CLINICAL ARTICLE

Forearm Interosseous Membrane Maintains the Stability of Proximal Radioulnar Joint

Ning Zhang, Jia-hu Fang

[1]The First Affiliated Hospital of Nanjing Medical University, Nanjing, China

Objective: To evaluate the effect of the proximal and central bundles of the interosseous membrane on the stability of proximal radioulnar joint.

Methods: Twenty fresh samples of human forearm provided by the anatomy room of the Department of Human Anatomy of Nanjing Medical University were included in this study. They were used to explore the effect of proximal interosseous membrane bundle on the stability of proximal radioulnar joint. The proximal bundle was reconstructed along the original attachment point. The reconstructions of central bundle were divided into the reconstruction of original attachment point on radius-midpoint of the ulnar original attachment point (reconstruction A) and original attachment point reconstruction (reconstruction B). The loads of the proximal radioulnar joint in different positions were measured. The load of the proximal radioulnar joint was analyzed in neutral, pronation, and supination positions.

Results: After resection of proximal and central fascicles, the loads of proximal radioulnar joint in neutral, pronation, and supination positions were significantly lower than those before resection ($P < 0.05$). After reconstruction, the loads of proximal radioulnar joint in neutral and supination positions were higher than those after resection ($P < 0.05$). After reconstruction, the loads of proximal radioulnar joint in neutral and supination positions were higher than those after resection ($P < 0.05$), and that after reconstruction B in pronation position was higher than that after resection ($P < 0.05$), while there was no significant difference between reconstruction A and after resection ($P > 0.05$). In supination position, the load of reconstruction B was higher than that of reconstruction A ($P < 0.05$). After reconstruction of the proximal and central bundles, the proximal radioulnar joint could not reached the same load as it could before resection ($P < 0.05$).

Conclusion: The stability of proximal radioulnar joint is affected by central bundle and proximal bundle. Reconstruction can increase the stability of proximal radioulnar joint.

Key words: Biomechanics; Central bundle; Proximal bundle; Proximal radioulnar joint

Introduction

The forearm interosseous membrane is the fibrous connective tissue connecting the radius and ulna of the human body[1]. The interosseous membrane is usually divided into proximal bundle, central bundle, and distal bundle, which can be further subdivided into central bundle, distal oblique bundle, accessory bundle, dorsal oblique bundle, and proximal oblique bundle[2]. The forearm interosseous membrane plays an important role in maintaining the longitudinal stability of the forearm[3]. It has been reported that forearm interosseous membrane can also maintain the stability of distal radioulnar joint[4]. However, there are few studies on the stability of the proximal radioulnar joint.

The proximal ulnar-radial joint, interosseous membrane, and distal ulnar-radial joint jointly connect the radius and the ulna, and together undertake the rotation and load conduction of forearm. The injury of forearm interosseous membrane also has an impact on proximal ulnar-radial joint[5]. The injury of forearm interosseous membrane is relatively rare in clinic, which is often accompanied by Essex-

Address for correspondence Jia-hu Fang, The First Affiliated Hospital of Nanjing Medical University, 300 Guangzhou Road, Nanjing, Jiangsu Province, China 210000 Tel: +86-025-83718836; Fax: +86-025-83718836; Email: jiahu2020@126.com

Disclosure: None.
Received 7 May 2020; accepted 18 October 2020

Lopresti injury. The incidence of the injury is less than 1% of the radial capitulum fractures, which may also be related to the misdiagnosis and missed diagnosis of most patients in the early stage. The injury of forearm interosseous membrane is common in traffic accidents and high-energy injuries such as falling from a height. The injury mechanism is mainly caused by longitudinal violence when forearm is overextended. During the transmission of violence from the wrist to the proximal, it caused the rupture of the interosseous membrane of the forearm, as well as the injury of the distal radioulnar joint and the fracture of the small head of the radius. The forearm interosseous membrane, radial capitulum, and distal radioulnar joint are all involved in maintaining the longitudinal stability of forearm. After the above structures are injured, the longitudinal stability of forearm will be weakened, which will lead to complications such as the displacement of radius to the proximal end, the injury of brachioradialar joint, and the impact of ulna and wrist. When the forearm is injured by the interosseous membrane, it should be diagnosed and treated correctly in time. When it develops into chronic injury with complications of elbow joint and wrist joint, the treatment difficulty will increase and the curative effect will be poor.

However, how to reconstruct the injured interosseous membrane and how to connect the ulnar and radial joints to restore the longitudinal stability of the forearm are also clinical problems[6]. Therefore, the purpose of this study was to explore the effects of excision and reconstruction of the central and proximal interosseous membrane on the stability of the proximal radioulnar joint, so as to understand the biomechanical characteristics of the forearm interosseous membrane and the effects of different reconstruction methods on the stability of the proximal radioulnar joint.

Materials and Methods

Experimental Materials

Twenty fresh samples of human forearms provided by the anatomy room of the Department of Human Anatomy of Nanjing Medical University were included in this study. There were seven males and three females, who were aged from 43 to 79 years with an average age of (63.27 ± 7.69) years. X-ray fluoroscopy was used to exclude the factors affecting the experimental data, including fracture and degenerative lesions in forearm specimens. The forearm muscles, including pronator quadratus muscles and unrelated soft tissues, were removed, leaving only forearm interosseous membrane, annular ligament, ulna, radius, and wrist (Fig. 1A).

Experimental Grouping

According to odd and even numbers, 10 forearm specimens were divided into two groups. Group A (10 cases) were used to explore the effect of proximal interosseous membrane bundle on the stability of proximal radioulnar joint. Group B (10 cases) were used to explore the effect of the central bundle of the forearm interosseous membrane on the proximal radioulnar joint.

Fixed Specimens

Two holes with diameter of 3.5 mm were drilled down about 5 cm from the distal humerus. The distance between the two holes was about 3.5 cm. Two external fixing screws with diameter of 3.8 mm were screwed in and two small external fixing frames were used to fix the screws. The ulna was rotated 6° around its rotation axis of the geometric center of the ulna head, while the deflection bone was pronated 81° around the rotation axis of the geometric center line of the deflection bone. Then the proximal pronation model of the ulnar-radial joint was obtained. In addition, the deflection bone was rotated 79° around the rotation axis, while the ulna maintained a fixed status, thus the proximal pronation model of the ulnar-radial joint was obtained.

Interosseous Membrane Reconstruction

As shown in Fig. 1B, the proximal bundle was reconstructed along the original attachment point. The central bundle was reconstructed in two ways, including reconstruction of the central bundle original attachment point on radius – midpoint of the ulnar original attachment point (reconstruction A) (Fig. 1C) and the original attachment point reconstruction (reconstruction B) (Fig. 1D). The reconstructed material we used was mousse thread. According to different reconstructed methods, the attachment points were marked on the ulna and radius to drill a hole about 4.0 mm in diameter. The mousse thread passed through the bone hole and was fixed by polyethylene button at one end. The other end was tightened as far as possible in the neutral position of forearm and then fixed with ORTHOFIX transhumeral radial joint external fixator and supporting stent screw (ORTHOFIX, Italy).

Biomechanical Test

The loads of proximal radioulnar joint were measured by CMT4104 multi-functional electronic testing machine (Tianshui Sansi New Technology Co., China) when the deflection of the forearm sample shifted from 0.5 to 5.0 mm (0.5 mm interval). Slowly increase the distance between the ulna and radius from 0.5 to 5.0 mm, 0.5 mm each time. The loads of the neutral position of the forearm: the elbow joint is straight, the forearm is rotated outwards, the wrist joint is straight, and the palm is forward. Pronation < pronation: with forearm as the neutral position, the palm and elbow joint are facing straight ahead. At this time, the movement of turning the thumb forward is pronation. Postrotation < external rotation: take forearm as an example, the neutral position is the palm and elbow joint facing straight back, and the backward rotation of thumb is back rotation. Position of the proximal bundle of the interosseous membrane of the forearm: anterolateral of the coronoid process of the ulna to the tuberosity of the radius. On the surface of biceps tendon. The width is 3.7 ± 1.6 mm and the thickness is

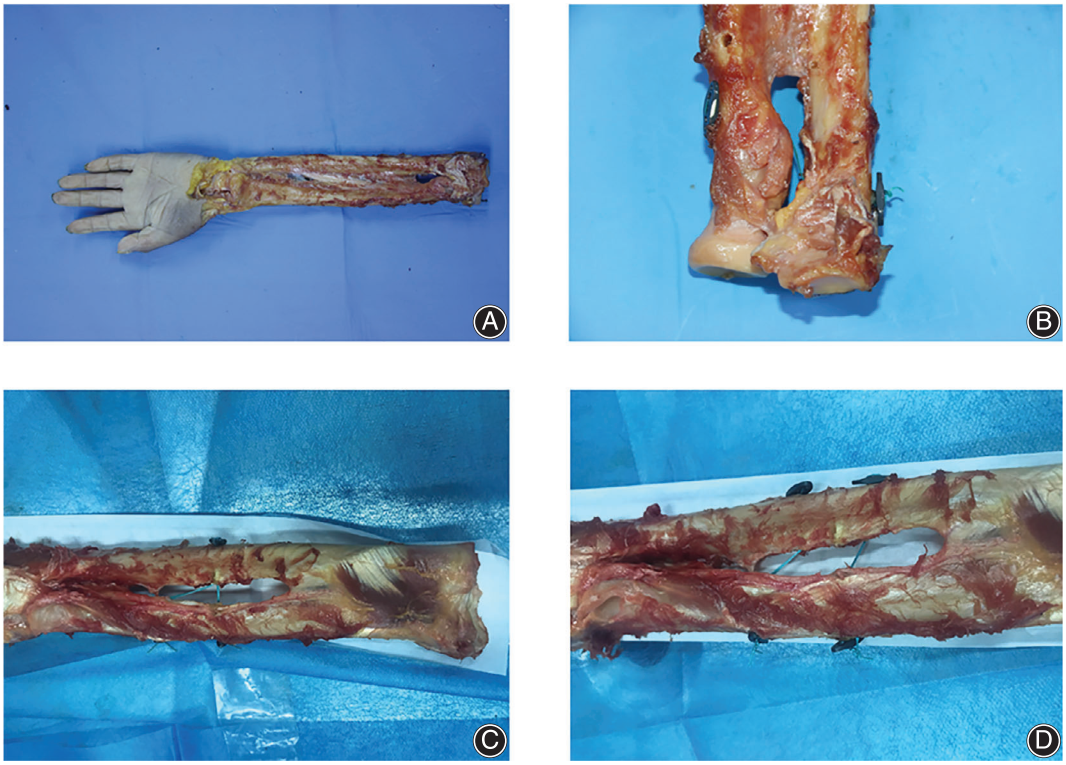

Fig. 1 The imagines of the patient. (A) The forearm muscles were removed, leaving only forearm interosseous membrane, annular ligament, ulna, radius, and wrist. (B) The proximal bundle was reconstructed along the original attachment point. (C) The method of reconstruction A. (D) The method of reconstruction B.

1.1 ± 0.5 mm. Central bundles < central bundles of interosseous membrane of forearm: the proximal end of radius obliquely ends at the distal end of ulna, forming an angle of 21° with radius and 28° with ulna. The distance from the attachment point of the distal and proximal edge of the central bundle to the styloid process of the radius is 53% and 64% of the total length of the radius, and the distance from the ulna to the ulnar head is 29% and 44% of the total length of the ulna. The width is 9.7 ± 3 mm and the thickness is 1.3 ± 0.2 mm. There are two methods of reconstruction: the reconstruction of the original start and end point of the button plate and the reconstruction of the middle point of the original attachment point of the radius – the original attachment point of the ulna. Each measurement was repeated three times.

Statistical Analysis

Statistical analysis was conducted using SPSS22.0 software (International Business Machines, corp., Armonk, NY, USA). Multivariable repeated variance analysis was used to analyze the load difference between the proximal and central bundles before resection, after resection, and after reconstruction. All data were expressed as means ± standard deviation (SD). Differences were considered statistically significant when $P < 0.05$.

Results

Effect of Proximal Bundle of Forearm Interosseous Membrane on Stability of Proximal Radioulnar Joint

With the proximal displacement of the radius, the variation trends of loads of proximal radioulnar joint in different positions showed significant difference before resection, after resection, and after reconstruction ($P < 0.05$). In addition, the loads of proximal radioulnar joint after proximal bundle resection were lower in neutral, pronation, and supination positions than those before resection ($P < 0.05$), while the loads of proximal radioulnar joint after reconstruction were higher in neutral and supination positions than those after resection ($P < 0.05$). However, there was no significant difference between pronation position and post-resection position ($P > 0.05$). The load after reconstruction was lower than that before resection ($P < 0.05$) (Tables 1, 2, and 3).

Effect of Central Bundle of Forearm Interosseous Membrane on Stability of Proximal Radioulnar Joint

With the proximal displacement of the radius, the variation trends of loads of proximal radioulnar joint in different positions showed marked differences before resection, after resection, and after reconstruction ($P < 0.05$). The loads of proximal radioulnar joint in neutral, pronation, and supination positions after central bundle resection were lower than

TABLE 1 The load of proximal bundle to proximal radioulnar joint (neutral position)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction (N)
0.50	6.44 ± 0.50	6.43 ± 0.26	6.55 ± 0.20
1.00	6.86 ± 0.52	6.74 ± 0.33	6.75 ± 0.24
1.50	7.58 ± 0.47	7.21 ± 0.46 [a]	7.15 ± 0.38 [a]
2.00	8.69 ± 0.86	8.02 ± 0.65 [a]	8.03 ± 0.54 [a]
2.50	11.93 ± 1.92	8.83 ± 0.65 [a]	9.71 ± 1.43 [ab]
3.00	17.56 ± 3.28	10.26 ± 0.96 [a]	13.19 ± 3.77 [ab]
3.50	27.14 ± 4.95	12.74 ± 1.71 [a]	18.32 ± 3.90 [ab]
4.00	41.60 ± 7.49	17.00 ± 2.56 [a]	26.93 ± 5.07 [ab]
4.50	58.71 ± 10.07	23.58 ± 4.63 [a]	37.55 ± 7.37 [ab]
5.00	77.98 ± 13.83	35.85 ± 8.45 [a]	53.44 ± 11.13 [ab]

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 175.289, $P < 0.001$; F (Interaction) = 6.792, $P < 0.001$; F (Intergroup) = 62.352, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; after reconstruction *vs* after resection, $P < 0.001$; after reconstruction *vs* before resection, $P < 0.001$.

TABLE 2 Loads of proximal bundle to proximal ulnar-radial joint (pronation)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction (N)
0.50	5.11 ± 0.73	5.09 ± 0.85	6.42 ± 1.62 [ab]
1.00	6.95 ± 1.05	6.46 ± 0.67	7.25 ± 1.56
1.50	9.13 ± 1.86	8.53 ± 0.90	9.33 ± 2.59
2.00	13.10 ± 2.99	10.46 ± 0.93 [a]	12.78 ± 3.33 [ab]
2.50	20.00 ± 4.94	12.37 ± 0.94 [a]	16.06 ± 4.30 [ab]
3.00	31.46 ± 7.64	16.36 ± 2.13 [a]	19.41 ± 4.83 [ab]
3.50	47.56 ± 9.74	22.75 ± 2.36 [a]	24.08 ± 5.31 [a]
4.00	69.48 ± 13.78	27.80 ± 3.32 [a]	30.25 ± 4.95 [a]
4.50	96.95 ± 14.65	35.59 ± 4.75 [a]	38.89 ± 7.52 [a]
5.00	128.41 ± 18.29	45.47 ± 4.29 [a]	49.35 ± 6.89 [a]

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 751.161, $P < 0.001$; F (Interaction) = 15.718, $P < 0.001$; F (Intergroup) = 106.114, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; after reconstruction *vs* after resection, $P = 0.209$; after reconstruction *vs* before resection, $P < 0.001$.

Table 3 The load of proximal bundle to proximal ulnar-radial joint (supination)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction (N)
0.50	13.10 ± 0.67	6.95 ± 0.40 [a]	10.87 ± 1.36 [ab]
1.00	16.09 ± 1.04	7.98 ± 0.84 [a]	16.05 ± 2.22 [b]
1.50	19.79 ± 1.40	9.93 ± 1.17 [a]	19.55 ± 2.65 [b]
2.00	24.84 ± 1.99	11.37 ± 1.49 [a]	24.30 ± 2.67 [b]
2.50	31.36 ± 3.30	13.56 ± 2.59 [a]	28.93 ± 2.41 [ab]
3.00	39.84 ± 3.84	15.85 ± 2.71 [a]	32.76 ± 1.57 [ab]
3.50	48.97 ± 4.72	19.02 ± 3.99 [a]	36.50 ± 2.05 [ab]
4.00	60.00 ± 6.52	22.57 ± 6.05 [a]	40.26 ± 1.85 [ab]
4.50	74.52 ± 7.37	27.33 ± 7.42 [a]	45.29 ± 3.38 [ab]
5.00	91.43 ± 11.66	34.21 ± 8.97 [a]	54.17 ± 5.73 [ab]

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 409.529, $P < 0.001$; F (Interaction) = 66.541, $P < 0.001$; F (Intergroup) = 226.057, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; after reconstruction *vs* after resection, $P = 0.209$; after reconstruction *vs* before resection, $P < 0.001$.

TABLE 4 The load of the central bundle on the proximal radioulnar joint (neutral position)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction A (N)	After reconstruction B (N)
0.50	8.85 ± 0.69	8.84 ± 0.36	9.01 ± 0.27	9.91 ± 0.30 [abc]
1.00	9.44 ± 0.72	9.26 ± 0.45	9.28 ± 0.33	10.20 ± 0.37 [abc]
1.50	10.42 ± 0.65	9.91 ± 0.63 [a]	9.83 ± 0.53 [a]	10.82 ± 0.58 [bc]
2.00	11.95 ± 1.18	11.02 ± 0.89 [a]	11.03 ± 0.74 [a]	12.14 ± 0.82 [bc]
2.50	16.40 ± 2.64	12.14 ± 0.90 [a]	13.35 ± 1.97 [ab]	14.68 ± 2.17 [b]
3.00	24.14 ± 4.51	14.11 ± 1.33 [a]	18.14 ± 2.77 [ab]	19.95 ± 3.04 [ab]
3.50	37.31 ± 6.80	17.52 ± 2.35 [a]	25.19 ± 5.36 [ab]	27.71 ± 5.90 ab
4.00	57.20 ± 10.30	23.38 ± 3.11 [a]	38.15 ± 6.99 [ab]	39.77 ± 7.66 [ab]
4.50	80.73 ± 13.85	32.43 ± 6.37 [a]	51.63 ± 10.14 [ab]	55.40 ± 20.26 [ab]
5.00	107.23 ± 19.01	49.29 ± 11.62 [a]	73.48 ± 15.30 [ab]	80.83 ± 16.83 [ab]

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Compared with after reconstruction A, $^{c}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 409.529, $P < 0.001$; F (Interaction) = 66.541, $P < 0.001$; F (Intergroup) = 280.334, $P < 0.001$. F (Interaction) = 4.402, $P < 0.001$; F (Intergroup) = 40.278, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; After resection *vs* after reconstruction A, $P < 0.001$; After resection *vs* after reconstruction B, $P < 0.001$; after reconstruction A *vs* after reconstruction B, $P = 0.118$; before resection *vs* after reconstruction A, $P < 0.001$; before resection *vs* after reconstruction B, $P < 0.001$.

TABLE 5 The load of central bundle on proximal radioulnar joint (pronation)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction A (N)	After reconstruction B (N)
0.50	7.03 ± 1.01	7.00 ± 1.16	8.83 ± 2.22 [ab]	9.71 ± 2.44 [ab]
1.00	9.56 ± 1.44	8.88 ± 0.92	9.97 ± 2.15	10.97 ± 2.15 [b]
1.50	12.55 ± 2.56	11.73 ± 1.24	12.83 ± 3.56	14.11 ± 3.91 [b]
2.00	18.02 ± 4.10	14.39 ± 1.28 [a]	17.58 ± 4.57 [b]	19.34 ± 5.03 [b]
2.50	27.51 ± 6.79	17.01 ± 1.30 [a]	22.08 ± 5.91 [ab]	24.29 ± 6.50 [b]
3.00	43.25 ± 10.51	22.49 ± 2.92 [a]	26.69 ± 6.34 [ab]	29.35 ± 7.30 [ab]
3.50	65.40 ± 13.40	31.28 ± 3.24 [a]	33.11 ± 7.30 [a]	36.42 ± 8.03 [ab]
4.00	95.54 ± 18.94	38.23 ± 4.57 [a]	41.59 ± 6.81 [a]	45.75 ± 7.49 [ab]
4.50	133.31 ± 20.14	48.94 ± 6.54 [a]	53.47 ± 10.35 [a]	58.81 ± 11.38 [ab]
5.00	176.56 ± 25.14	62.52 ± 5.90 [a]	67.86 ± 9.47 [ab]	74.64 ± 10.42 [ab]

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Compared with after Reconstruction A, $^{c}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 968.699, $P < 0.001$; F (Interaction) = 6.361, $P < 0.001$; F (Intergroup) = 77.318, $P < 0.001$. F (Interaction) = 4.402, $P < 0.001$; F (Intergroup) = 40.278, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; After resection *vs* after reconstruction A, $P = 0.196$; After resection *vs* after reconstruction B, $P = 0.014$; after reconstruction A *vs* after reconstruction B, $P = 0.027$; before resection *vs* after reconstruction A, $P < 0.001$; before resection *vs* after reconstruction B, $P < 0.001$.

those before resection ($P < 0.05$). After reconstruction of the central bundle, the loads in the neutral and supination positions were higher than those after resection ($P < 0.05$). While the load of proximal radioulnar joint in pronation position in reconstruction B group was higher than that after resection ($P < 0.05$), there was no significant difference in load in reconstruction A group before and after resection ($P > 0.05$). However, the loads of the proximal radioulnar joint after reconstruction in the two groups were lower than those before resection ($P < 0.05$).

In comparison with reconstruction A and B, there were no significant differences in the loads of proximal radioulnar joint between the two reconstruction methods in neutral and pronation positions ($P > 0.05$). However, in supination position, the load of reconstruction B was higher than that of reconstruction A ($P < 0.05$) (Tables 4, 5, and 6).

Discussion

At present, the biological function of forearm interosseous membrane can be summarized as four points: transferring the wrist load to the elbow joint; dispersing the radial load to the ulna; maintaining the forearm longitudinal stability; and stability of ulnar-radial joint[5]. Under normal condition, the load on the distal radius and ulna are transferred to the proximal radioulnar joint. In this process, the load on the proximal radius is decreased, while the load on the ulna is gradually increased, so as to stabilize the radioulnar joint. In the case of interosseous membrane injury, the load on the proximal radius is relatively increased, while the load on the proximal ulna is relatively decreased, which may cause the instability of the ulnar-radial joint. The main reason may be that the interosseous membrane can disperse the load from the radius to the ulna, and the destruction of the

TABLE 6 The load of the central bundle on the proximal radioulnar joint (supination)

Distance (mm)	Before resection (N)	After resection (N)	After reconstruction A (N)	After reconstruction B (N)
0.50	18.02 ± 0.92	9.56 ± 0.55	14.95 ± 1.87 ab	16.44 ± 2.05 abc
1.00	22.12 ± 1.43	10.97 ± 1.15 a	22.07 ± 3.05 b	24.27 ± 3.35 b
1.50	27.21 ± 1.93	13.65 ± 1.61 a	26.88 ± 3.64 b	29.57 ± 4.01 b
2.00	34.16 ± 2.74	15.63 ± 2.05 a	33.41 ± 3.68 b	36.75 ± 4.05 abc
2.50	43.12 ± 4.54	18.65 ± 3.56 a	39.78 ± 3.32 ab	43.76 ± 3.65 bc
3.00	54.77 ± 5.28	21.79 ± 3.73 a	45.04 ± 2.16 ab	49.55 ± 2.37 abc
3.50	67.33 ± 6.50	26.16 ± 5.49 a	50.19 ± 2.82 ab	55.21 ± 3.10 abc
4.00	82.50 ± 8.96	31.03 ± 8.31 a	55.35 ± 2.54 ab	60.89 ± 2.79 abc
4.50	102.47 ± 10.13	37.58 ± 10.20 a	62.27 ± 4.65 ab	68.50 ± 5.12 abc
5.00	125.72 ± 16.03	47.04 ± 12.33 a	74.48 ± 7.88 ab	81.93 ± 8.66 abc

Compared with before resection, $^{a}P < 0.05$; compared with after resection, $^{b}P < 0.05$. Compared with after reconstruction A, $^{c}P < 0.05$. Mauchly spherical test, $P < 0.001$; F (In group) = 739.778, $P < 0.001$; F (Interaction) = 9.530, $P < 0.001$; F (Intergroup) = 176.027, $P < 0.001$. F (Intergroup) = 40.278, $P < 0.001$. After resection *vs* before resection, $P < 0.001$; After resection *vs* after reconstruction A, $P = 0.196$; After resection *vs* after reconstruction B, $P = 0.014$; after reconstruction A *vs* after reconstruction B, $P = 0.008$; before resection *vs* after reconstruction A, $P < 0.001$; before resection *vs* after reconstruction B, $P < 0.001$.

interosseous membrane can cause the biomechanical discrepancy between the ulna and the radius[6]. It may affect the stability of the ulnar-radial joint. Lanting *et al*. has confirmed that radius head is an important structure against the proximal displacement of the radius, and the removal of radius head can cause obvious proximal displacement of radius[7]. However, the integrity of interosseous membrane is maintained while the radius head is excised, and the displacement of the proximal radius is relatively reduced, which indicates that interosseous membrane plays an important role in maintaining the stability of the forearm and the ulnar-radial joint.

In our study, the load of proximal radioulnar joint after resection of proximal and central fascicles was significantly lower than that before resection, indicating that the stability of proximal ulnar-radial joint was significantly affected by the destruction of interosseous membrane. The central bundle is a thicker and tougher tissue structure in the interosseous membrane. It ends obliquely from the proximal radius to the distal end of the ulna, at an angle of 21° to the radius and 28° to the ulna. The distance from the distal and proximal edges of the central bundle to the styloid process of the radius are 53% - 64% of the total length of radius and 29% - 44% of the total length of ulna[8]. The proximal bundle is soft and weak, which is located at the proximal end of the central bundle, originating from the anterolateral coronal process of ulna and ending at the trochanter of radius. The destruction of the two causes obvious obstacles to the transmission of mechanical load and the connection between ulna and radius. Interosseous membrane reconstruction is an important method for clinical restoration of forearm longitudinal stability, but how to reconstruct and the effect of reconstruction on ulnar-radial joint is still the focus of clinical research[9].

After reconstructing the proximal bundle along the attachment point, the stresses of proximal radioulnar joint in neutral and supination positions were significantly higher than those after resection. It indicated that the proximal bundle reconstruction could restore the stability of proximal ulnar-radial joint to a certain extent. However, it was still lower than the stress load before resection, which indicated that the proximal bundle reconstruction alone might not be able to effectively restore the strength of the interosseous membrane. At the same time, there was no significant difference in the load of proximal radioulnar joint between reconstruction and resection. The possible reason was that the proximal bundle in pronation position was mainly subjected to compressive stress, while the reconstructed Mussel line mainly provided a tensile stress[10], which had a significantly enhanced effect on central and post-rotation positions.

The loads of the proximal radioulnar joint in neutral and supination positions after reconstruction of central tract were significantly higher than those after resection, which were lower than those before resection. In pronation position, the difference in reconstruction A group was not significantly different before and after resection, while the difference in reconstruction B group was lower after resection than that before resection. It also showed that central bundle reconstruction improved the tension stress of the interosseous membrane and can restore the stability of the proximal radioulnar joint, but it cannot reach the optimal biomechanical state. In our study, two methods were chosen for the reconstruction of central bundle. The reconstruction of the original attachment of central bundle can restore the biomechanical characteristics of the interosseous membrane as much as possible and the longitudinal stability of the forearm as possible. However, the reconstruction of original attachment was difficult and complicated. Especially for the future clinical operation, it can be reconstructed directly along the midpoint of the original radius-ulna attachment, which can also tightly connect the ulna and radius, disperse the radial load to the ulna, and the operation was relatively simple[11]. In comparison of the two reconstruction methods, the load of proximal radioulnar joint on the original attachment reconstruction in supination position was significantly higher than that of reconstruction of the midpoint of the original radius-ulna attachment, but there was no significant difference between pronation and central positions. It indicated that the original attachment reconstruction could enhance the stability of proximal ulnar-radial joint in supination position. The tension requirement of the interosseous membrane was higher in supination position, and the reconstruction of original attachment seemed to be more suitable for this tension requirement. In addition, in anterior position, reconstruction of original attachment can improve the instability of proximal radioulnar joint after central bundle resection, but the midpoint reconstruction cannot achieve this mechanical effect. Therefore, it showed that the reconstruction of original attachment of central bundle was more beneficial to the rotation of forearm.

However, there are some drawbacks in this study. First of all, this is a qualitative experiment rather than a quantitative one. Second, all measurements are made at static state without considering the dynamic state. However, it still provided an effective way to stabilize proximal radioulnar joint. In the future, we can further verify the results of this study in clinical practice.

References

1. Matthias R, Wright TW. Interosseous membrane of the forearm. J Wrist Surg, 2016, 5: 188–193.
2. Shepard MF, Markolf KL, Dunbar AM. The effects of partial and total interosseous membrane transection on load sharing in the cadaver forearm. J Orthop Res, 2001, 19: 587–592.
3. Adams JE, Culp RW, Osterman AL. Central band interosseous membrane reconstruction for forearm longitudinal instability. J Wrist Surg, 2016, 5: 184–187.
4. Oldfield CE, Boland MR, Greybe D, *et al*. Ultrasound imaging of the distal radioulnar joint: a new method to assess ulnar radial translation in forearm rotation. J Hand Surg Eur Vol, 2017, 42: 389–394.
5. Pfaeffle HJ, Tomaino MM, Grewal R, *et al*. Tensile properties of the interosseous membrane of the human forearm. J Orthop Res, 1996, 14: 842–845.
6. Noda K, Goto A, Murase T, *et al*. Interosseous membrane of the forearm: an anatomical study of ligament attachment locations. J Hand Surg Am, 2009, 34: 415–422.
7. Lanting BA, Ferreira LM, Johnson JA, *et al*. The effect of excision of the radial head and metallic radial head replacement on the tension in the interosseous membrane. Bone Joint J, 2013, 95: 1383–1387.
8. McGinley JC, Kozin SH. Interosseous membrane anatomy and functional mechanics. Clin Orthop Relat Res, 2001, 383: 108–122.
9. Markolf KL, Dunbar AM, Hannani K. Mechanisms of load transfer in the cadaver forearm: role of the interosseous membrane. J Hand Surg Am, 2000, 25: 674–682.
10. McGinley JC, D'addessi L, Sadeghipour K, Kozin SH. Mechanics of the antebrachial interosseous membrane: response to shearing forces. J Hand Surg Am, 2001, 26: 733–741.
11. Moritomo H, Noda K, Goto A, Murase T, Yoshikawa H, Sugamoto K. Interosseous membrane of the forearm: length change of ligaments during forearm rotation. J Hand Surg Am, 2009, 34: 685–691.