Scissoring of cerebral aneurysm clips: mechanical endurance of clip twisting

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Abstract

Although the cerebral aneurysm clip “scissoring” phenomenon is known to occur due to twisting of the aneurysm clip blades during surgery, there have been few previous studies of scissoring. In the present study, we examined the in vitro endurance of clip twisting to assess clip scissoring. To evaluate the clip scissoring effect, we measured torque at the rotating aneurysm clip head (Sugita and Yasargil clips) using own manufactured product. A silicon sheet 1 mm thick was clipped at several depths (3, 6, and 9 mm) and the clip head was mechanically rotated. Straight and fenestrated clips of titanium alloy were used in the present study. Cobalt alloy straight clips were also examined. Preliminary experiments indicated that torque values during clip head rotation dropped when the blades crossed. In addition, torque values before blade crossing showed resistance to slippage of the blades. Torque values of both Sugita and Yasargil clips were directly proportional to the blade depth. There were no differences between straight and fenestrated Sugita clips. Although the torque was greater in cobalt alloy than titanium alloy Sugita clips, the torque values of Yasargil cobalt and titanium clips were identical. We found some differences in torque values during clip head rotation between Sugita and Yasargil clips. Based on the results of twisting experiments, scissoring is likely to occur when occluding the neck of the aneurysm only with the tips of long clip blades.

Key words: aneurysm clip, subarachnoid hemorrhage, scissoring, surgery

Introduction

Cerebral aneurysm clip scissoring occurs due to twisting of the clip blades during clipping surgery (Figure 1) [1, 3, 4]. Although titanium is an attractive material for aneurysm clips because of its ability to decrease artifacts in neuroimaging, there have been a number of reports of scissoring using Spetzler [1] and Yasargil [3, 4] clips made of pure titanium and titanium alloy, respectively. If scissoring occurs when applying a clip, it can injure the neck of the aneurysm causing aneurysm rupture. Scissoring may result from both inappropriate clip selection and application [5]. In addition, aneurysm characteristics, such as mural thrombus, calcification, broad neck, and large or giant aneurysm may affect scissoring [1, 3, 6]. However, little information on scissoring has been reported in previous clinical and laboratory investigations [1, 3, 4]. To evaluate the clip scissoring effect, we measured torque at clip head rotation using our own manufactured product.

Methods

Evaluation of clip scissoring: Cerebral aneurysm clips were set into a newly developed torque measurement system (Figure 2). The clip blades were attached to a silicon sheet (1 mm in thickness) mounted on a micro-torque sensor (Suzuko Co., Yokohama, Japan). The clip head was mechanically rotated in both directions (Figure 2) at a rotation speed of $12°\cdot s^{-1}$. This speed was determined as described previously [3]. Torque value was monitored and recorded every 0.5°. An excess of clip head rotation artificially induced scissoring (Figure 2). Our preliminary experiments indicated that the torque increased in parallel with clip head rotation and decreased above 80° – 90° when clip blades were twisted. In addition, torque values before blade twisting presented resistance to blade slippage. Therefore, the torque value was indirectly proportional to scissoring. Several depths (3, 6, and 9 mm) of clipping were applied (Figure 2).

Aneurysm clips: Sugita clips (Mizuho Co., Ltd., Tokyo, Japan) and Yasargil clips (Aesculap, Inc., Center Valley, PA) were used in this investigation. Table 1 lists the cerebral aneurysm clips used in this study. Long blade clips were selected because they may be more liable to show scissoring compared with short blade clips [3, 4]. To compare shape, material, and type of clips, blades of the same length were selected (Table 1). All except the custom aneurysm clips (Table 1) were representative of the final manufactured versions and were not used before the present experiments. Both cobalt (Elgiloy or Phynox) and titanium alloy clips were tested and compared. Titanium II Clips® are a new type of titanium Sugita clip introduced in 2007, which have a smaller spring portion and thinner blades than the original Sugita titanium clips [2]. Sugita Titanium II clips were used in this study. Straight and fenestrated type clips were also evaluated. One kind of the Sugita titanium clip (17-001-18) blades was adjusted to compare a straight clip with a fenestrated clip.

Statistical analysis: All data are presented as means ± standard deviation and *n* represents the number of clips. Comparisons were made using unpaired *t* test or ANOVA with post hoc Tukey’s test, as appropriate. Statistical analysis was performed with PASW statistics 18 (SPSS Japan, Tokyo, Japan). In all analyses, $P < .05$ was taken to indicate statistical significance.

Results

Depth of clipping: Plots of torque values during Sugita **(17-001-18)** and Yasargil **(FT792D)** titanium straight clip head rotation are presented in Figure 3. The torque values of both clips (*n* = 5) increased significantly depending on the length of silicon sheet clipping. With clipping at depths of 3 and 6 mm, torque increased raised up to 70° and then reached a plateau or decreased slightly for clips of both types. In contrast, with a depth of 9 mm, torque increased in parallel with clip head rotation. Sugita clips had significantly higher torque values than Yasargil clips, especially at greater depths (Table 2).

Shape of the clip: With clipping at a depth of 3 mm, there were no differences in torque values between straight **(custom clip; see Table 1 and Method section in detail)** and fenestrated **(17-001-30)** Sugita titanium clips (*n* = 5, Table 3). These results were consistent with those for Elgiloy **(07-940-30)** clips (data not shown). Yasargil straight and fenestrated clips were not compared because straight Yasargil clips with the same blade length were not available. Sugita titanium fenestrated **(17-001-30)** clips with clipping at a depth of 3 mm showed a significantly greater torque value than Yasargil titanium fenestrated **(FT650T)** clips (*n* = 5, Table 3).

Clip material: Torque values of Elgiloy **(07-940-18)** clips were greater than those of Titanium II **(17-001-18)** clips with clipping at a depth of 3 mm (*n* = 5, Figure 4A). In contrast, there were no differences in torque between Yasargil Phynox **(FE792K)** and titanium **(FT792D)** clips (*n* = 5, Figure 4B).

Discussion

This study was performed to induce and analyze the scissoring phenomenon in vitro. This was accomplished by clip head rotation and torque measurements. The torque value before blade twisting represented resistance to scissoring.

Clip blade lengths: Torque value was directly proportional to clip depth in both Sugita and Yasargil titanium clips. These phenomena suggest that scissoring tends to occur with occlusion of the neck of the aneurysm only with the tips of long clip blades. Therefore, clipping using only the tips of long clips tends to cause scissoring, especially in large aneurysms, such as internal carotid artery aneurysms with a broad neck [3, 5]. Papadopoulos and colleagues [4] also suggested that long clips may be prone to scissoring because 15 mm Yasargil titanium clip blades showed scissoring after 10 min of sustained opening. Schmid-Elsaesser and Steiger [5] proposed that long clips made of both cobalt and titanium alloy are not appropriate for single clipping in broad-necked aneurysms on large-diameter arteries to prevent clip slippage and scissoring because the closing force and anti-scissoring of a single long blade clip may be insufficient. Therefore, combination clipping using several clips, including fenestrated types, is essential for large broad-necked aneurysms and temporary parent artery occlusion is also helpful to adjust clipping. On the other hand, using only the tips of long clips is useful for deep-seated basilar artery aneurysms with a small neck as long clips allow the neurosurgeon better visualization of the aneurysmal neck and surrounding structures in patients with basilar artery aneurysms.

Straight versus fenestrated clips: In the present study, no differences in torques were observed between Sugita straight and fenestrated titanium clips during clip head rotation. These results indicated that fenestrated clips were similar to straight clips with regard to the scissoring phenomenon although the former is thought to be more prone to scissoring than the latter. Based on the results of the present study, torque at clip head rotation may be regulated by the length from the crossover portion of the clip. The Sugita fenestrated clip (17-001-30) used in the present study has a ring 5 mm in diameter and 9-mm jaws. The torque value would be identical when the linear lengths from the clipping site to the crossover portion were the same between the straight and fenestrated clips used in this study. However, the torque may also be influenced by material, clip design, and blade size. Therefore, a distinction between two types of clip would appear when other types of fenestrated clips are applied. Further evaluations are necessary to make definitive conclusions regarding this issue.

Sugita versus Yasargil titanium clips: The torque values were dependent on clip depth and the degree of head rotation for both Sugita and Yasargil titanium clips. The difference in torque of Sugita and Yasargil titanium clips may be due to their designs. The Sugita clip has a single stabilizing wire to prevent scissoring and to maintain the opposition of the clamping surfaces (Figure 5). The stabilizing wire has no pinching effect of closing. In contrast, in the Yasargil clips, the blades are welded onto the spring in a “box lock” structure to prevent scissoring (Figure 5). In 2000, Carvi y Nievas and Hollerhage [3] reported intraoperative clip scissoring in a patient with internal carotid artery aneurysms using the 20-mm straight Yasargil titanium clip (FT790T). At that time, the long Yasargil titanium clip had a single “box lock.” Recently, however, the double “box lock” system has been adopted in long blade (15, 17.5, and 20 mm blades) titanium alloy clips (Figure 5).

There is another possible explanation for the differences in torque between Sugita and Yasargil clips—the torque value on clip head rotation may be affected by the blade width and thickness of the blades. The thickness and width of the blades of the Sugita (17-001-18) and Yasargil (FT792D) titanium straight clips used in the present study were measured. The blades were the same width (1.3 mm) in both clips, while the thickness varied along the length of the blade; the blades of Sugita and Yasargil clips were 1.4 and 1.4 mm thick at 3 mm from the tip, 1.8 and 1.5 at 6 mm, and 2.1 and 1.7 at 9 mm, respectively. Thus, the Yasargil clip blade width is thinner than that of the Sugita clip.

Titanium versus cobalt alloy clip: Sugita and Yasargil titanium clips are produced using a titanium alloy containing aluminum and vanadium (Titanium-6A1-4V) rather than pure titanium due to its superior mechanical properties. As titanium is superior to cobalt with regard to radiological features, titanium clips have been developed and are commonly used in clipping surgery. However, in some complicated aneurysm cases, neurosurgeons may hesitate to use titanium clips because of their inferior mechanical characteristics [3, 5, 6]. There have been a number of case reports of scissoring using titanium clips [1, 3]. In the present study, Elgiloy Sugita clips showed better torque values during clip head rotation than titanium alloy clips. In contrast, there were no differences in torque between Yasargil clips. This difference between Sugita and Yasargil clips may have contributed to the prevention of scissoring described above although both Elgiloy and Phnox clips are made using the same composition of cobalt alloy (cobalt-chromium-nickel-molybdenum-iron alloy). Therefore, Yasargil long titanium clips have a double box lock, while Phynox clips have a single box lock (Figure 5). Double box lock systems may be superior to single box lock systems with regard to prevention of scissoring. **To prevent the scissoring phenomenon, it is important to develop new designed and/or material clips. Since the crossover portion of the clip is the key structure, the double stabilizing wires in Sugita titanium clip may be effective if available.** Further studies using other types of clip, such as short straight clips, are necessary to understand the scissoring effects in greater detail.

Limitation of the present study: Although actual scissoring will occur as a result of rotating vectors applied to the clip blades, it is difficult to set these conditions in vitro and vivo experiments. Therefore, we used the clip head rotation method described in this paper to evaluate scissoring. This method has successfully induced the artificial scissoring and the torque value before blade twisting represented a resistance to scissoring.

Conclusions

Appropriate clip selection and application require consideration of numerous factors, including clip size, shape, closing force, material (cobalt versus titanium), anatomical characteristics of the aneurysmal neck, clip applier, surrounding structures, etc. Furthermore, the anti-scissoring is an important factor in evaluation of clip performance. The present study demonstrated that application of clips using only the blade tip may cause scissoring. Further studies of scissoring are required to increase safety and accuracy of clipping in aneurysm surgery.

Conflict of Interest

All authors have no financial, commercial, legal, or professional relationship with other organizations or with the people working with us that may exert an influence on this research. Therefore, we have disclosed any conflict of interest in the making of this paper.

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Figure legends

Figure 1: Schematic drawing of normal clipping blades (left) and scissored blades (right). Note that clip blades are twisted and opened in the right figure.

Figure 2: Photographs showing the torque measurement system (A and B) and clip blade crossing (C) on clip head rotation. Clip head rotation in both directions and 1-mm silicon sheet clipped with Sugita or Yasargil aneurysm clip. **The used clip in this figure is a Sugita titanium clip (17-001-18).**

Figure 3: Effects of clipping depth on torque value (n = 5) during titanium clip head rotation (A: Sugita clip; B: Yasargil clip). * and †, Significantly different from depths of 3 and 6 mm, respectively ($P < .05$).

Figure 4: Effects of titanium and cobalt alloy clips on torque values during clip head rotation. A: Titanium II versus Elgiloy Sugita straight clips (n = 5). B: Titanium versus Phynox Yasargil straight clips. *, Significantly different from titanium clip ($P < .05$).

Figure 5: Photographs of Sugita (17-001-18) and Yasargil clips (FE792K and FT792D) showing “stabilizing wire,” “single box lock,” and “double box lock.”

Table 1. Characteristics of the aneurysm clips used in the present study

Clip name	Product name or material	Catalog number	Shape	L1 (mm)	L2 (mm)	Anti-scissoring	Applied number
Sugita	Titanium II	17-001-18	Straight	18.0	-	stabilizing wire	5
	Elgiloy	07-940-18	Straight	18.0	-	stabilizing wire	5
Yasargil	Titanium	FT792D	Straight	17.5	-	double box-lock	5
	Phynox	FE792K	Straight	17.5	-	single box-lock	5
Sugita	Titanium II	17-001-30	Fenestrated	9	15.7	stabilizing wire	5
	Titanium II	Custom clip*	Straight	15.8	-	stabilizing wire	5
	Elgiloy	07-940-30	Fenestrated	9	15.7	stabilizing wire	5
Yasargil	Titanium	FT650T	Fenestrated	9	15.7	single box-lock	5

L1: regular blade length, L2: regular blade length plus diameter of fenestration. *: this clip was shortened and made with catalog number of 17-001-18 to compare with fenestrated clip.

Table 2. Torque values (mN*m) in several depths between Sugita (17-001-18) and Yasargil (FT792D) straight titanium clips.

	3 mm in depth			6 mm in depth			9 mm in depth		
Rotation Degree	Sugita	Yasargil	P Value	Sugita	Yasargil	P Value	Sugita	Yasargil	P Value
10	0.07 ± 0.05	0.08 ± 0.06	0.582	0.13 ± 0.10	0.13 ± 0.07	0.918	0.27 ± 0.10	0.13 ± 0.08	0.003
20	0.34 ± 0.05	0.29 ± 0.06	0.053	0.51 ± 0.14	0.37 ± 0.10	0.019	0.74 ± 0.13	0.43 ± 0.08	< 0.001
30	0.54 ± 0.05	0.45 ± 0.08	0.007	0.81 ± 0.12	0.65 ± 0.08	0.002	1.16 ± 0.11	0.78 ± 0.12	< 0.001
40	0.69 ± 0.07	0.57 ± 0.09	0.006	1.06 ± 0.13	0.87 ± 0.08	0.001	1.55 ± 0.14	1.05 ± 0.14	< 0.001
50	0.80 ± 0.07	0.72 ± 0.10	0.051	1.23 ± 0.12	1.01 ± 0.13	0.001	1.81 ± 0.19	1.30 ± 0.11	< 0.001
60	0.93 ± 0.12	0.82 ± 0.12	0.064	1.30 ± 0.19	1.09 ± 0.14	0.013	1.91 ± 0.28	1.48 ± 0.14	< 0.001
70	0.92 ± 0.21	0.84 ± 0.15	0.352	1.38 ± 0.22	1.16 ± 0.18	0.028	2.09 ± 0.29	1.60 ± 0.25	0.001
80	0.91 ± 0.22	0.76 ± 0.22	0.148	1.40 ± 0.28	1.04 ± 0.38	0.026	2.27 ± 0.29	1.71 ± 0.26	< 0.001
90	0.91 ± 0.31	0.63 ± 0.28	0.048	1.44 ± 0.32	0.99 ± 0.37	0.009	2.45 ± 0.31	1.87 ± 0.31	0.001

Table 3. Torque values (mN*m) of straight (Sugita) and fenestrated (Sugita and Yasargil) titanium clips.

	Sugita			Yasargil	
Rotation Degree	Straight (Custom)	Fenestrated (17-001-30)	P* Value	Fenestrated (FT650T)	P† Value
10	0.08 ± 0.05	0.10 ± 0.05	0.416	0.09 ± 0.06	0.556
20	0.38 ± 0.06	0.35 ± 0.03	0.130	0.28 ± 0.06	0.005
30	0.59 ± 0.09	0.56 ± 0.05	0.347	0.43 ± 0.10	0.002
40	0.78 ± 0.08	0.79 ± 0.05	0.716	0.52 ± 0.12	<0.001
50	0.98 ± 0.10	0.96 ± 0.07	0.615	0.66 ± 0.14	<0.001
60	1.13 ± 0.12	1.13 ± 0.07	1.000	0.71 ± 0.21	<0.001
70	1.20 ± 0.13	1.24 ± 0.14	0.576	0.71 ± 0.29	<0.001
80	1.33 ± 0.15	1.31 ± 0.12	0.685	0.69 ± 0.29	<0.001
90	1.45 ± 0.19	1.40 ± 0.21	0.523	0.68 ± 0.34	<0.001

P* value indicating differences between Sugita straight and fenestrated clips. P† value showing differences between Sugita and Yasargil fenestrated clips.

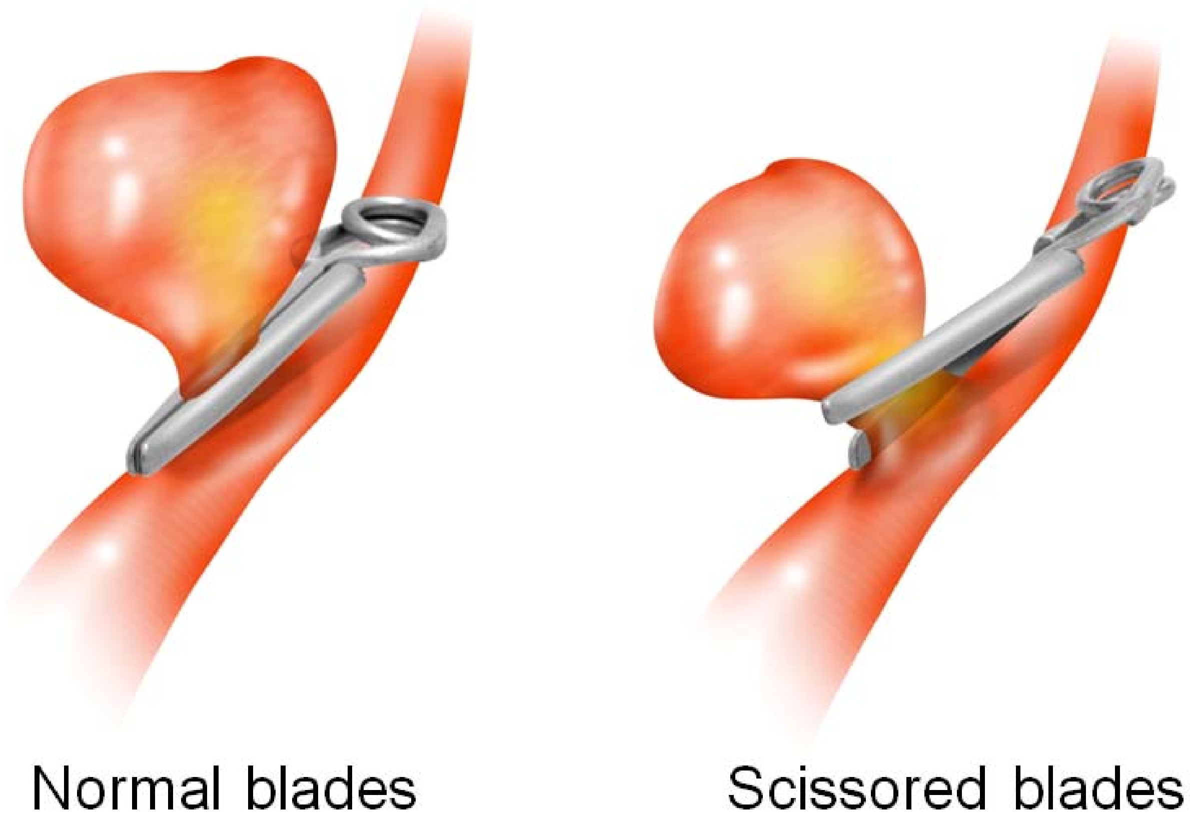


Figure 1

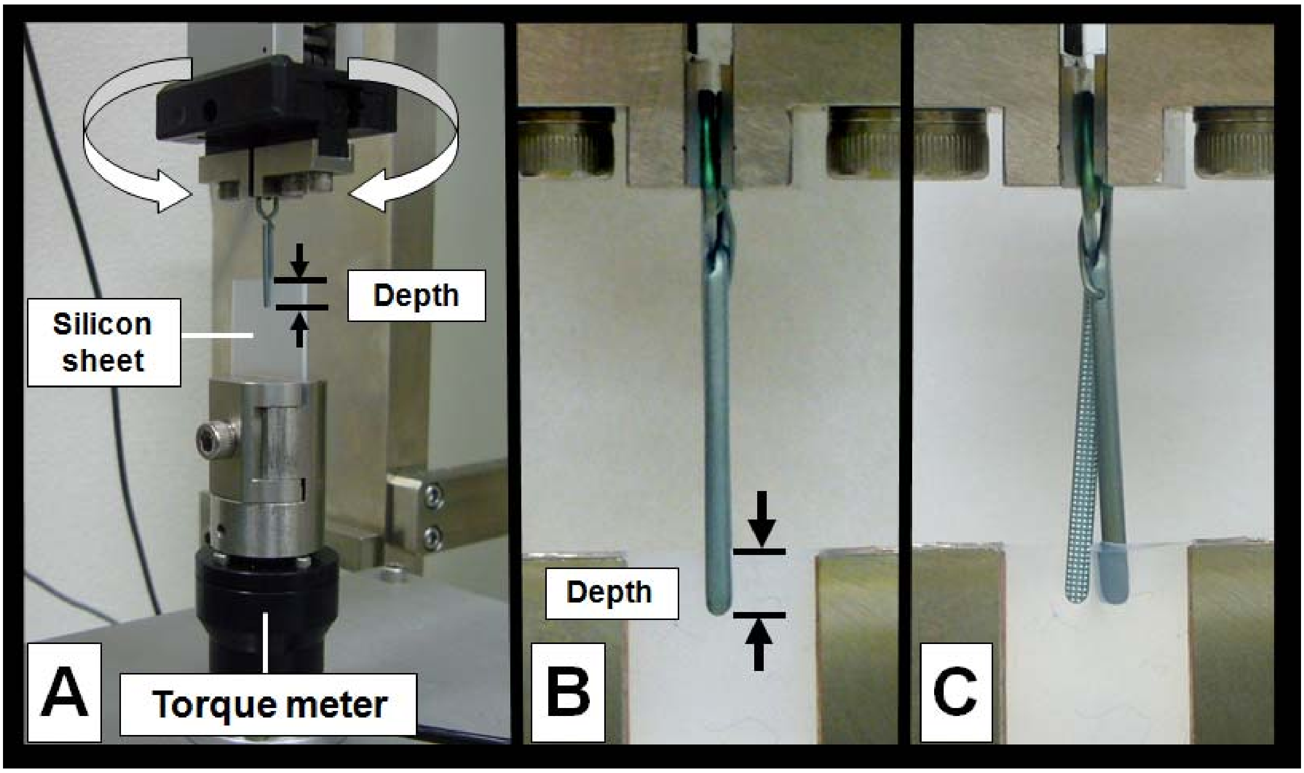


Figure 2

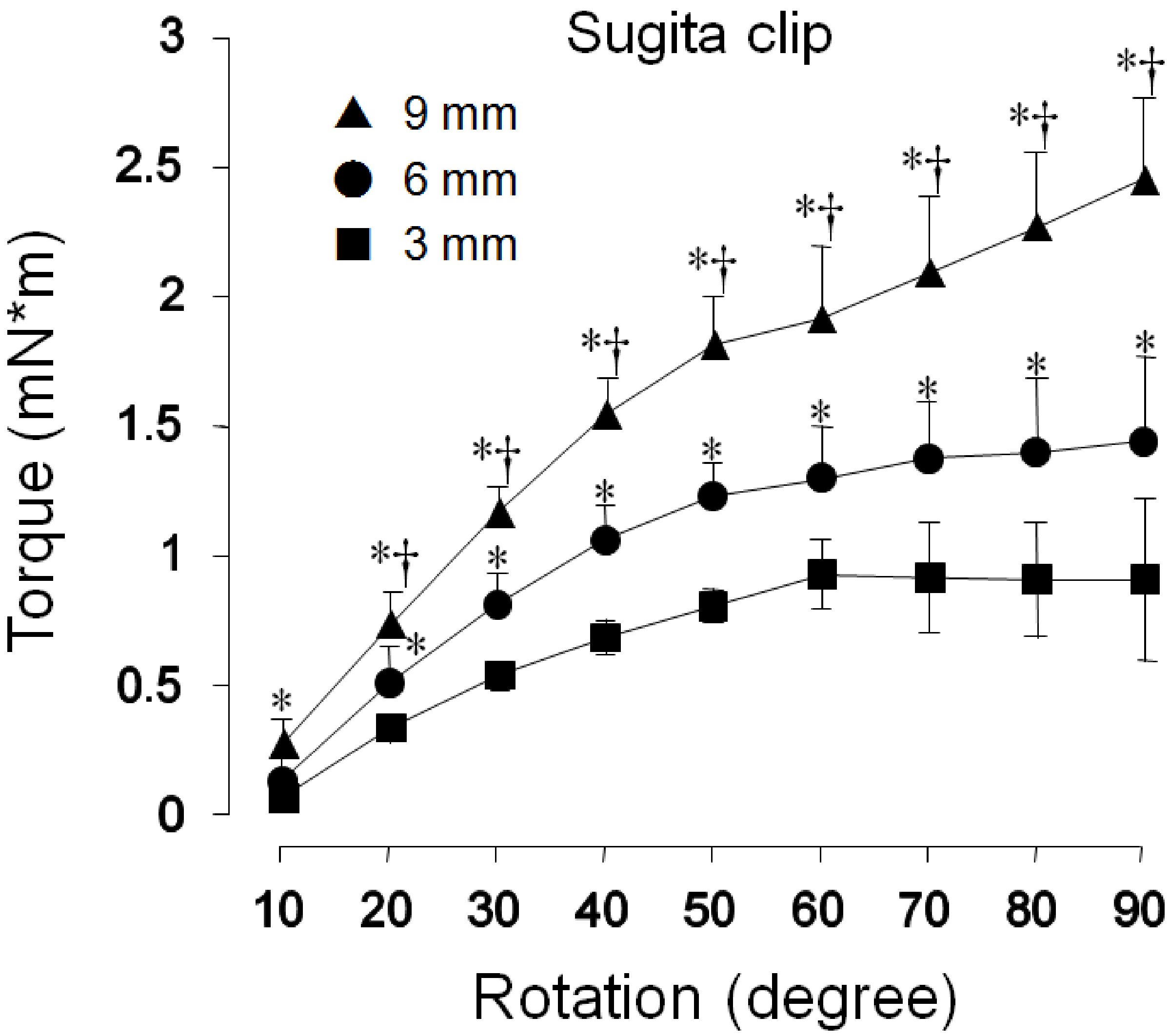

Sugita clip
9 mm
6 mm
3 mm
Torque (mN*m)
Rotation (degree)
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
70
80
90

Figure 3A

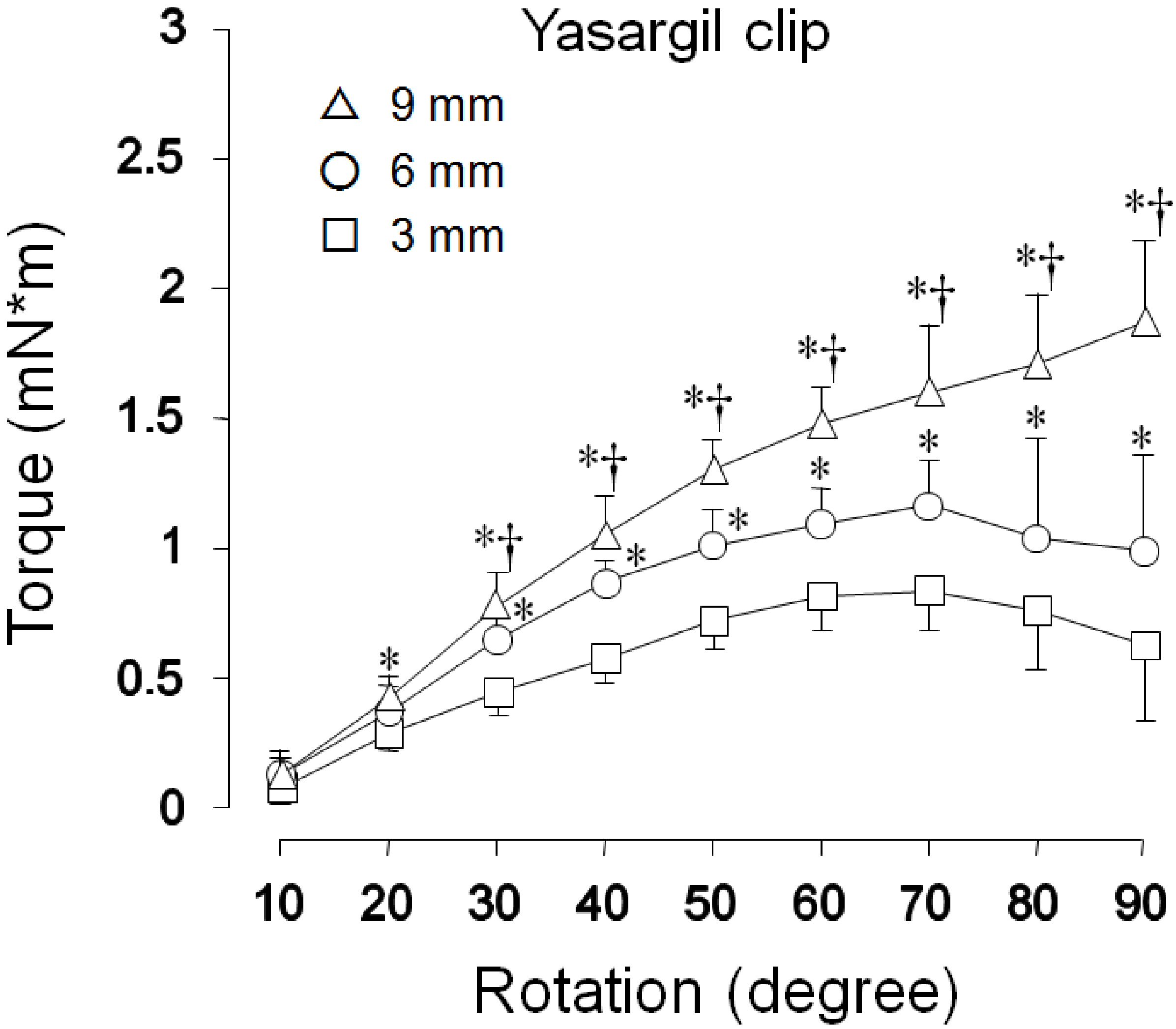
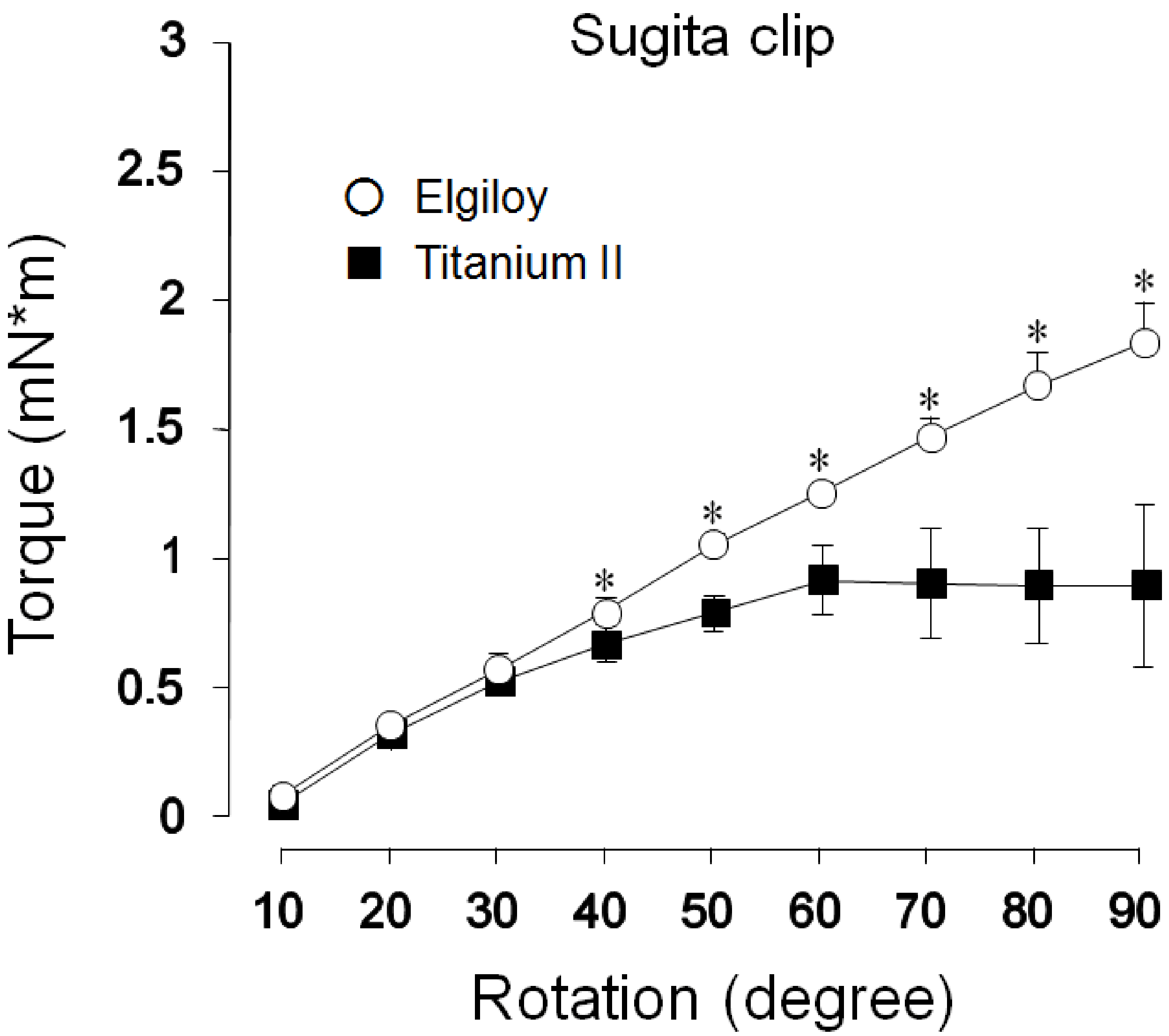

Yasargil clip
9 mm
6 mm
3 mm
Torque (mN*m)
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
70
80
90
Rotation (degree)

Figure 3B



Sugita clip
Elgiloy
Titanium II
Torque (mN*m)
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
70
80
90
Rotation (degree)

Figure 4A

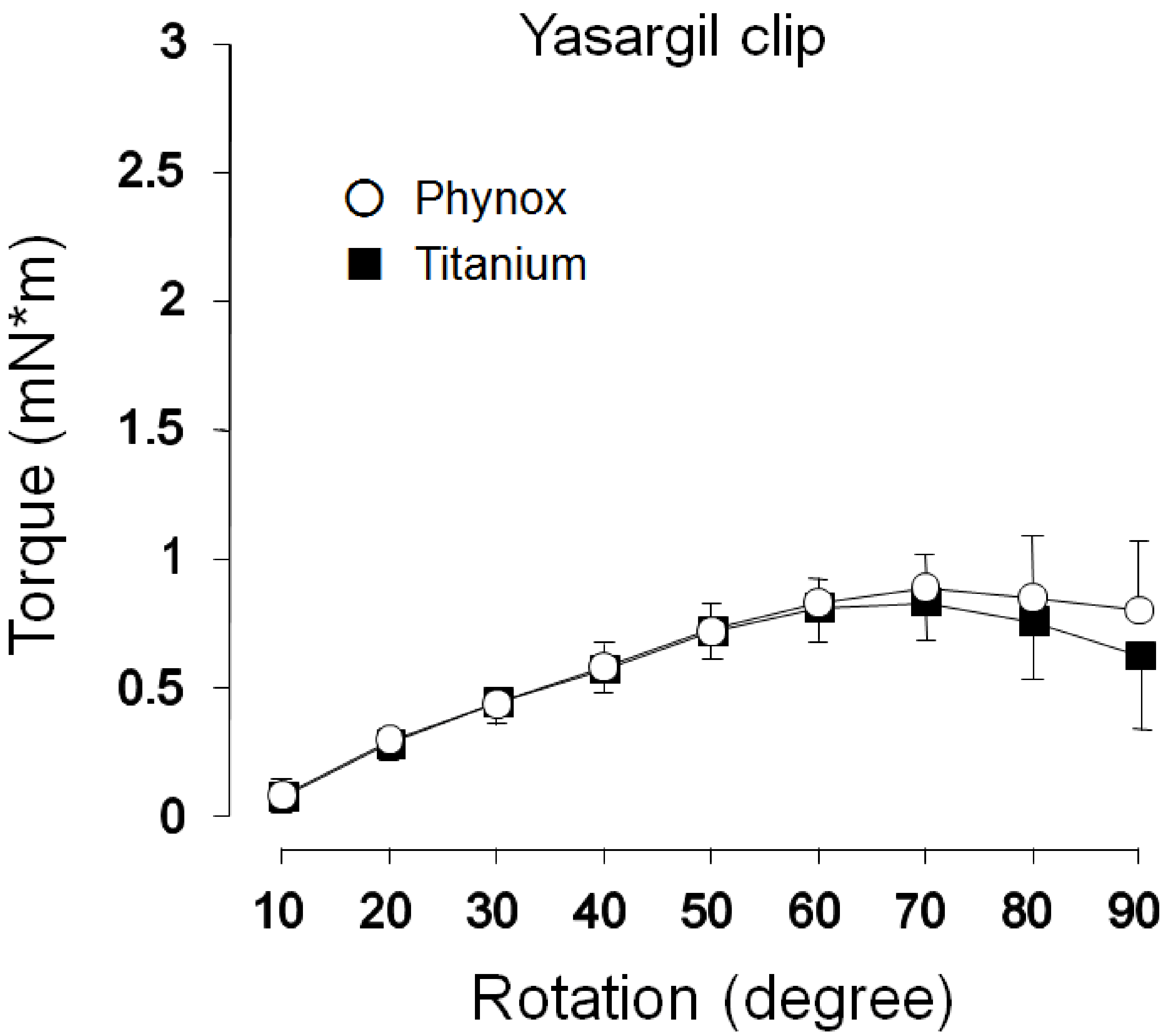

Yasargil clip
Phynox
Titanium
Torque (mN*m)
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
70
80
90
Rotation (degree)

Figure 4**B**

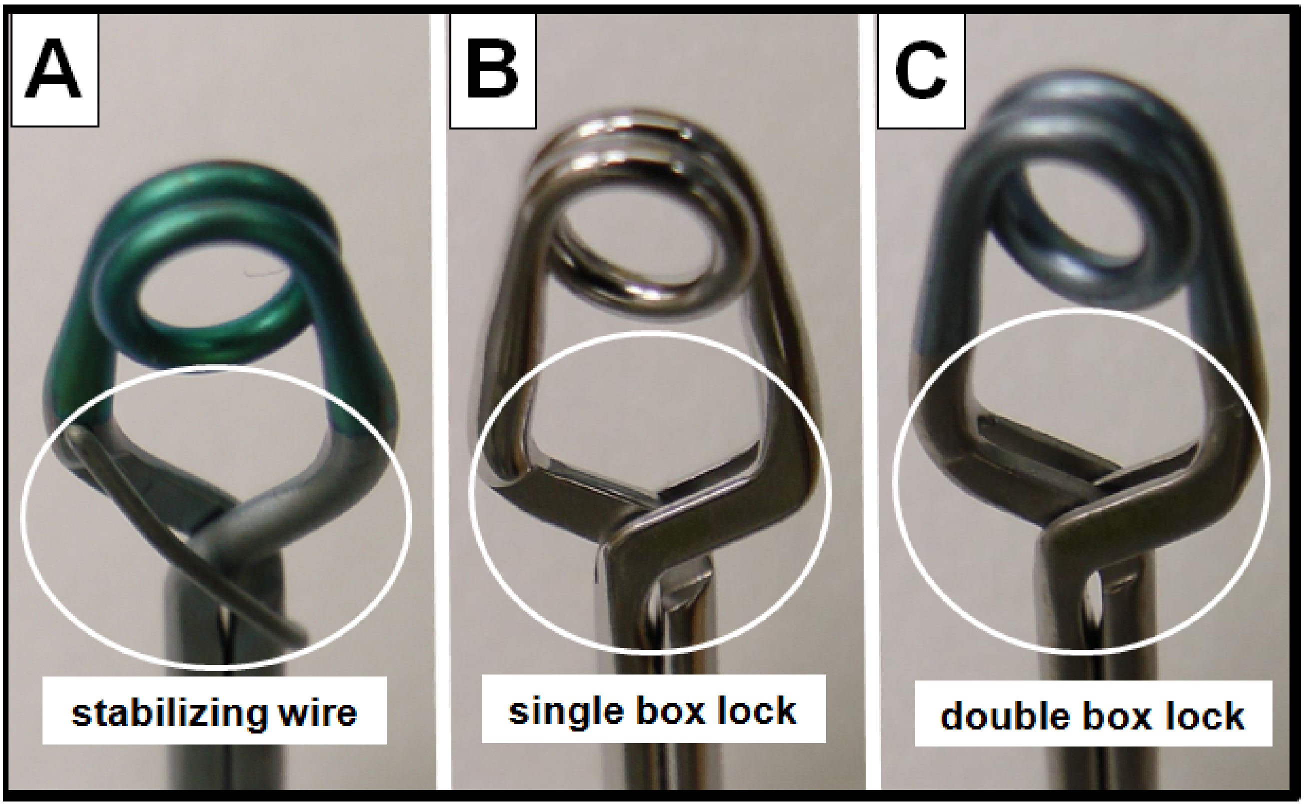


Figure 5