® device was implanted. The deep silicon surface of the Canaletto® was applied against the median nerve, and its edges were sutured to the ends of the neo-retinaculum with two 3/0 nylon sutures (Fig. 2). For all the patients, skin closure was carried out with three nylon 1/0 sutures. No cast immobilization was prescribed postoperatively; patients were encouraged to gently mobilize their wrist and fingers immediately. Strenuous movements were allowed only after the 6th week.

The outcome assessment was based on the preoperative and postoperative measurement of sensory, motor and functional criteria. Pain intensity was assessed by a VAS ranging from 0 (no pain) to 10 (maximum pain). The Quick Disabilities of the Arm, Shoulder and Hand score (QuickDASH score) is based on a questionnaire [5] of 11 items generating a weighted sum ranging from 0 (no discomfort) to 100 (impossible to use the upper limb). Grip strength was measured in kilograms using a Jamar

Table 1
Case series of 16 CTS revisions treated with Dynavisc® in 15 patients (group I).

N	Patient						Characteristics of lesions			Intraoperative findings	
	Age (years)	Sex (F/M)	Dominant side (R/L)	Affected side (R/L)	Occupation (M/S/R)	Symptom free (weeks)	OD (Y/N)	PNP (Y/N)	Retinaculum appearance (N/T)	Nerve Position (N/R/U/S)	Nerve Appearance (N/E/F)	Flexor Synovitis (Y/N)
1	46	M	R	L	M	32	Y	N	T	N	F	Y
2	67	M	R	L	R	720	Y	N	T	R	F	Y
3	58	F	R	R	M	52	Y	N	T	N	F	N
4	72	F	R	L	R	760	Y	N	T	U	F	Y
5	89	F	R	R	R	2400	Y	Y	T	R	F	Y
6	72	F	R	R	R	960	Y	Y	T	R	F	Y
7	41	F	R	L	M	24	Y	N	T	R	F	Y
8	60	M	R	R	S	364	Y	N	T	R	F	Y
9	63	F	R	L	R	192	Y	N	T	R	F	Y
10	72	F	R	L	R	768	Y	N	T	U	F	Y
11a	81	M	R	R	R	768	Y	N	T	R	F	Y
11b	81	M	R	L	R	480	Y	N	T	R	F	Y
12	80	M	R	R	R	28	Y	N	T	N	F	N
13	58	M	R	L	S	20	Y	N	T	R	F	Y
14	83	M	R	R	R	1200	Y	Y	T	R	F	Y
15	40	F	R	R	M	76	Y	N	T	N	F	Y

M: male; *F*: female; *R*: right; *L*: left; *M*: manual; *S*: sedentary; *R*: retired; *OD*: occupational disease; *PNP*: polyneuropathy on EMG; *Y*: yes; *N*: no.
Retinaculum appearance: *N*: normal, *T*: thickened.
Nerve position: *N*: normal; *R*: radial; *U*: ulnar; *S*: superficial.
Nerve appearance: *N*: normal; *E*: edema; *F*: flattened.

Table 2
Case series of 16 CTS revisions treated with Canaletto® + Dynavisc® (group II).

N	Patient						Characteristics of lesions		Intraoperative findings			
	Age (years)	Sex (F/M)	Dominant side (R/L)	Affected side (R/L)	Occupation (M/S/R)	Symptom free (weeks)	OD (Y/N)	PNP (Y/N)	Retinaculum appearance (N/T)	Nerve Position (N/R/U/S)	Nerve Appearance (N/E/F)	Flexor Synovitis (Y/N)
1	57	F	R	L	M	0	Y	N	T	R	E	Y
2	66	F	R	L	S	118	N	N	T	R	E	Y
3	57	F	R	L	M	250	Y	Y	T	R	E	Y
4	56	F	R	L	M	0	Y	N	T	R	E	Y
5	51	F	R	R	S	4	N	N	T	U	E	N
6	46	M	R	R	M	0	N	N	T	N	E/F	N
7	53	F	R	R	M	106	?	N	T	R	E	Y
8	52	M	R	R	S	490	N	Y	T	R	E	Y
9	69	M	R	R	S	4	N	N	T	R	E	Y
10	59	F	R	R	S	60	N	N	T	R	N	N
11	63	M	R	L	S	0	N	N	T	R	E	N
12	73	F	R	R	S	736	N	N	T	R	E	Y
13	49	F	R	R	M	0	N	Y	T	N	E	N
14	53	F	R	R	M	0	N	Y	N	R	E	N
15	77	M	R	R	S	0	N	N	T	R	F	Y
16	42	F	?	R	M	?	N	N	T	R	F	Y

M: male; *F*: female; *R*: right; *L*: left; *M*: manual; *S*: sedentary; *R*: retired; *OD*: occupational disease; *PNP*: polyneuropathy on EMG; *Y*: yes; *N*: no.
Retinaculum appearance: *N*: normal, *T*: thickened.
Nerve position: *N*: normal; *R*: radial; *U*: ulnar; *S*: superficial.
Nerve appearance: *N*: normal; *E*: edema; *F*: flattened.

dynamometer® on setting 2 (Arex™, Palaiseau, France). The presence of a neurological deficit was diagnosed based on hypoesthesia in the territory of the median nerve as well as atrophy of the superficial thenar muscles. EMB measured the speed of sensory nerve conduction in m/s and distal motor latency in milliseconds. Complications were documented.

The purpose of the statistical analysis was to determine whether there was a significant difference between the two groups in the preoperative and postoperative data collected during the last follow-up visit for the five paired quantitative variables (pain, QuickDASH score, grip strength, sensory nerve conduction speed, distal motor latency) and the two paired qualitative variables (hypoesthesia, atrophy). Given the small numbers in our sample, conventional "frequentist" methods, expressed in the form of p values, have poor reliability. In our study, Bayesian analysis methods were used instead. This analysis is based on calculating the likelihood of observing a difference and has better reliability. This calculation provides a likelihood figure ranging from 0 to 1, which is more accurate than the binary response connected to the p value ($p < \text{or } p > 0.05$). The likelihood of having a difference in the credibility intervals between the two groups of more than 90% represents a strong difference. The likelihood of having a difference in the credibility intervals between the two groups of more than 95% represents a very strong difference. The

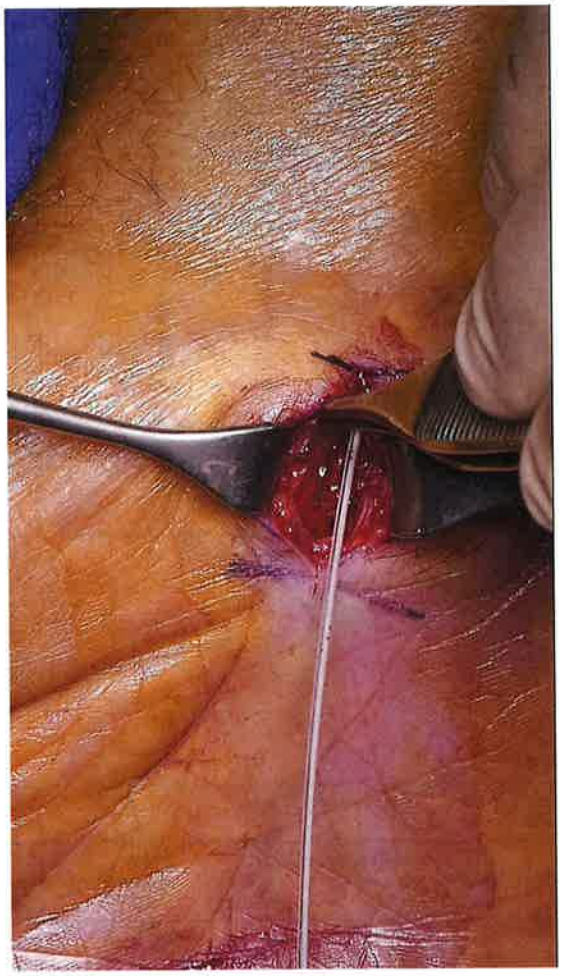

Fig. 1. Dynavisc® gel injection along the median nerve's surface.

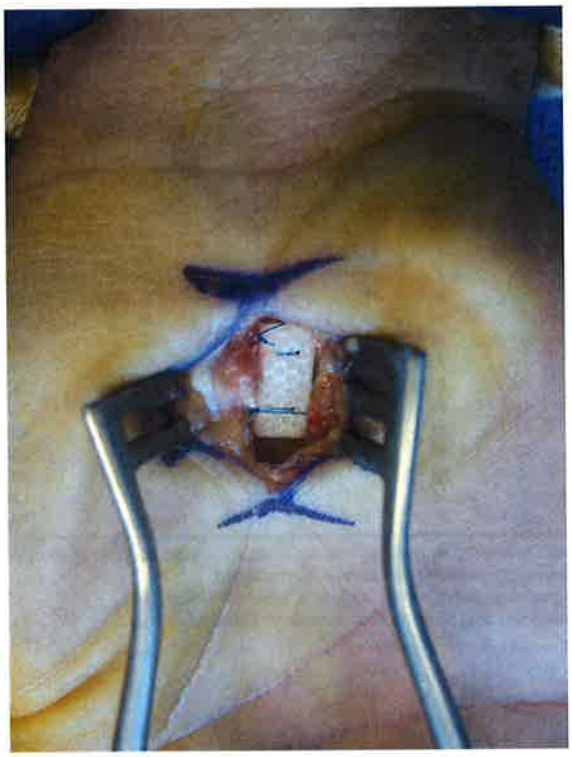

Fig. 2. Intraoperative view of the Canaletto® implant after being sutured with the ends of the neo-retinaculum.

likelihood of having a difference in the credibility intervals between the two groups of more than 97.5% represents a significant difference. All analyses were performed using R (3.1.0 version) and JAGS software packages.

Results

The results are reported in Tables 3 and 4. The mean follow-up time was 8 months in Group I and 11 months in Group II.

Among the five paired quantitative variables, the mean preoperative/postoperative variation in the reported pain was 1.38/10 in group I and 2.04/10 in group II. The estimated difference was 12% and the estimated improvement was −0.663 [−2.478; −0.994]. Therefore, the likelihood that the preoperative/postoperative pain variation in group II is greater than the variation of group I was above 77%, which was a non-significant difference.

The preoperative/postoperative variation of the QuickDASH score was on average −20.1/100 in Group I and −20.48/100 in Group II. The estimated difference was 0.80% and the improvement was −14.503 [−26.809; −0.869]. Therefore, the likelihood that the preoperative/postoperative QuickDASH score variation in group II is greater than the variation in Group I was above 98%, which was a significant difference.

The pre-operative/postoperative variation in the overall hand strength was on average 8.18% in Group I and 19.66% in Group II. The estimated difference was 31% and the estimated improvement was 7.168 [−6.5; 20.9]. Therefore, the likelihood that the preoperative/postoperative variation in the overall hand strength of the group II hand is greater than the variation of Group I was above 85%, which was a non-significant difference.

The preoperative/postoperative variation in the sensory nerve conduction speed was on average 23.20 m/s in group I and 15.51 m/s in group II. The estimated difference was 16% and the estimated improvement was 3.334 [−5.579; 12.133]. Therefore, the likelihood that the preoperative/postoperative variation in the sensory nerve conduction speed of group II is greater than the variation in group I was above 77%, which was a non-significant difference.

The preoperative/postoperative variation in distal motor latency was on average 1.55 m/s in group I and 1.21 m/s in group II. The estimated difference was 40% and the estimated improvement was 0.043 [−1.692; 1.745]. Therefore, the likelihood that the preoperative/postoperative variation in distal motor latency in group II is greater than the variation in distal motor latency in group I was above 48%, which was a non-significant difference.

Regarding the two paired qualitative variables, 3 patients recovered from hypoesthesia in group I and 7 patients in group II. The estimated difference was −1.2% [−33.69; 30.8]. Therefore, the likelihood that the improvement of the hypoesthesia in group II is greater than the improvement in group I was 53%, which was a non-significant difference.

Six patients regained good trophicity of the external thenar muscles in group I and 2 patients in group II. The estimated difference was 3% [−9.0; 67.1]. Therefore, the likelihood that the improvement in atrophy of the external thenar muscles in group II is greater than the improvement in group I was 7%, which was a non-significant difference.

Regarding the complications, 2 patients in group II (10 and 16) had not improved after carpal tunnel revision surgery. In both cases, unexplained pain persisted although the EMG had become

Table 3
Postoperative outcomes in a case series of 16 CTS revisions treated with Dynavisc® in 15 patients (group I).

Patient	Delay	Follow-up	Preoperative								Postoperative						
(#)	(months)	(months)	DN4 (0/10)	Pain (0/10)	QuickDASH score (0–100)	Grip strength (% contralateral)	Hypoesthesia (Y/N)	Thenar amyotrophy (Y/N)	NCV (m/s)	Distal latency (ms)	Pain (0/10)	QuickDASH score (0–100)	Grip strength (% contralateral)	Hypoesthesia (Y/N)	Thenar amyotrophy (Y/N)	NCV (m/s)	Distal latency (ms)
1	26	12	7	5	47.37	100	Y	Y	28	6.9	7	63.64	40	N	N	44.4	4.4
2	192	4	4	5	52.57	72	Y	Y	0	4.9	1	4.55	72	N	N	44.7	3.47
3	14	9	–	5	52.72	20	Y	N	23.6	5	4	20.45	50	Y	N	34.9	4.8
4	195	6	–	6	72.73	83	Y	N	15	5.2	1	15.91	66.66	N	N	42	3.8
5	600	12		7	84.09	–	Y	N	35.1	5.6	6	68.18	66.66	N	N	54	6.63
6	252	6		1	63.91	80	Y	N	0	6.4	3	45.45	–	N	N	37.4	4
7	6	4		8	65.91	68.42	Y	N	37.9	3.03	5	25	83.33	N	N	45	3.5
8	94	3		3	40.91	83.33	Y	N	32	3.9	4	70.45	25	N	N	49	3.7
9	45	6		7	70.45	73.68	Y	N	14.4	7.4	5	36.6	73.77	N	N	41.2	3.9
10	190	5		6	72.73	83.33	Y	Y	32	3.4	1	15.9	66.67	N	N	48	3.5
11a	196	9		6	43.13	250	Y	N	0	7.8	5	31.6	400	Y	N	25.2	4.1
11b	127	9		6	43.13	40	Y	Y	0	7.8	5	31.8	25	Y	N	23	3.8
12	12	3		3	50	–	Y	Y	0	11.8	1	31	–	N	N	40.2	4.6
13	11	8		6	52	33.33	Y	N	37	4.2	8	34	100	N	N	50	3.9
14	300	7		3	29.55	88.89	Y	Y	0	6.3	0	31.81	100	N	N	47	6.0
15	18	14	5	3	27.27	100	Y	N	49	2.84	2	20.45	100	N	N	50.9	3.30

Delay: time elapsed between primary and revision surgery; *DN4*: neuropathic pain questionnaire, *Y*: yes; *N*: no; *NCV*: nerve conduction velocity.

Table 4
Postoperative outcomes in a case series of 16 CTS revisions with Canaletto® + Dynavisc® (group II).

Patient	Delay	Follow- up	Preoperative								Postoperative						
(#)	(months)	(months)	DN4 (0/10)	Pain (0/10)	QuickDASH score (0–100)	Grip strength (% contralateral)	Hypoesthesia (Y/N)	Thenar Amyotrophy (Y/N)	NCV (m/s)	Distal latency (ms)	Pain (0/10)	QuickDASH score (0–100)	Grip strength (% contralateral)	Hypoesthesia (Y/N)	Thenar Amyotrophy (Y/N)	NCV (m/s)	Distal latency (ms)
1	6	12	4	5	34.09	83.3	Y	N	26.9	9	1	11.3	100	N	N	46.9	4.8
2	114	10	4	5	59.09	69.6	Y	N	58.5	4.7	3	72.7	63	N	N	41.4	3.5
3	187	19	2	0	45.45	100	N	Y	0	8.75	0	34.0	82	Y	Y	28.9	9.01
4	10	23	4	7	79.55	30	Y	Y	22.7	5.7	5	43.1	68	N	Y	45.6	3.93
5	54	20	3	7	54.55	100	Y	N	33	4	6	59.0	104	Y	N	41	3.5
6	9	12	5	7	70.45	69.7	Y	Y	46	7.16	2	38.6	75	Y	Y	55.1	4.78
7	69	6	5	4	50	90	N	N	33.3	5.4	3	50	107	N	N	37.5	5.3
8	275	7	6	5	63.64	77	Y	N	0	6.7	0	0	119	N	N	45.5	4
9	4	16	6	5	9.09	75	Y	Y	25.9	8.52	2	2.27	87	Y	N	23.8	2.81
10	24	7.5	3	5	43.18	75	Y	Y	30.2	4.3	6	9.09	95	N	N	53.3	3.9
11	7	6	5	3	29.55	33	Y	N	34	6.3	0	4.55	200	Y	N	41	4.8
12	194	6	4	6	65.91	20	Y	Y	0	5.9	2	40.9	83	Y	Y	33	6
13	8	11	4	6	59.09	50	Y	N	47.9	3.95	3	70.4	75	Y	N	50	3.6
14	6	8	5	8	81.82	50	Y	N	21.4	4.9	0	13.6	85	N	N	44.1	4.5
15	108	10	4	4	52.27	85	Y	Y	30.8	7.51	0	29.5	55	Y	Y	32.9	6.62
16	23	9	4	5	59.09	40	Y	Y	43.3	10	7	50	?	Y	Y	48	6

Delay: time elapsed between primary and revision surgery; *DN4*: neuropathic pain questionnaire, *Y*: yes; *N*: no; *NCV*: nerve conduction velocity.

normal. One patient from group II (patient 6) suffered a wound infection attributed to *Staphylococcus aureus* 6 weeks postoperatively. The Canaletto® implant was removed and extensive lavage of the surgical site was performed. The infection resolved. Carpal tunnel signs and symptoms improved slightly clinically and on EMG.

Discussion

When assessing failures of CTS primary surgery, recalcitrant cases (where symptoms do not disappear after primary surgery) should be distinguished from recurrent cases (where symptoms disappear after the primary surgery but reappear 3 months or more later) [6]. The most common cause of recalcitrant CTS is incomplete transection of the flexor retinaculum. Iatrogenic nerve lesions are a rare cause of recalcitrant syndrome [7]. The most common cause of recurrent CTS is perineural fibrosis [8].

For both recalcitrant and recurrent CTS, it is widely recognized that the revision procedure should repeat the median nerve release to prevent new perineural fibrosis. Many procedures have been described, such as the interposition of biomaterials [9] or the use of a flap to envelop the nerve and restore a gliding plane [10]. Regardless of the procedure, the outcomes are poor or even unpredictable even after multiple operations, because symptoms persist in 43%–90% of revision cases. Among these cases, 20% are treatment failures [11,12]. While one study concluded that the best outcomes were obtained using the Canaletto implant® [13], only 17 of the 400 cases were recurrent CTS and the results did not distinguish recurrent CTS cases from other cases.

Our study sought to compare the Canaletto® implant combined with resorbable Dynavisc® gel *versus* resorbable Dynavisc® gel alone.

The Canaletto® implant was positioned through a short incision that was long enough to carry out another nerve release but short enough to avoid extensive dissection. When the nerve had deviated to the radial side of the carpal tunnel, this second nerve release allowed it to return to the center in all cases. The Canaletto® implant has two advantages. First of all, it avoids elongating the median nerve by reconstructing a gliding surface thanks to the silicone that covers the deep aspect of the implant facing the nerve. Secondly, it avoids anterior subluxation of the median nerve through reconstruction of the retinaculum, which is usually lax after primary surgery [3]. The Canaletto® implant has two drawbacks. The first is related to its connection to the two ends of the retinaculum. If the connection is made with absorbable sutures, the implant is likely to migrate into the carpal tunnel. If the connection is made with non-absorbable sutures, impingement between the knots and the adjacent soft tissues may occur. However, we did not encounter such complications in our case series. The second drawback is related to the fact that the implant's anti-adherent effect only happens on the volar surface of the median nerve. Therefore the combination with Dynavisc® absorbable gel seems advantageous.

The Dynavisc® gel is a compound of two polymers: polyethylene oxide and carboxymethylcellulose. Polyethylene oxide is a high molecular weight polymer that prevents adhesions because of its biochemical properties. It prevents fibrosis by inhibiting the recruitment of fibroblasts. Carboxymethylcellulose is a polymer that prevents adhesions by acting as a physical barrier [14]. It has several advantages. First, this gel is dissolved by hydrolysis in 1 months' time. Clinical studies in spine surgery [15] and gynecology [16] have confirmed these properties. Secondly, applying this gel around the median nerve recreates an area of circumferential gliding, which differs from the mechanism of the Canaletto® implant.

Our study had some limitations. From a statistical point of view, the low number of patients recruited limits our interpretation of the results. From a descriptive point of view, the two groups were not strictly comparable. Nineteen percent of the patients in Group I had polyneuropathy whereas 25 percent had polyneuropathy in group 2. The presence of diabetes as comorbidity, since it is a common cause of polyneuropathy, is usually associated with poor outcomes in CTS revision surgery [17,18]. None of the diabetic patients included in our study had poor outcomes. None of the patients in group I and 7 patients in group II suffered from persistent CTS. Persistent CTS in the absence of an iatrogenic cause or associated to cervical syndromes leads to poorer results compared to those of recurrent CTS [19]. This is not what we observed in the 7 cases of persistent CTS in our case series. Our analysis showed that 3 patients in Group I (patient 3,11a,11b) did not improve after carpal tunnel revision surgery. These patients did not have additional risk factors, except for one patient who had been diagnosed with an occupational disease (3). The diagnosis of an occupational illness is considered a risk factor for poor outcomes [20].

The main hypothesis was not verified since the difference in the preoperative versus postoperative pain in patients who had undergone revision surgery combining the Canaletto® implant and Dynavisc® gel was not significantly lower than the difference in the group treated with Dynavisc® gel alone. Only the secondary hypothesis about the difference between the preoperative/postoperative QuickDASH score was verified, since the difference in the group treated with Canaletto® and Dynavisc® gel was lower than the difference in the group treated with Dynavisc® gel alone. Our additional secondary hypotheses were not verified: strength, paresthesia, atrophy, sensory conduction speed and distal motor latency.

Our results seem to show that for recurrent or recalcitrant CTSs, the combination of Dynavisc® gel applied around the median nerve and the Canaletto® implant after nerve release produces results as good as using the Dynavisc® gel alone. Moreover, a significant improvement of the QuickDASH score was found when no Canaletto® implant was used.

Conclusion

For recurrent or recalcitrant CTS, we recommend applying Dynavisc® anti-adhesion gel alone around the median nerve after neurolysis. This technique seems as effective as other techniques described in literature, but is less invasive and time-consuming, and is not associated with donor site morbidity.

Conflicts of interest

Philippe Liverneaux has conflicts of interest with Newclip Technics®, Argomedical™.

None of the other authors have conflicts of interest.

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