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Original Article

Relationship between Shape Retention and X-ray Absorption Value of the Tip of Microcatheters in Neuroendovascular Treatment

Tomotaka Ohshima[1] Fuminori Ato[2] Reo Kawaguchi[2] Naoki Matsuo[2] Shigeru Miyachi[1,2]

[1] Neuroendovascular Therapy Center, Aichi Medical University, Nagakute, Aichi, Japan
[2] Department of Neurosurgery, Aichi Medical University, Nagakute, Aichi, Japan

Address for correspondence Tomotaka Ohshima, MD, PhD, Neuroendovascular Therapy Center, Aichi Medical University, 1-1 Yazakokarimata, Nagakute, Aichi 480-1195, Japan (e-mail: tmtkoh@gmail.com).

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Abstract

Objective We noticed that the X-ray absorption value of the tip of each microcatheter used for aneurysm treatment varied from product to product. We hypothesized that the differences were caused by variations in the metal's density braid, which could be related to the ability of the tip to retain its shape.

Methods The X-ray absorption value of each microcatheter tip was measured. Next, heat forming was performed using a shaping mandrel at 6 mm and 90 degrees to determine whether there was a correlation between the X-ray absorption value and the forming angle. Next, the optimal mandrel angle for forming each microcatheter at 90 degrees was investigated. We also examined the shape retention after 20 times wire insertions into each microcatheter.

Results and Conclusion It was found that the higher the X-ray absorption value, the harder it was for the microcatheter to be formed. The mandrel angle required to form 90 degrees was determined by the X-ray absorption value. The higher the X-ray absorption value, the higher the shape retention of the tip shape. The heat formation and shape-retention conditions of the microcatheter tip were correlated with the X-ray absorption value of the metal braid. Even for unknown microcatheters, the optimum shaping conditions can be inferred from the X-ray absorption value.

Keywords
- ► microcatheter
- ► neuroendovascular treatment
- ► retention
- ► shape
- ► X-ray absorption value

Introduction

The tip shape of the microcatheter is critical to the treatment strategy and outcome in the endovascular treatment of cerebral aneurysms. Each surgeon bends the shaping mandrel to form the tip of the microcatheter based on their own experience. However, it is unclear how much the mandrel should be bent to achieve the expected shape because there is no information available for microcatheters that have little experience in use.

We mainly performed cone-beam computed tomography (CT) during coil embolization with a stent to confirm stent dilation and microcatheter position. In that image, we wondered why the visibility of each microcatheter was different (►**Fig. 1**). We thought that the differences in visibility could be quantified by X-ray absorption value. We further

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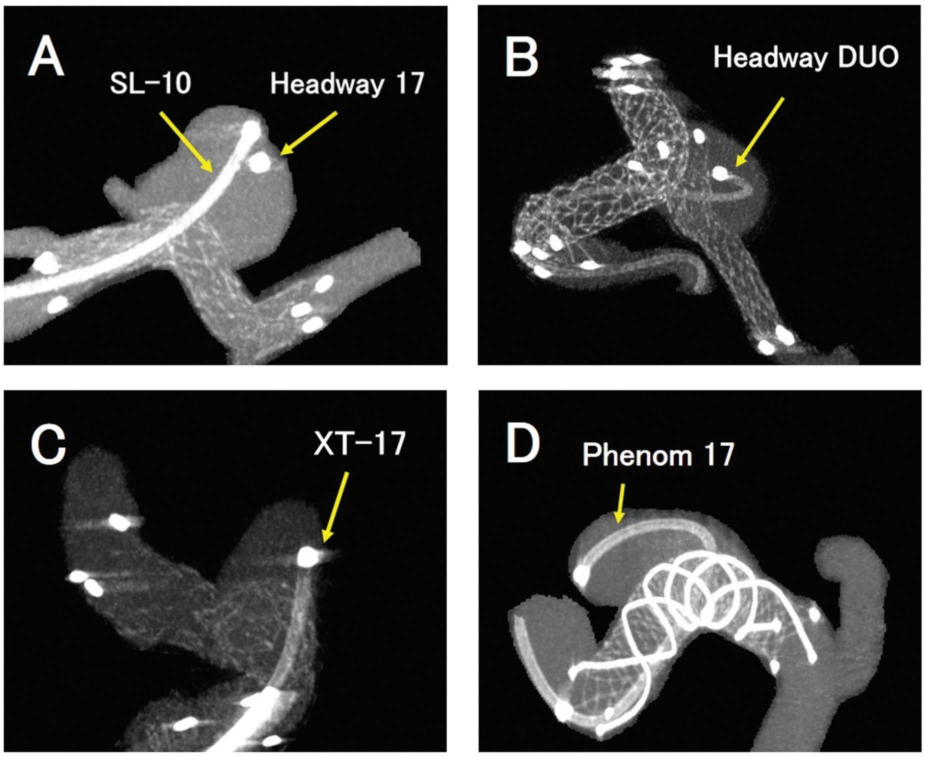

Fig. 1 Differences in the visibility of various microcatheter tips by cone-beam CT. (**A**) Excelsior SL-10 (Stryker) and Headway 17 (Terumo). (**B**) Headway DUO (Terumo). (**C**) XT-17 (Stryker). (**D**) Phenom 17 (Medtronic).

hypothesized that this value represents the density of the metal braid at the tip of the microcatheter and may be involved in its shape-retention ability. Finally, we report our experimental results and discussion.

Materials and Methods

Eight types of microcatheters, always available in our angiography room, were simultaneously imaged with cone-beam CT in their boxes to measure X-ray absorption values. Products included Excelsior SL-10 (Stryker, Kalamazoo, Michigan, United States), XT-17 (Stryker), Excelsior 1018 (Stryker), Headway DUO (Terumo, Tokyo, Japan), Headway 17 (Terumo), Headway 21 (Terumo), Phenom 17 (Medtronic, Irvine, California, United States), and Echelon 10 (Medtronic). Next, five microcatheters (Excelsior SL-10, Excelsior 1018, Headway DUO, Headway 17, and Phenom 17) that were available for this study were thermally formed with a hot-air gun, and the following experiments were performed.

- Experiment 1: The shaping mandrel was bent 90 degrees, forming a 6-mm microcatheter tip (►**Fig. 2A,B**). The hot-air gun was used to heat-form at a measured temperature of 110°C for 30 seconds (►**Fig. 2C,D**). We examined whether there was a correlation between the X-ray absorption value and the angle of the finished microcatheter.

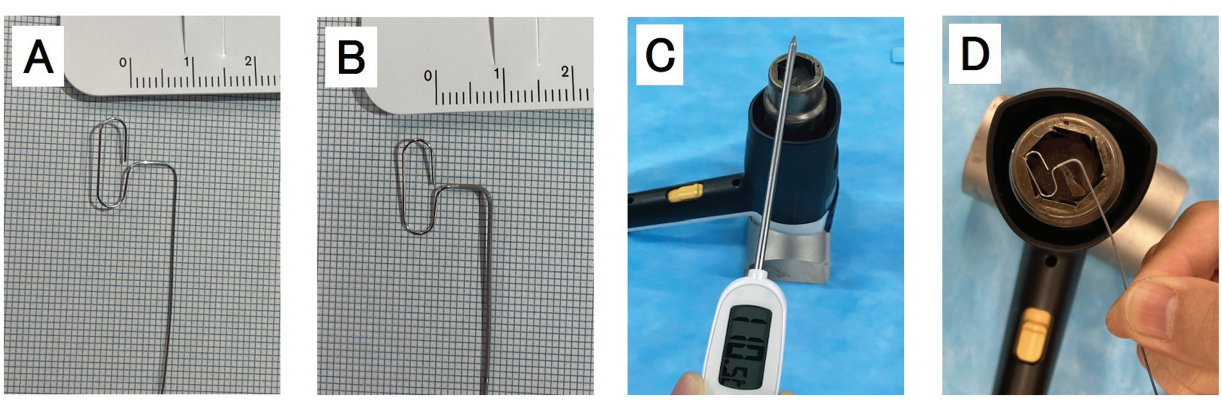

Fig. 2 Photographs of Experiment 1. (**A**) The shaping mandrel was bent at 90 degrees to form a 6-mm microcatheter tip. (**B**) A microcatheter tip was set over the shaping mandrel. (**C**) The hot-air gun was used to heat-form at a measured temperature of 110°C. (**D**) Photograph of heat forming.

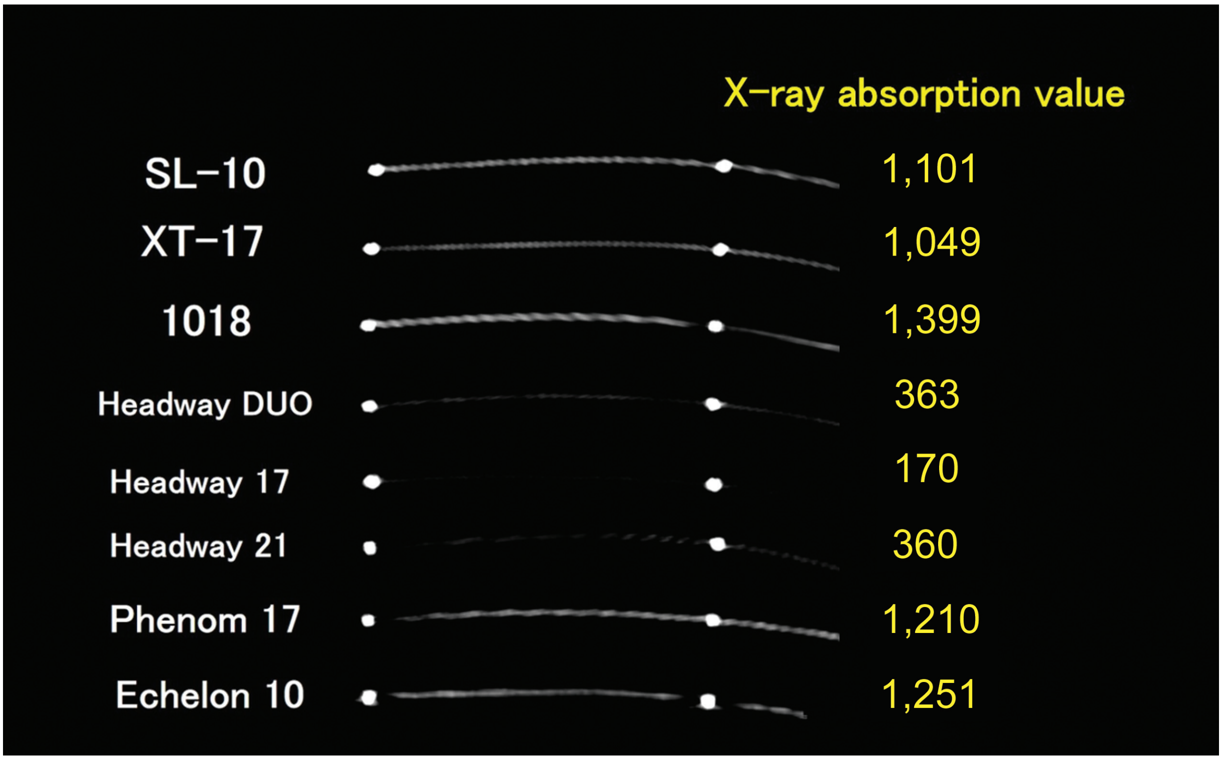

Fig. 3 The visibility of each microcatheter tip by the cone-beam CT and the measured X-ray absorption value of the metal braid.

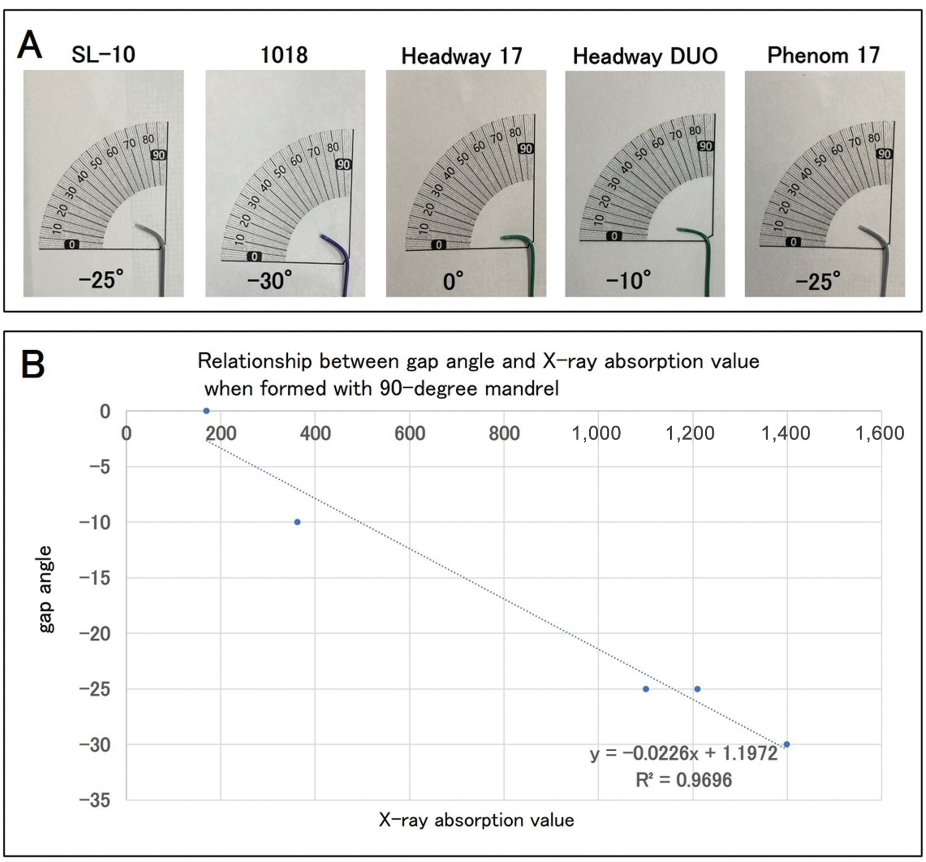

Fig. 4 Results of Experiment 1. (A) Photographs of five microcatheters after forming a 90-degree mandrel. (B) Graphical representation of the relationship between shape memory and X-ray absorption value.

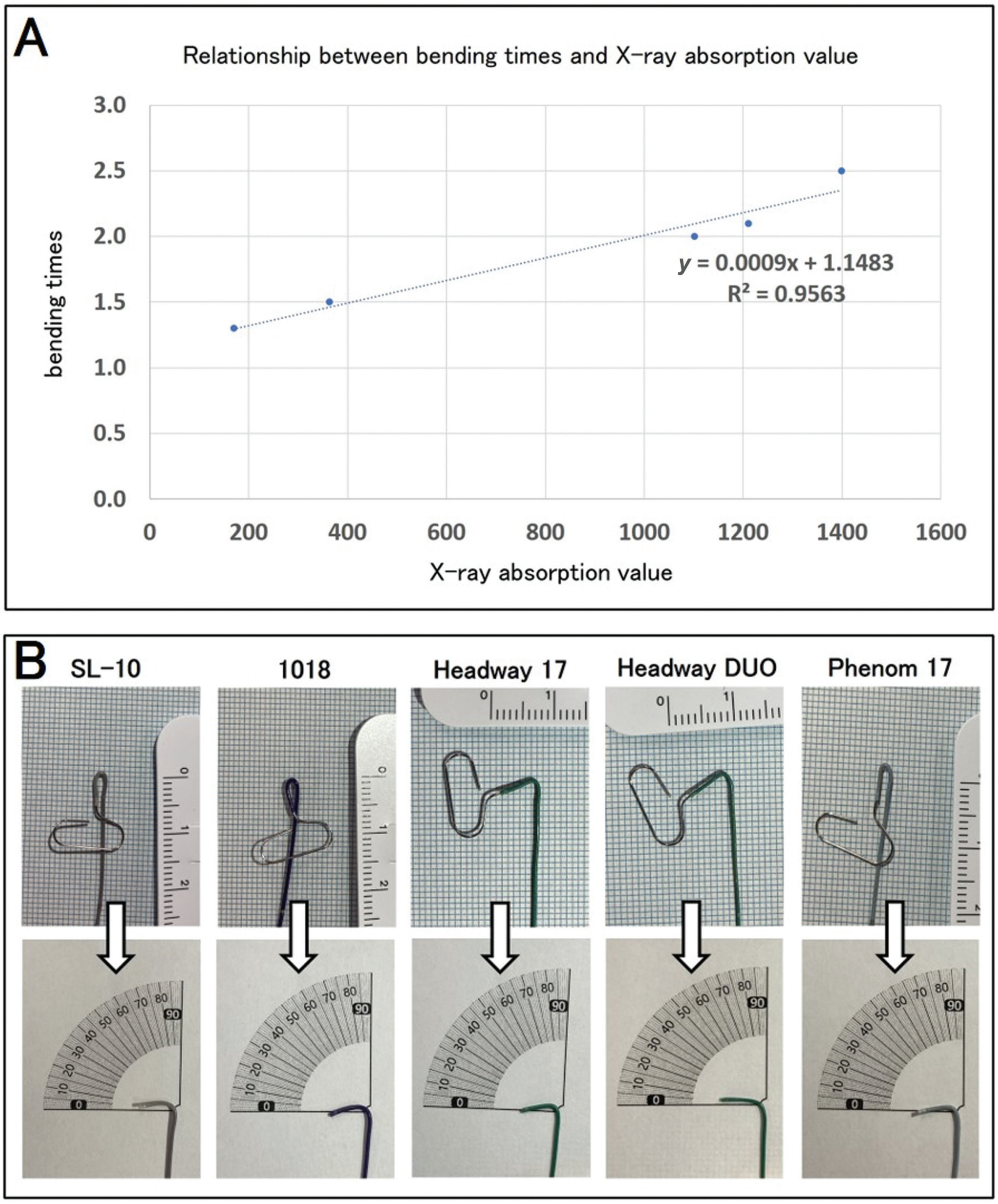

Fig. 5 Results of Experiment 2. (**A**) The X-ray absorption value was used to calculate the angle of the mandrel to form each microcatheter at 90 degrees. (**B**) Photographs of each microcatheter formed.

- Experiment 2: The optimum mandrel angle for forming each microcatheter to 90 degrees was calculated using the X-ray absorption value and thermally formed under the same conditions as Experiment 1.
- Experiment 3: The shape-retention ability of each microcatheter formed at 90 degrees in Experiment 2 was examined after 20 insertions and removals of a Traxcess micro-guidewire (Terumo).

Results

The X-ray absorption values of each of the eight microcatheters are shown in ►**Fig. 3**. A photograph of each microcatheter tip shape following Experiment 1 is shown in ►**Fig. 4A**. The relationship between these angles and the X-ray absorption value was directly proportional, as shown in ►**Fig. 4B**. Experiment 2 was conducted to investigate the relationship between the X-ray absorption value and the empirical bending ratio that was used, which was 1.3 times for Headway 17 and 2 times for SL-10. The results are shown in ►**Fig. 5A**. Using the bending ratio of each microcatheter calculated from this table and formed as shown in ►**Fig. 5B**, we configured all catheters to 90 degrees. The results of Experiment 3 are shown in ►**Fig. 6A,B**. The shape-retention ability of the microcatheters with higher X-ray absorption values was higher, demonstrating a directly proportional relationship.

Discussion

In endovascular therapy, the performance of microcatheters is very important and is related to therapeutic outcomes. There have been several reports on the shape retention of

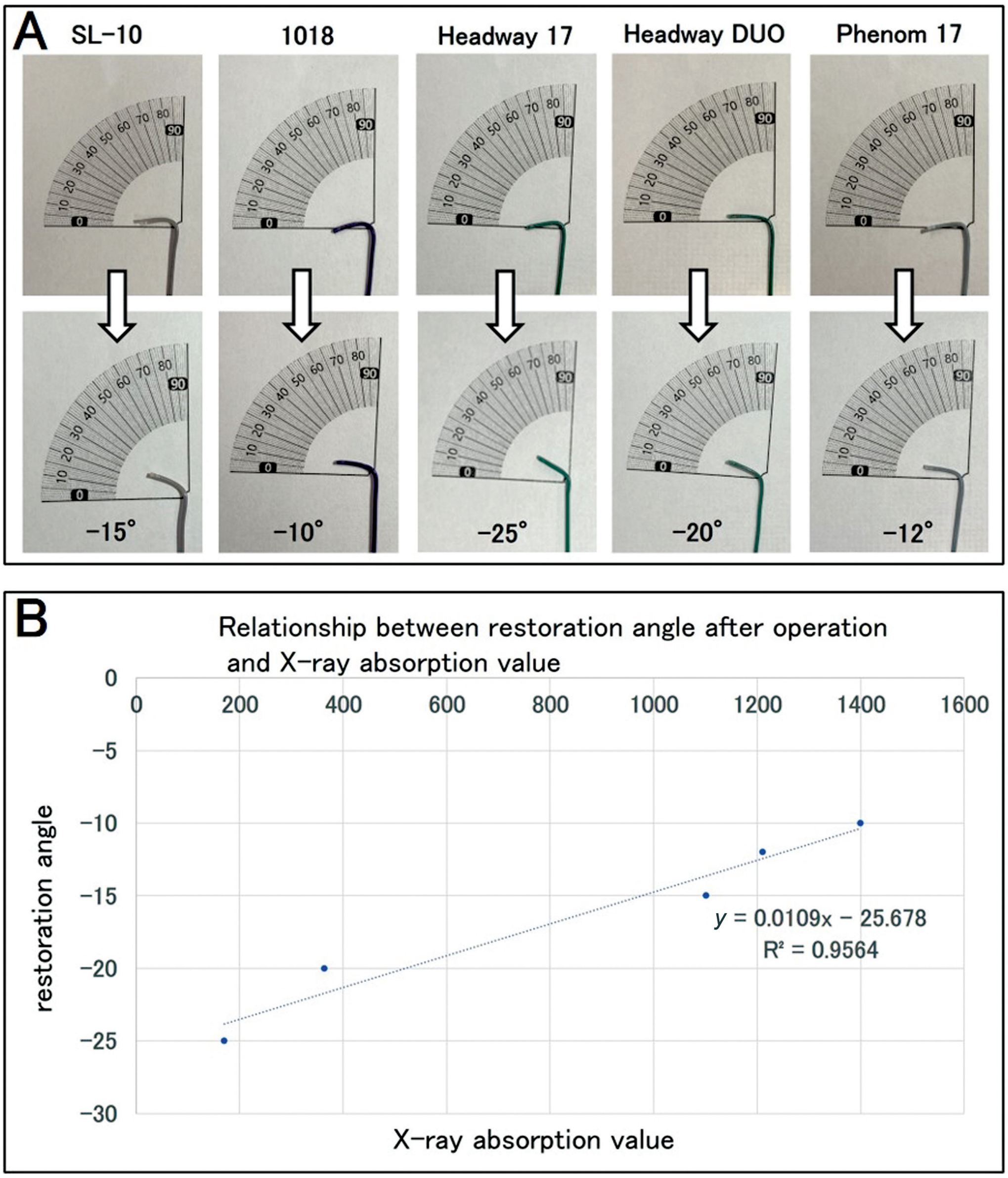

Fig. 6 Results of Experiment 3. (**A**) Photographs are shown after the guidewire has been inserted and withdrawn 20 times into each microcatheter formed at 90 degrees in Experiment 2. (**B**) The relationship between the shape-retention ability of each microcatheter and the X-ray absorption value.

microcatheters used for endovascular therapy, including the characteristics of individual products and morphological changes after use.[1–3] However, with the ever-increasing number of products, there are no studies that mention the shape-retaining conditions of each product.

The X-ray absorption value is a unitless number like the CT value and is approximately the same regardless of which X-ray device is used to measure it. This study confirms our hypothesis that the X-ray absorption value of the microcatheter tip represents the density of the metal braid and may correlate with the heat-forming conditions. It could be shown as a clean, directly proportional graph. The higher the X-ray absorption value, the more difficult it was to form the tip shape. It was found that the X-ray absorption value determines the optimum bending ratio for heat-forming microcatheters. Furthermore, the higher the X-ray absorption value, the higher the shape-retention ability.

Knowing the X-ray absorption value will help determine the optimal bending ratio even for unknown microcatheter that have never been used. The bending ratio of the recently marketed GREACH microcatheter (Tokai Medical Products, Aichi, Japan) with an X-ray absorption value of 730, for example, can be calculated as 1.8 times using the formula $y = 0.0009x + 1.1483$.

If operators expect the same tip shape at the end of the procedure, a microcatheter with a high X-ray absorption value should be chosen. Alternatively, a microcatheter with a low X-ray absorption value is preferred for aneurysms that require a strong catheter shape at the beginning of the procedure but a straight one at the end of the procedure. The Γ (gamma) tip method,[4] in which the tip of the microcatheter is bent to a small size, is less stressful on the bleb of the aneurysm and allows safe and tight coil packing. In lateral wall–type aneurysms, the coil can be effectively inserted into the aneurysm's inflow zone even at the end of the embolization phase. However, in terminal-type aneurysms, a straight catheter tip is preferred at the end of embolization. Therefore, if a catheter with a low X-ray absorption value is selected, the shape of the catheter will change on its own between the beginning and end of the procedure, allowing for ideal coil insertion.

This study evaluated only the conditions that formed each microcatheter at right angles. Therefore, 45 degrees and J-shaped bending rates may vary. Additionally, each microcatheter was assessed only once in this study, making the experiment unreliable. Thus, a further large-scale investigation is mandatory to increase reliability.

The heat-forming and shape-retention conditions of the microcatheter tip were correlated with the X-ray absorption value of the metal braid. Even for unknown microcatheters, the optimum shaping conditions can be inferred from the X-ray absorption value. Depending on the morphology of the aneurysm and the treatment strategy, a microcatheter can be selected based on the X-ray absorption value. Further large-scale validation is needed to increase this study's reliability.

Funding
None.

Conflict of Interest
S. M. and T. O. have received speaker fees from Medtronic.

Authors' Contributions
Concepts, design, literature search, manuscript preparation was done by T.O. Critical revision of the article was performed by all authors. Final approval of the article was given by all authors. Manuscript editing and review was done by S.M.

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