Revisit of aneurysm clip closing forces:

Comparison of titanium versus cobalt alloy clip.

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Abstract

Although closing force of cobalt alloy clip is well studied, there is only little information of titanium alloy clip available in the literature. In the present study, we examined and compared closing forces of various types and points of cerebral titanium and cobalt aneurysm clips for cerebral aneurysms. Straight, temporary, bayonet, angled, and fenestrated titanium or cobalt alloy clips were tested by measuring the closing forces at various points along their blade length. Closing forces of all the tested clips linearly increased from tip to base of clip blades. Sugita Titanium II clips had bigger closing forces than Elgiloy clips in all type clips except for the temporary clips. The closing forces of Sugita Titanium II and Yasargil titanium clips were similar in straight permanent type clip although there were some differences in closing forces between other types of Sugita and Yasargil clips. Our data showed that the closing forces differed depending not only on manufacturers but also on materials and shapes.

Key words: aneurysm clip, closing force, surgery

Introduction

Open surgical clipping has been the means of method for more complex aneurysms. Knowledge of the physical characteristics of aneurysm clips including closing forces is essential for their proper use [1,2-6]. Currently, intracranial aneurysm clips made of titanium instead of cobalt alloy are more commonly used. Although closing forces of cobalt alloy clips are well studied [5,6], there is little study on closing forces of titanium alloy clip [4]. This study was undertaken to assess and compare objectively the closing forces of cobalt and titanium alloy clips, especially those of Sugita clips.

Materials and Methods

Aneurysm clips: Sugita cobalt (Elgiloy) and titanium (Titanium II) alloy clips (Mizuho Co., Ltd, Tokyo, Japan) were used in this investigation. Titanium II clips are a new type of titanium Sugita clip introduced in 2007[3,4]. The straight, bayonet, angled, L-shaped, and fenestrated clips made of cobalt and titanium alloys were used and they have similar blade lengths (Table 1). Each one similar Yasargil cobalt (Phynox) or titanium clip (Aesculap, Inc., Center Valley, PA) was selected and applied for comparison (Table 1). Sugita clips were donated from the manufacturer and Yasargil clips were purchased.

Closing force measurements: A bench analysis was set up for the closing pressure force of several clips. **Commercial closing forcemeter of aneurysm clip was not available**. A clip closing forcemeter was **lent without charge from** Mizuho Co., Ltd, Tokyo, Japan and used in all experiments. Details of this forcemeter have been previously described [4,5]. Briefly, the device automatically measured and displayed the

closing force of a clip. The closing forces from the tip to the base of the blades were measured in 1.0-mm increments. Blade separation distance was set at 1.0 mm. **The forcemeter was calibrated before every use.**

Statistical analysis: Data are presented as mean ± standard deviation and *n* represents the number of clips. Comparisons for continuous variables were made using unpaired *t* test and linear regression. Statistical significance was defined by $P < 0.05$. Data were analyzed using PASW statistics 18 (SPSS Japan, Tokyo, Japan).

Results

The total number of clips used in the present study was mentioned in the Table 1. The closing forces of all clip types increased linearly from the tip of blades to the clip head (Figure 1 to 5). There were significant positive correlations between closing force and distance from blade tip (Figure 1, 2, and 3). Straight permanent clips showed a sharper rise in closing forces than those of other clip types (Figure 1). Sugita titanium alloy straight (only the permanent type) clips had significantly greater closing forces than did cobalt alloy clips (Figure 4 **left, n = 6**). Angled (**n = 5**), L-shaped (**n = 5**), and fenestrated (**n = 6**) permanent Sugita clips also showed similar results (Figure 4 and 5). In contrast, closing forces of Yasargil titanium straight clip (permanent type) were relatively less than those of Yasargil cobalt alloy clips. Both Sugita and Yasargil temporary clips had identical closing forces along clip blades, both in titanium and cobalt alloys (Figure 2). The closing force of Yasargil temporary clips rose more sharply than those of Sugita temporary clips (Figure 2). In comparison of Sugita and Yasargil non-straight titanium clips, closing forces depended on clip shapes (Figure 1

and 3). In bayonet clips, closing forces of Yasargil clips were stronger than those of Sugita clips. On the contrary, fenestrated clips showed the opposite result (Figure 3).

We also measured closing forces of other straight Sugita Titanium II clip. There was no significant difference at the same distance from the tip of blades among different length straight clips (data not shown).

Discussion

While acknowledging that the most important component of aneurysm clip selection is a subjective preference, objective decisions based on closing force may be relevant. The International Organization for Standardization (ISO) recommended that the closing forces of aneurysm clips should be measured at a point equal to one-third of the blade length from the blade tip, with a blade separation distance of 1.0 mm [2]. The closing force of each Sugita or Yasargil clip at this point is labeled at the package. However, the closing forces of at the tip or base of blades are not well known in cobalt and titanium clips. This information is essential for performing a safe clipping surgery. Neurosurgeons usually assume that closing forces of the titanium clips are weaker than those of the cobalt ones. Therefore, large aneurysms and the deep-seated aneurysms are treated using cobalt clips not titanium alloy clips. However, our results of closing forces showed the opposite. **Additionally, the original Sugita titanium clips have smaller opening width of blades comparing with cobalt ones. However, Sugita Titanium II clips have similar or better opening width of blades.**

Sugita titanium clip was originally innovated in 1998 and renewed as Titanium II in 2007 [3,4]. Nagatani and co-workers [4] found no difference in closing force between Sugita cobalt and original titanium clips. In the present study, Sugita Titanium

II clips were stronger than Sugita Elgiloy clips especially at the blade base. These differences between original titanium and Titanium II clips might be caused by clip design especially in spring portion and is not caused by the material, because Sugita original titanium and Titanium II clips are made of same titanium alloy (Titanium-6A1-4V) [3,4]. Professor Sugita thought that the ideal aneurysm clip closing forces were the same along any blade portions (personal communication). This clip character can allow a neurosurgeon successfully to use only the tip of the long clip blade for a deep seated aneurysm with a small neck such as basilar bifurcation aneurysm. In addition, the same distribution of closing force can avoid aneurysmal neck and/or parent artery injuries due to excessive closing force at the blade base [5,6]. Therefore, strong closing pressure is not always safe in any situations. According to Professor Sugita's philosophy, Elgiloy clip has better distribution of closing force. However, it has more artifacts during CT and MRI scan. Titanium II clips are commonly used and have some advantages such as small clip head and thinner blades compared with Elgiloy and original titanium clips [3,4].

The main purpose of the present study was comparison between Sugita Titanium II clips and Sugita Elgiloy clips. **Direct comparison between Sugita and Yasargil clips was not considered necessary in this study. Therefore, only one each Yasargil clip was tested.**

Yasargil cobalt clip has a bigger closing force compared with Yasargil titanium clips in the previous [4] and present study. In addition, the previous study [5] demonstrated that all Yasargil cobalt clip had greater closing forces than Sugita cobalt clips. Interestingly, in the present study, the closing forces of Sugita Titanium II and Yasargil titanium clips were similar in straight permanent type clip, although there were

some differences in closing forces between other types of Sugita and Yasargil clips. As previously known in cobalt alloy clip [5], bayonet, angled, L-shaped, and fenestrated titanium clip closing forces gently increased along the blades than straight clips. These findings indicate that non-straight clips are weaker than straight clips. The weaker closing forces in non-straight clips might be caused by twisting movement in springs generated by the blade opening [5].

Conclusions

We have examined closing forces of the commonly used aneurysm clips. The current Sugita titanium clips (Titanium II) have stronger closing forces than cobalt clips. This study can serve as a recommendation for neurosurgeon in selecting the proper clip based on the present features of closing forces.

Disclosure

No financial support was provided in the present study. Mizuho Co., Ltd donated Sugita clips and lent the forcemeter, however, the company did not have any role in data analysis, interpretation, nor in writing of this manuscript. The authors have no perceived conflicts of interest.

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Figure legends

Figure 1: Scatter graphs show the relationship between distance from tip and closing force and linear regression lines for cobalt or titanium alloy permanent straight clip: left; Sugita clip (17-001-02 and 07-940-02) and right; Yasargil clip (FT750T and FE750K).

Figure 2: Scatter graphs show the relationship between distance from tip and closing force and linear regression lines for cobalt or titanium alloy temporary clip: left**;** Sugita clip (17-001-52 and 07-940-52) and right; Yasargil clip (FT250T and FE751K).

Figure 3: Scatter graphs show the relationship between distance from tip and closing force and linear regression lines for Sugita or Yasargil permanent titanium alloy clip: left; bayonet clip (17-001-13 and FT758T) and right; fenestrated clip (17-001-30 and FT650T).

Figure 4: Effect of distance from tip on Titanium II and Elgiloy closing forces: left; straight clip (17-001-02 and 07-940-02) and right; angled clip (17-001-49 and 07-940-49). Asterisk indicates significant differences between Titanium II and Elgiloy.

Figure 5: Effect of distance from tip on Titanium II and Elgiloy closing forces: left; L-shaped clip (17-001-22 and 07-940-22) and right; fenestrated clip (17-001-30 and 07-940-30). Asterisk indicates significant differences between Titanium II and Elgiloy.

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

Clip name	Product name or material	Catalog number	Shape	Purpose	Blade length	Applied number
Sugita	Titanium II	17-001-02	Straight	Permanent	10	6
	Elgiloy	07-940-02	Straight	Permanent	10	6
Yasargil	Titanium	FT750T	Straight	Permanent	9	1
	Phynox	FE750K	Straight	Permanent	9	1
Sugita	Titanium II	17-001-52	Straight	Temporary	10	6
	Elgiloy	07-940-52	Straight	Temporary	10	6
Yasargil	Titanium	FT250T	Straight	Temporary	9	1
	Phynox	FE751K	Straight	Temporary	9	1
Sugita	Titanium II	17-001-13	Bayonet	Permanent	10	6
Yasargil	Titanium	FT758T	Bayonet	Permanent	9	1
Sugita	Titanium II	17-001-30	Fenestrated	Permanent	9	6
	Elgiloy	07-940-30	Fenestrated	Permanent	9	6
Yasargil	Titanium	FT650T	Fenestrated	Permanent	9	1
Sugita	Titanium II	17-001-49	Angled	Permanent	10	5
	Elgiloy	07-940-49	Angled	Permanent	10	5
Sugita	Titanium II	17-001-22	L-shaped	Permanent	10	5
	Elgiloy	07-940-22	L-shaped	Permanent	10	5

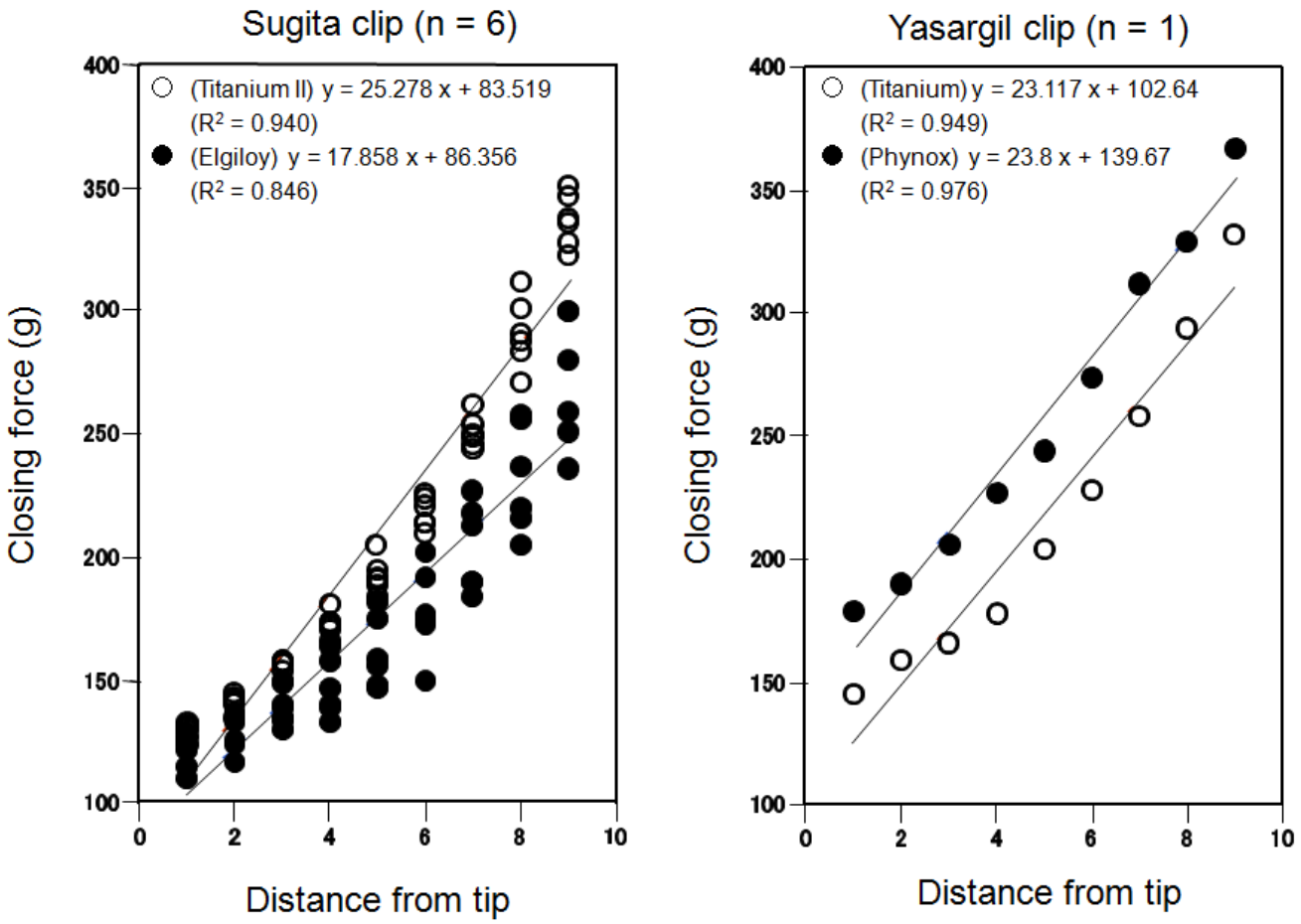
Sugita clip (n = 6)
(Titanium II) y = 25.278 x + 83.519
(R² = 0.940)
(Elgiloy) y = 17.858 x + 86.356
(R² = 0.846)
Closing force (g)
Distance from tip
Yasargil clip (n = 1)
(Titanium) y = 23.117 x + 102.64
(R² = 0.949)
(Phynox) y = 23.8 x + 139.67
(R² = 0.976)
Closing force (g)
Distance from tip

Figure 1

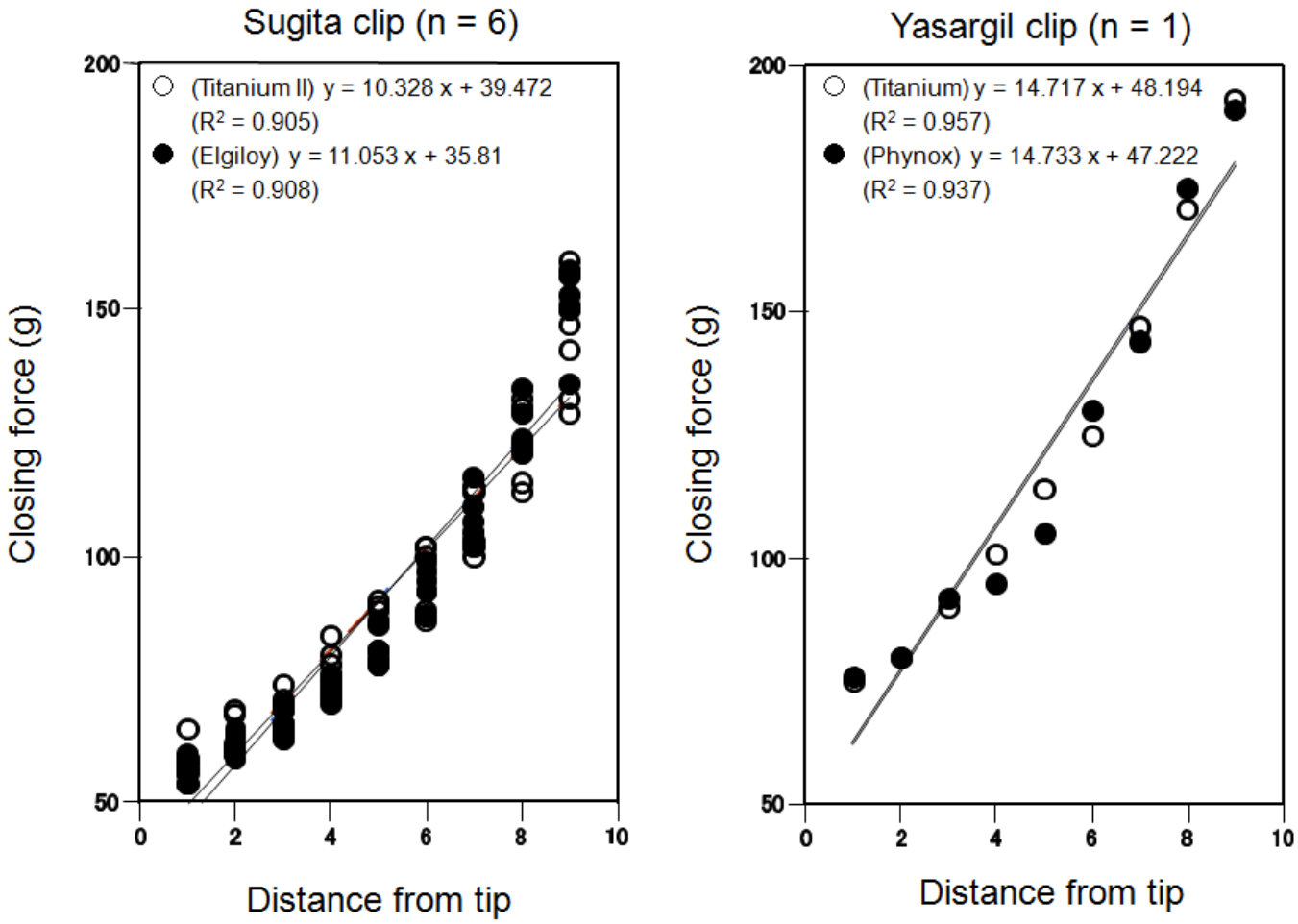
Sugita clip (n = 6)
(Titanium II) y = 10.328 x + 39.472
(R² = 0.905)
(Elgiloy) y = 11.053 x + 35.81
(R² = 0.908)
Closing force (g)
Distance from tip
Yasargil clip (n = 1)
(Titanium) y = 14.717 x + 48.194
(R² = 0.957)
(Phynox) y = 14.733 x + 47.222
(R² = 0.937)
Closing force (g)
Distance from tip

Figure 2

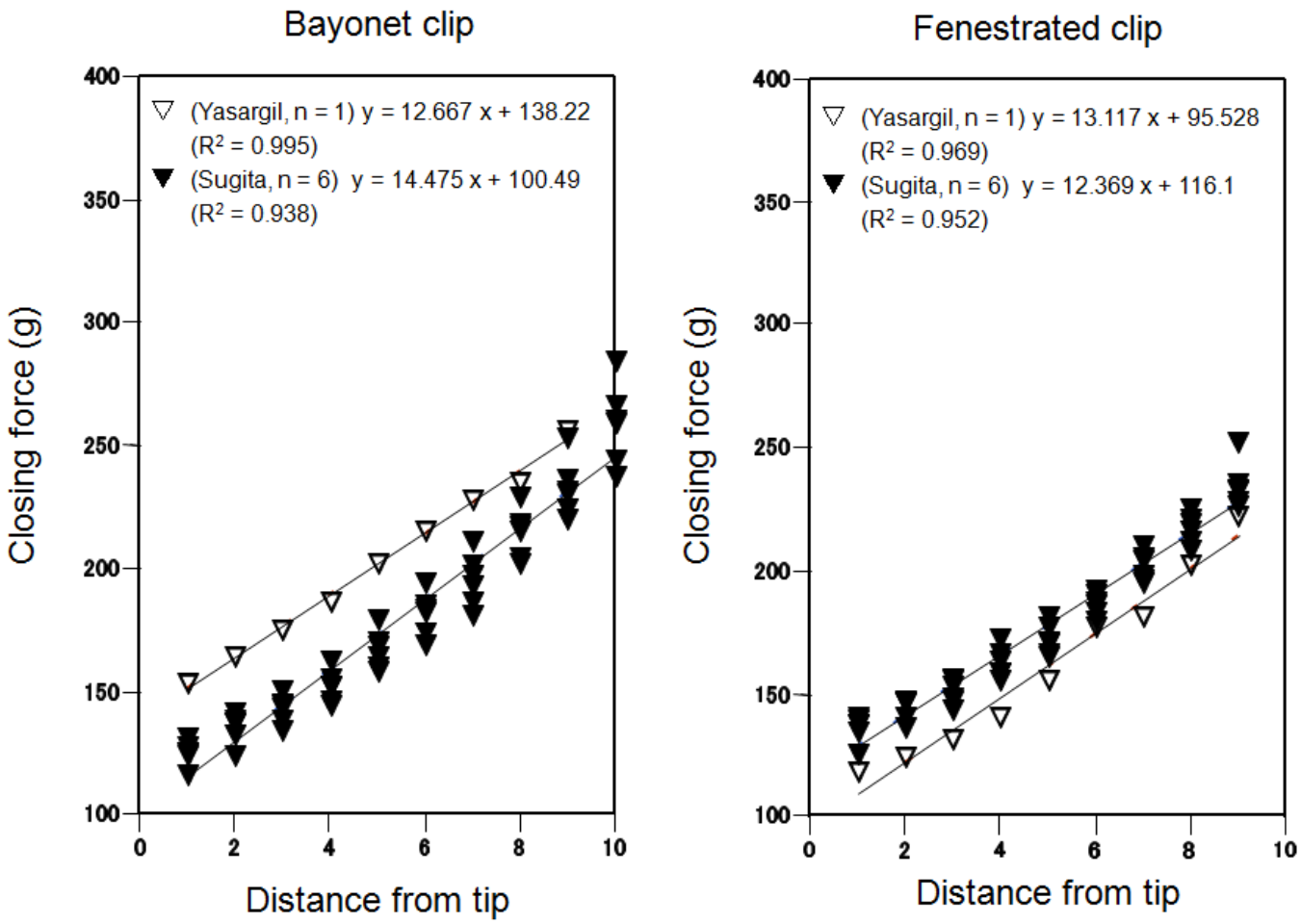
Bayonet clip
(Yasargil, n = 1) y = 12.667 x + 138.22
(R² = 0.995)
(Sugita, n = 6) y = 14.475 x + 100.49
(R² = 0.938)
Closing force (g)
Distance from tip
Fenestrated clip
(Yasargil, n = 1) y = 13.117 x + 95.528
(R² = 0.969)
(Sugita, n = 6) y = 12.369 x + 116.1
(R² = 0.952)
Closing force (g)
Distance from tip

Figure 3

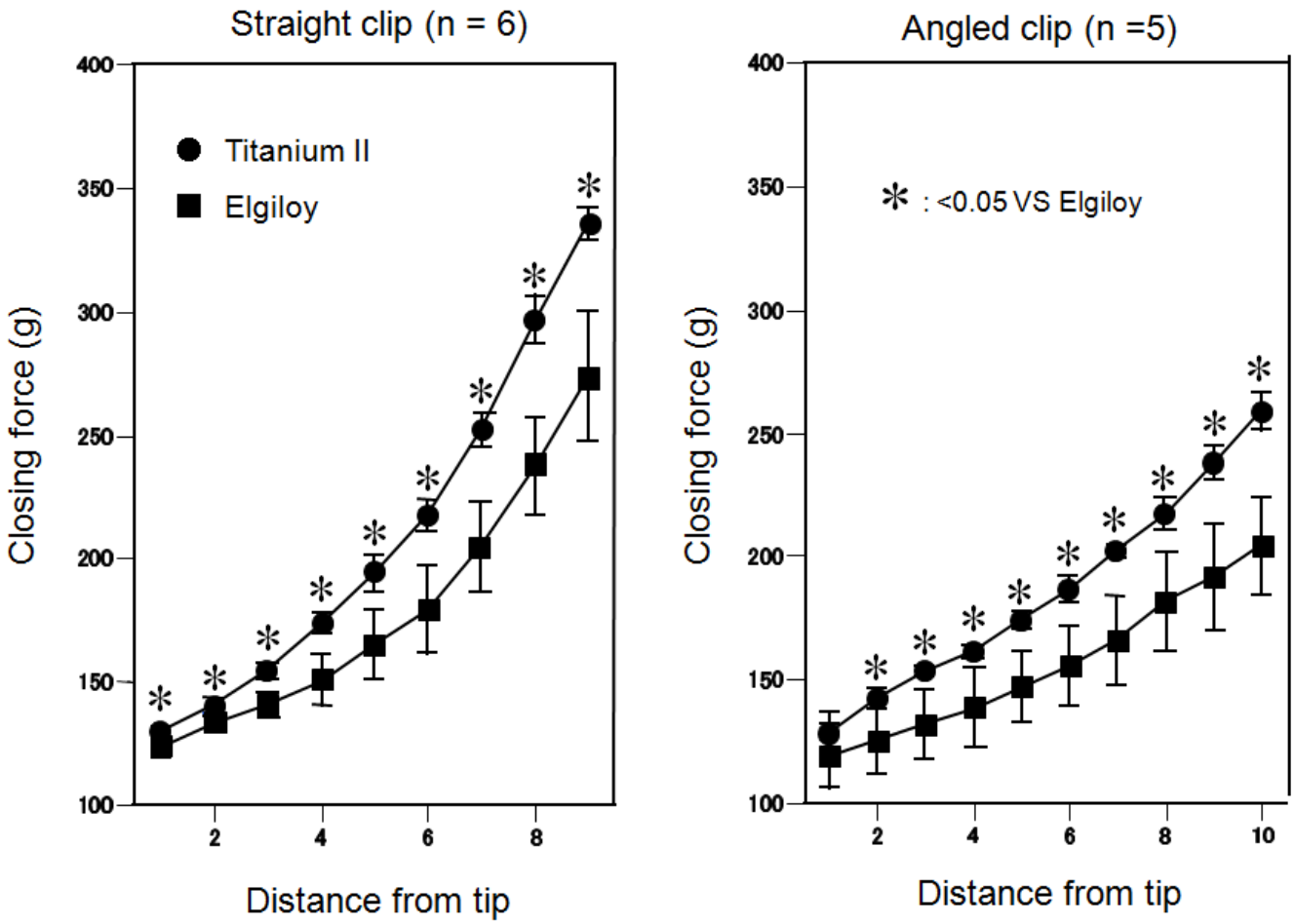
Straight clip (n = 6)
Titanium II
Elgiloy
Closing force (g)
Distance from tip
Angled clip (n =5)
* : <0.05 VS Elgiloy
Closing force (g)
Distance from tip

Figure 4