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Tobacco use predicts poorer clinical outcomes and higher post-operative complication rates after open elbow arthrolysis

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Abstract

Introduction Tobacco use is a worldwide public health problem, and has been found to be a predisposing factor for adverse functional outcomes and increased postoperative complication rates after various orthopedic operations. The purpose of this study was to determine the potential impact of tobacco use on open arthrolysis for post-traumatic elbow stiffness.

Materials and methods A database search identified 145 patients with open arthrolysis performed for post-traumatic elbow stiffness; these were divided into three groups: current tobacco users (37), former users (28), and nonusers (80). All surgeries were performed using the same technique by the same doctor. General patient data, functional performance, and complications were documented and analyzed.

Results Demographic data and disease characteristics were comparable at baseline. Postoperatively, significant differences were found among the three groups in terms of range of motion ($P < 0.001$), Mayo Elbow Performance Score ($P = 0.006$), visual analog scale score for pain ($P = 0.015$), Dellon classification for ulnar nerve symptoms ($P = 0.013$), and total complication rates ($P < 0.001$). The current tobacco users group had the poorest clinical outcomes and highest complication rates, while no significant differences were found between former users and nonusers.

Conclusions Current tobacco users reported increased risk of poorer clinical outcomes and higher postoperative complication rates after open arthrolysis. Former users were found to have outcomes similar to those of nonusers. This study underlines the importance of discontinuing tobacco use for patients with post-traumatic elbow stiffness who are considering open arthrolysis.

Level of evidence Level III; Retrospective Cohort Design; Therapeutic Study.

Keywords Post-traumatic elbow stiffness · Open arthrolysis · Tobacco use · Clinical outcomes · Complications

Introduction

Normal elbow motion ranges between approximately 0° (full extension) and 140°–150° of flexion. Forearm rotation varies, but averages about 75° of pronation and 85° of supination. Morrey et al. estimate that the minimum motion required for relatively normal function is an extension–flexion arc of 100° (between 30° and 130°) and forearm rotation of 100° combined pronation and supination [20]. The elbow is more susceptible than any other joint to motion loss after trauma. Post-traumatic elbow stiffness is a well-recognized disabling condition that causes functional impairment in the upper limb and interferes with daily activities, with an incidence ranging from 3 to 20% [10]. Fibrosis and thickening of the capsule and periarticular soft tissues [12] as well as heterotopic ossification (HO) formation [22] are the most important and most common etiologies. The purpose of treatment is to achieve a functional range of motion (ROM)

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and a pain-free, stable elbow [13]. Open arthrolysis is still the most common treatment method and has been proven to be effective, with a relatively low incidence of complications, by releasing soft tissue and excising ectopic bone [4].

Tobacco use is a worldwide public health problem. About one billion people in the twenty-first century are expected to die from tobacco use, according to a global tobacco epidemic report from the World Health Organization [8]. Besides large negative impacts on age-related chronic diseases [18], tobacco use has been suggested to be a deleterious factor on clinical outcomes and postoperative complications in elective orthopedic surgeries [7, 27, 28, 32], including increased postoperative infection [28] and dissatisfied nerve function recovery [5, 24], and so on, in part owing to its effects on tissue oxygenation and inflammatory healing processes [29].

To our knowledge, however, no previous study has discussed the impact of tobacco use on the clinical outcomes and complications of open arthrolysis for post-traumatic elbow stiffness; this was the aim of this study. Given the evidence that tobacco use is a predisposing factor for adverse functional outcomes and increased complications after various orthopedic procedures, we hypothesized that tobacco use would have a similar negative effect on open elbow arthrolysis.

Materials and methods

Patients

This was a retrospective cohort design study that assessed patients who presented to our institution with elbow stiffness between January 2015 and December 2016. Patient medical records were reviewed via an electronic database. Our indications for arthrolysis were: (1) failed 6-month preservative therapy;(2) extension > 30° or flexion < 130°; and (3) willingness to undergo surgery. Contraindications were: (1) HO in development; (2) local history of soft tissue infection; (3) complete destruction of articular cartilage or articular fusion; (4) inability to cooperate with postoperative rehabilitation program; or (5) severe systematic disorders and intolerance to surgery. For patients who underwent arthrolysis, inclusion criteria were: (1) stiffness caused by trauma and (2) patient treated with open arthrolysis. Exclusion criteria were: (1) patient being less than 18 years at the time of arthrolysis; (2) stiffness being associated with severe burns or central nervous system injuries; (3) stiffness being associated with nonunion or malunion of the elbow joint; (4) stiffness being associated with forearm rotation dysfunction caused by abnormal distal radioulnar joint or forearm interosseous membrane; or (5) prior elbow release. During the period of this study, 256 patients underwent surgery for elbow stiffness at our institution. Of these, 208 met the inclusion criteria, and 47 were discounted by the exclusion criteria. In addition, 16 of the remaining 161 patients were excluded because of refusal to participate or loss to follow-up.

For the purposes of this study, patients were categorized by their smoking status, according to previously described methods [7, 32]. Among these, "current tobacco users" were defined as those who reported tobacco use within 1 year prior to arthrolysis, regardless of history of smoking by pack-years (calculated as the number of packs of cigarettes smoked per day multiplied by the number of years the patient has smoked). "Former users" were defined as those who reported no tobacco use in the past year but who reported at least one pack-year of smoking in their lifetime. Patients who reported no tobacco use in the past year, and for whom no pack-year history of smoking was recorded, were called "nonusers." Accordingly, the 145 participants were divided into three groups, with 37 patients in the current tobacco users group (CU), 28 in the former users group (FU), and 80 in the nonusers group (NU).

Surgical technique

All procedures were performed in the supine position under general anesthesia by the same surgeon (Cunyi Fan), with a sterile air tourniquet applied. The incision was chosen depending on prior surgical approach and location of disease. In general, a combination of the lateral column approach and medial approach posterior to medial epicondyle was performed, unless the patient had previously undergone surgery via a posterior approach.

In the medial approach, identification and release of the ulnar nerve were routinely performed from the ligament of Struthers, proximally, to its entry under the flexor carpi ulnaris, distally. Then, the margins of the triceps tendon were split and reflected off the distal humerus, and the posterior capsule and medial collateral ligament (posterior and transverse bundles) released. Bony impediments or scar tissue present within the olecranon fossa were removed under direct visualization, and plasty of the olecranon was performed. A pie-crusting technique of triceps tendon release was often performed to improve flexion contracture [31].

In the lateral approach, the extensor origins of the brachioradialis and extensor carpi radialis longus tendons were elevated off the lateral epicondyle to expose the anterior part of the elbow. The brachialis was then mobilized off the distal humerus to the medial-anterior part with the radial nerve, using an elevator. The lateral collateral ligament was partially released, and the hypertrophic anterior capsule excised. Then, the radial and coronoid fossae were cleared under direct visualization, and plasty of the coronoid fossa was performed. When the patient presented with limited forearm rotation, the annular ligament and radiohumeral joint were released, with attention paid to the posterior interosseous nerve. An exploration and release of the radial nerve would be performed if the patient had a very long disease duration or injury in childhood, especially for severe extension deformity.

For patients with an internal fixator, which would be a probable block factor for motion restriction or would hinder operative procedures such as HO excision or soft-tissue release, an internal fixator removal could be performed if the previous fractures were well healed as evaluated by X-ray, CT, and clinical symptoms; however, the principle of "release first, removal next" in the case of iatrogenic fractures [3] should be followed.

Though accompanied by pin-related complications, the following benefits were reported in our former studies for applying a hinged external fixator: properly resisting rotatory, shearing, and varus-valgus force; maintaining elbow stability, and improving the efficacy of daily rehabilitation [17, 33]. A hinged external fixator (Orthofix, Verona, Italy) was routinely applied to the elbow along its rotational axis and identified by C-arm radiography for all patients. First, the fixator was fixed to the elbow along the rotational axis after drilling a 2.0-mm Kirschner wire into the lateral humeral condyle. Second, blunt dissection up to the bone surface was performed with the help of a separator rod and protection sleeve, after two parallel skin incisions on the lateral side of the arm. Third, two respective 4.5-mm fixator pins were inserted vertically into the middle humerus through predrilled holes. A similar surgical procedure was performed on the distal component, with the forearm maintained in supination. Two 4.0-mm pins were inserted into the dorsolateral side of the distal radius.

After proper external fixation, the Kirschner wire was pulled out. Collateral ligaments were repaired by anchor sutures. The ulnar nerve was transposed subcutaneously. Two drainage tubes were left to prevent hematoma, and the wound was closed in layers after local application of vancomycin powder.

Postoperative treatment

A postoperative rehabilitation program was introduced, consisting of three steps.

1. From the first day to 6 weeks, celecoxib (200 mg orally, twice daily) was prescribed as a precaution against HO. Patients were instructed to lift the upper limb and perform active muscle contraction. Early rehabilitation with cryotherapy was administrated under supervision: active-assisted-passive cycles of flexion and extension (30 on the first day, increasing by 30 per day until 300 were achieved) and forearm rotation exercises (temporary removal of the external fixator, at least 2 times per day).
2. The second step, lasting 3 months, began after the hinged external fixator was removed at 6 weeks in the outpatient operating room. In this step, besides flexion and extension exercises, a systematic forearm rotation rehabilitation program was initiated.
3. In the third stage, lasting until at least 1 year, continued exercises (for at least 30 min, 3 times per day) were instructed, and weight-bearing exercises were encouraged, starting with 1 kg under supervision.

Clinical evaluation

For all participants, demographic characteristics, history of injury and treatment, elbow function and pain evaluation, ulnar nerve symptoms, and HO classification were recorded at baseline. Demographic data included sex, age, and body mass index. Detailed initial injury data included disease duration, affected dominant limb, fracture location, and treatment history. Fracture location was classified as singular (distal humerus, radial head, olecranon, or coronoid) or combined (concomitant fractures of the distal humerus, radial head, or proximal ulna involving more than one location). Original treatment history was classified as operation or non-operative treatment. Physical examinations of the elbow included flexion, extension, and ROM (flexion–extension). Motion was measured by a handheld goniometer. The Mayo Elbow Performance Score (MEPS) and the visual analog scale (VAS) for pain were also obtained at baseline. MEPS is a widely used elbow-specific scoring system, whose scores are classified into four categories: excellent, 90–100; good, 75–89; fair, 60–74; and poor, 0–59. The VAS is a widely used tool to measure pain intensity along a 10-cm line, ranging from no pain (left end) to worst pain (right end). The ulnar nerve was evaluated by the Dellon classification [6]. Hastings [11] proposed a radiographic and clinical classification, distinguishing three classes of elbow HO: I, no functional limitation; IIA, limited flexo-extension; IIB, limited prono-supination; IIC, IIA combined with IIB; III, ankylosis. At the final postoperative follow-up, elbow motion and function, pain, and ulnar nerve symptoms were all evaluated. In addition, postoperative complications such as new onset or exacerbation of nerve symptoms, recurrent HO, elbow instability, wound infection, and pin-related complications were also recorded.

Statistical analysis

Continuous variables were presented as mean ± standard deviation (range) when they are normally distributed; otherwise, the median and interquartile range were reported. Qualitative variables were presented as number and percentages.

Analysis of variance (ANOVA) or Kruskal–Wallis test was used to compare continuous data, and the least significant difference test was chosen to evaluate intergroup differences when ANOVA showed significant differences among the three groups. Kruskal–Wallis, Fisher's exact, or Pearson's χ^2 test was used to compare qualitative data. Associated P values < 0.05 were considered statistically significant. Statistical analysis was performed with IBM SPSS software (version 22.0; IBM, Armonk, NY, USA).

Results

Demographic data, clinical characteristics, and preoperative data were comparable at baseline (Tables 1, 2; Fig. 1). At the final follow-up, significant improvements in mean elbow motion, functional and pain scores, and ulnar nerve symptoms were found (Figs. 1, 2). Among these, physical examination findings indicated significant differences among the three groups in extension ($P = 0.001$), flexion ($P = 0.001$), and ROM ($P < 0.001$). Interestingly, ROM in the FU group (125 ± 11, $P < 0.001$) and the NU group (118 ± 17, $P < 0.001$) were higher than in the CU group (105 ± 23); while no difference was found between the NU and FU groups ($P = 0.074$; Table 3; Fig. 1a). As for clinical function scores, the MEPS in the CU group (88 ± 11 points) was the worst ($P = 0.006$) among the three groups, with no difference ($P = 0.324$) between the FU (95 ± 7 points) and NU (93 ± 9 points) groups, as well as the score ratings ($P = 0.027$), in which the FU ($P = 0.023$) and NU ($P = 0.017$) groups were both better than the CU group (Table 3; Fig. 1b). The mean VAS pain scores in the FU and NU groups were 0.8 ± 1.2 ($P = 0.015$) and 0.9 ± 1.4 ($P = 0.008$) points, both lower than in the CU group (1.8 ± 1.8 points), with a significant difference among the three groups ($P = 0.015$; Table 3; Fig. 1c). A total of 25 patients complained of ulnar nerve symptoms at the final follow-up, including 11, 4, and 7 graded I according to the Dellon classification [6] in CU (Fig. 2a), FU (Fig. 2b), and NU (Fig. 2c), respectively; one graded II for each group; and the rest with no ulnar nerve symptoms: a significant difference was found among the three groups ($P = 0.013$; Table 3), showing that the CU group had the worst results.

Due to the relatively small number of patients and relatively low complication rates, complications in the CU group were compared with a combined FU and NU (FNU) group (Table 4). The total complication rate of the CU group, at 49%, was significantly higher ($P < 0.001$) than that of the FNU group, at 18%. In addition, 6 (16%) patients in the CU group presented with new onset or exacerbation of ulnar nerve symptoms, while only 6

Table 1 Demographics and clinical characteristics of patients

Characteristics	CU	FU	NU	P value
No. of patients	37	28	80	
Male, *n*	29 (77)	20 (71)	48 (60)	0.124
Age, years	35 ± 12	39 ± 12	37 ± 11	0.490
Body mass index, kg/m^2	23.6 ± 3.1	22.5 ± 2.8	22.9 ± 3.2	0.326
Disease duration[a], months	15, 11–21	15, 11–25	14, 10–20	0.685
Dominant Limb, *n*	20 (54)	19 (68)	46 (58)	0.511
Initial injury, *n*				0.576
Singular fracture	28 (76)	23 (82)	67 (84)	
Combined fractures	9 (24)	5 (18)	13 (16)	
Treatment history, *n*				0.447
Operation	34 (92)	23 (82)	68 (85)	
Conservative therapy	3 (8)	5 (18)	12 (15)	
Follow-up Time[b], months	24 ± 7	22 ± 6	22 ± 7	0.320

Categorical variables are presented as number (%)

Continuous variables are presented as mean ± standard deviation, or median, interquartile range

CU current tobacco users group, *FU* former users group, *NU* nonusers group, *BMI* body mass index

[a]Length of time with stiff elbow

[b]Postoperative period after elbow release

Table 2 Clinical evaluation of patients: preoperative data

Characteristics	CU	FU	NU	P value
No. of patients	37	28	80	
Extension, °	41 ± 15	40 ± 19	39 ± 19	0.806
Flexion, °	76 ± 23	79 ± 21	81 ± 21	0.512
ROM, °	35 ± 26	39 ± 26	42 ± 27	0.386
MEPS, points	70 ± 11	64 ± 13	69 ± 13	0.106
Excellent, *n*	3 (8)	1 (4)	5 (6)	0.129
Good, *n*	11 (303)	7 (25)	27 (34)	
Fair, *n*	21 (57)	12 (43)	40 (50)	
Poor, *n*	2 (5)	8 (29)	8 (10)	
Pain VAS, points	1.5 ± 1.6	1.9 ± 2.4	1.5 ± 1.8	0.572
Ulnar nerve symptoms, *n* (Dellon classification [6])				0.970
None	27 (73)	21 (75)	59 (74)	
Grade I	5 (14)	4 (14)	12 (15)	
Grade II	4 (11)	3 (11)	6 (8)	
Grade III	1 (3)	0 (0)	3 (4)	
HO, *n* (Hastings and Graham classification [11])				0.181
None	5 (14)	8 (29)	18 (23)	
Grade IIA	15 (41)	8 (29)	40 (50)	
Grade IIC	8 (22)	9 (32)	9 (11)	
Grade III	9 (24)	3 (11)	13 (16)	

Categorical variables are presented as number (%)

Continuous variables are presented as mean ± standard deviation

CU current tobacco users group, *FU* former users group, *NU* nonusers group, *ROM* range of motion, *MEPS* Mayo Elbow Performance Score, *VAS* visual analog scale, *HO* heterotopic ossification

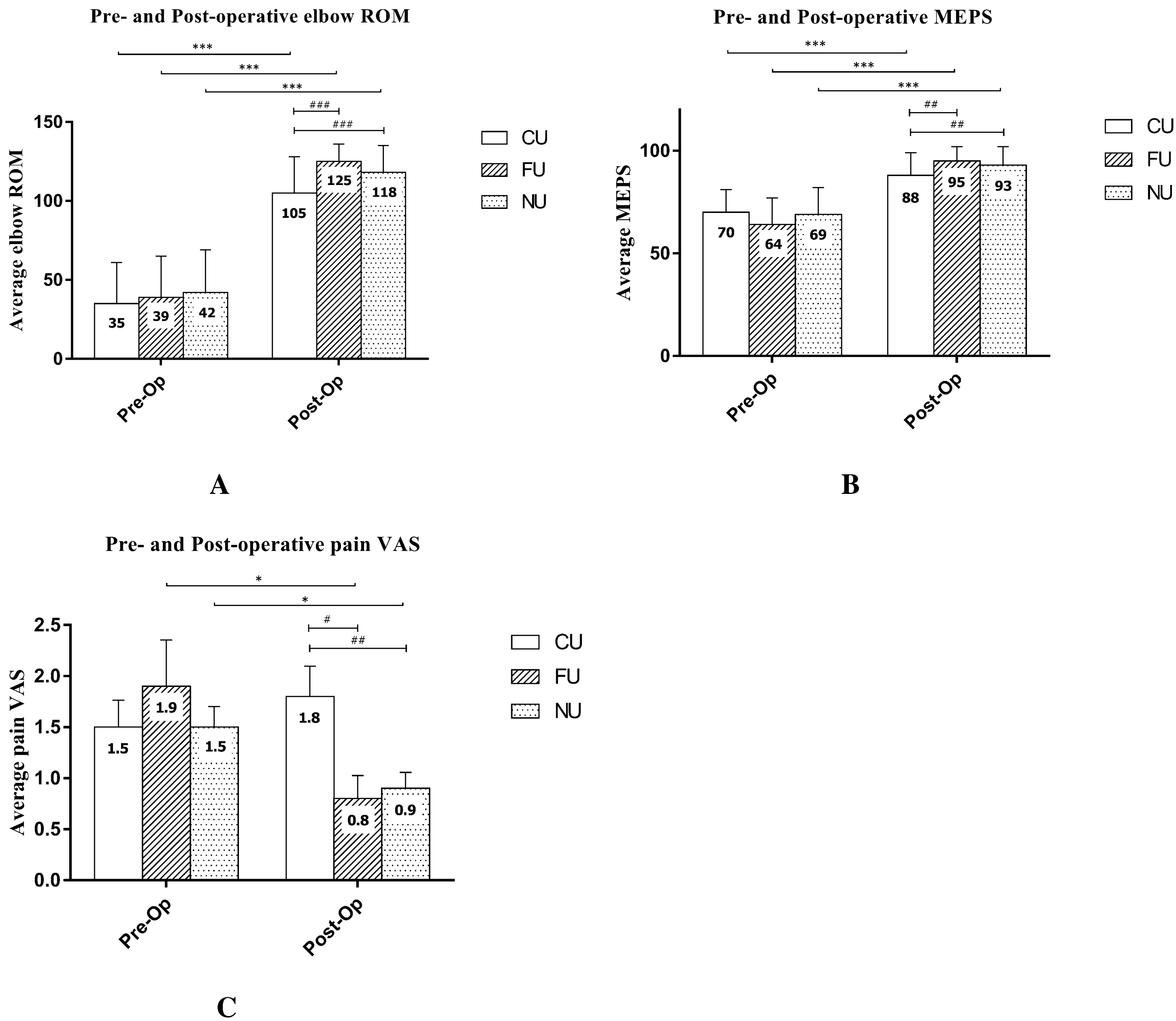

Fig. 1 Comparison of elbow ROM (**a**), MEPS (**b**), and pain VAS (**c**) pre-operatively and post-operatively. (1) Intra-group differences between pre- and post-operative data in group CU, FU, and NU, respectively: $^{*}P<0.05$, $^{**}P<0.01$, and $^{***}P<0.001$. (2) Inter-group differences among group CU, FU, and NU pre- and post-operatively: $^{\#}P<0.05$, $^{\#\#}P<0.01$, and $^{\#\#\#}P<0.001$. (3) *CU* current tobacco users group, *FU* former users group, *NU* nonusers group, *ROM* range of motion, *MEPS* Mayo Elbow Performance Score, *VAS* visual analog scale for pain, *Pre-op* pre-operation, *Post-Op* post-operation

(6%) in the FNU group did so ($P=0.042$). Furthermore, 11% recurrent HO was found in the CU group, including three grade IIA and one grade IIC; this was higher (not significant, $P=0.128$) than the FNU group (3%), which included two for IIA and one for IIC. One patient in each group ($P=0.447$) had moderate elbow instability (< 10° of varus-valgus laxity), which was regained by the final follow-up. As for infection complication, two wound infections were found in each group ($P=0.269$); however, the pin-related complication rate in the CU group (11%) was higher ($P=0.037$) than in the FNU group (2%).

Discussion

With an activated myofibroblast-mast–cell-neuropeptide axis [12] and a local osteoinductive microenvironment [22], the elbow is more vulnerable to motion loss after trauma than any other joint. A systematic review of 798 patients in 30 studies reported the effect of open (with or without external fixation) or arthroscopic arthrolysis for post-traumatic elbow stiffness, in which a mean gain in motion of 40° was shown for arthroscopic arthrolysis, 51°

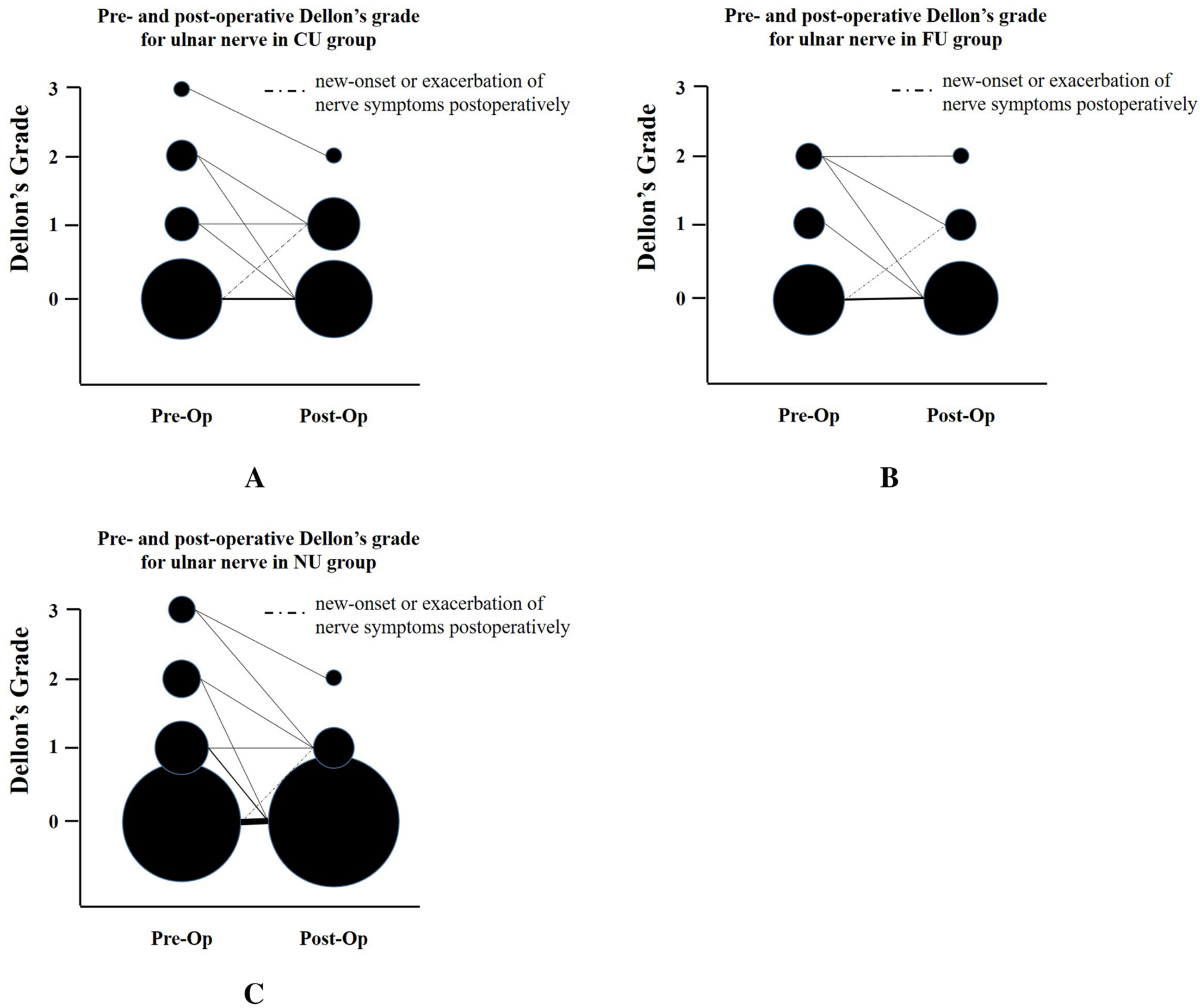

Fig. 2 Dellon's grade for ulnar nerve in CU (**a**), FU (**b**), and NU (**c**) groups pre- and post-operatively. (1) Significant difference was found between preoperative and postoperative data in NU group ($P = 0.005$). (2) *CU* current tobacco users group, *FU* former users group, *NU* nonusers group, *Pre-op* pre-operation, *Post-Op* post-operation

for open arthrolysis, and 88° for open arthrolysis combined with an external fixation [13]. The follow-up results in our study showed a mean gain of 78° after open arthrolysis with external fixation, with a total complication rate of 25.5%, which was similar with the average level after open arthrolysis [4]. For years, the gold standard for the treatment of stiff elbows was open surgical release; arthroscopic arthrolysis was predominantly performed in elbows with simple contractures with a minor restriction in ROM [2], depending on the surgeon's expertise level with elbow arthroscopy, status of the ulnar nerve, formation and location of HOs, extent of the contracture, and articular surface damage.

Recently, great attention has been paid to the relationship between tobacco use and orthopedic surgery outcomes, mostly showing negative effects on postoperative outcomes [7, 21, 30, 32] and increased complication rates [14, 28, 32]. This study reported new data concerning the association of tobacco use with poorer clinical outcomes and higher complication rates after open arthrolysis in patients with post-traumatic elbow stiffness. Although most patients showed significant improvement after operation, the postoperative outcomes of current tobacco users were inferior to those of former users or nonusers, underlining the importance of discontinuing tobacco use for patients with post-traumatic elbow stiffness who are considering open arthrolysis.

Fibrosis and adhesion have been reported to have a close relationship with smoking through ERK [15] and TGF-Beta [26] signaling pathways, which have been presumed to play an important role in the development of post-traumatic

Table 3 Clinical evaluation of patients: postoperative data

Characteristics	Results			*P* value	Comparison		
	CU (*N* = 37)	FU (*N* = 28)	NU (*N* = 80)		CU vs. FU	CU vs. NU	FU vs. NU
Extension, °	17 ± 17	5 ± 5	9 ± 12	0.001**	< 0.001***	0.003**	0.122
Flexion, °	121 ± 11	130 ± 6	127 ± 9	0.001**	< 0.001***	0.002**	0.165
ROM, °	105 ± 23	125 ± 11	118 ± 17	< 0.001***	< 0.001***	< 0.001***	0.074
MEPS, points	88 ± 11	95 ± 7	93 ± 9	0.006**	0.003**	0.009**	0.324
Excellent, *n*	14 (38)	18 (64)	49 (61)	0.027*	0.023*	0.017*	0.685
Good, *n*	20 (54)	10 (36)	28 (35)				
Fair, *n*	3 (8)	0 (0)	3 (4)				
Pain VAS, points	1.8 ± 1.8	0.8 ± 1.2	0.9 ± 1.4	0.015*	0.015*	0.008**	0.721
Ulnar nerve symptoms, *n* (Dellon classification [6])				0.013*	0.212	0.003*	0.266
None	25 (67)	23 (82)	72 (90)				
Grade I	11 (30)	4 (14)	7 (9)				
Grade II	1 (3)	1 (4)	1 (1)				

Categorical variables are presented as number (%)

Continuous variables are presented as mean ± standard deviation

CU current tobacco users group, *FU* former users group, *NU* nonusers group, *ROM* range of motion, *MEPS* Mayo Elbow Performance Score, *VAS* visual analog scale

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Table 4 Distribution of postoperative complications

Characteristics	CU	FU and NU	*P* value
No. of patients	37	108	
Total number of complications, *n*	18 (49)	19 (18)	< 0.001***
Nerve complications[a], *n*	6 (16)	6 (6)	0.042*
Ulnar nerve	6 (16)	6 (6)	
Radial nerve	0 (0)	0 (0)	
Median nerve	0 (0)	0 (0)	
Recurrent heterotopic ossification, *n*	4 (11)	3 (3)	0.128
Elbow instability, *n*	1 (3)	1 (1)	0.447
Wound infection, *n*	2 (5)	2 (2)	0.269
Pin-related complications, *n*	4 (11)	2 (2)	0.037*
Others[b], *n*	1 (3)	5 (5)	0.519

Categorical variables are presented as number (%);

CU current tobacco users group, *FU* former users group, *NU* nonusers group

*$P < 0.05$; ***$P < 0.001$

[a]New-onset or exacerbation of nerve symptoms postoperatively

[b]Including refracture, hematoma, synovitis, tricep avulsion, incomplete wound healing with a sinus, wound dehiscence and intrarticular bleeding

joint contractures and tendon adhesions [16]. The negative effects of smoking on disability scores were reported in a study including 13,704 patients with spinal disorders [21], as well as on patients' quality of life after surgery for herniated lumbar disks [30]. In our study, the CU group not only had significantly lower MEPS scores (88 points, $P = 0.006$), but also lower excellent–good ratings on MEPS (38–54%, $P = 0.027$). In addition, the elbow ROM of the CU group (105°, $P < 0.001$) was inferior to that of the FU (125°) and NU (118°) groups at the final follow-up. Therefore, current tobacco users should be counseled preoperatively to temper their postoperative expectations.

Several studies have shown the intimate relationship between smoking and pain; on the one hand, analgesic effects can be produced when nicotine interacts with nicotinic acetylcholine receptors (nAChRs), while on the other hand, the structure and function of nAChRs change in long-term smokers, resulting in the desensitization of nAChRs and the increase in the number of receptors, which may lead to pain hypersensitivity [1]. A significant association ($X^2 = 546.3$, $P < 0.001$) was reported between back pain and tobacco use, and back pain was found to increase with increased smoking exposure [9]. In addition, tobacco use was reported to be associated with increased postoperative pain and narcotic use in patients after total shoulder arthroplasty [32]. In our study, the CU group had the highest VAS (1.8 points, $P = 0.015$) for pain at the final follow-up.

Multiple studies have suggested that individuals who smoke are at increased risk of developing ulnar neuropathy at the elbow due to a microvascular change, which is positively associated with a dose–response effect [23]. Tobacco use was also reported to be a risk factor for the outcomes of simple decompression of the compressed ulnar nerve [5] and peripheral nerve injury recovery [24]. In our study, a total of 25 patients complained of ulnar nerve symptoms: 11 (30%) grade I and 1 (3%) grade II in the CU group, for a significant difference ($P = 0.003$) compared with the 7 (9%) grade I and 1 (1%) grade II in the NU group, according to the Dellon classification [6] at the final follow-up.

A systematic review involving 810 patients reported overall new onset or exacerbation of ulnar nerve symptoms (8.6%), recurrent HO (5.6%), elbow instability (1.0%), wound infection (1.6%), pin-related complications (17.4%), and total complication rate (24.3%) after elbow arthrolysis [4]. Most complication rates in the CU group were higher than average, while lower than average in the FU and NU groups; the total complication rate of the CU group (49%) was significantly higher ($P < 0.001$) than that of the FNU group (18%). A significant difference was found in new onset or exacerbation of ulnar nerve symptoms ($P = 0.042$); however, due to incomplete data on how many patients had had ulnar nerve addressed at the first surgery with neurolysis and possibly transposition, unfortunately, it is hard to separate the late complications of worsening or initiation of ulnar neuropathy from the effect of tobacco use, and this finding should, therefore, not be ascribed to the arthrolysis itself. This would influence the results regarding the negative impact of tobacco use on the nerve complication rate, and should be investigated in another prospective study in the future. As for postoperative infection, in a prospective study including 8370 patients who underwent primary THA or TKA at the Mayo Clinic, from 2010 to 2013, the hazard ratios for deep infection (HR = 2.37; 95% CI = 1.19–4.72; $P = 0.01$) were higher in tobacco users [28]. Furthermore, smokers have been reported to have a significantly higher risk of surgical site infection (OR = 1.26; 95% CI = 1.05–1.51) in a meta-analysis including 26 independent observational studies involving 67,405 patients who underwent spinal surgery [14]. A similar significant difference was found in the pin-related infection complication rate (11% vs 2%, $P = 0.037$) in our study.

An important finding of this study is the comparison between patients who currently smoke (CU) and those who have had a history of smoking but quit (FU), demonstrating improved outcomes after arthrolysis in those who quit smoking. To date, the effect of smoking cessation has remained unclear, because the previous studies have shown mixed results [19, 25]. In this study, conversely, the FU group was found to have similar postoperative outcomes to the NU group. This finding is of particular interest in that it identifies tobacco use as a risk factor that is modifiable; similar results were also reported in other studies [7, 32]. Recognizing tobacco use as a modifiable risk factor is important, because it allows improved preoperative counseling; it is possible that, through smoking cessation, patients may achieve better elbow function as well as decreased complication rates post-arthrolysis.

In addition to the study's retrospective nature, the relatively heterogeneous case series (due to the low prevalence of elbow stiffness) and the low number of patients analyzed were also limitations, which made it difficult to make more meaningful statistical comparisons among the three groups (especially for complications); therefore, further prospective research with a larger population from multiple clinical centers is needed to validate the results of this study.

Conclusions

Current tobacco users reported increased risk of poorer clinical outcomes and higher postoperative complication rates after open elbow arthrolysis. Former users were found to have outcomes similar to those of nonusers. This study underlines the importance of discontinuing tobacco use for patients with post-traumatic elbow stiffness who are considering open arthrolysis.

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Compliance with ethical standards

Conflict of interest The authors declare no competing financial interests.

Ethical approval The Ethics Committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital concluded that no approval was necessary for this study based on its retrospective design. Data were analyzed anonymously; all patients approved the publication of the results of this study by oral consent. The oral consent approval was documented in the patients' files. This was approved by the Ethics Committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital. All clinical investigations were conducted in accordance with the guidelines of the Declaration of Helsinki.

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