A Comparison of Clinical and Radiological Outcomes Between Target 360 Nano and Microplex Hypersoft 3D Used as Finishing Coil

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ABSTRACT

AIM: To compare the clinical outcomes of Target 360 nano (TG) and Microplex hypersoft 3D (MH) used as a finishing coil (FC).

MATERIAL and METHODS: From January 2018 to December 2020, we retrospectively reviewed 243 coil embolization procedures performed using TG (n=152) and MH (n=91) coils of 1mm x 2 cm the same size as FC. Further, the clinical and radiographic results were compared by matching the propensity score between the two groups.

RESULTS: There were no statistically significant differences in the clinical and angiographic results of the two coils after the propensity score matching. Successful occlusion was 89% and 86.8% and FC insertion failure was 20.9% and 28.6%. There were no differences in procedure-related complications and recurrence between the groups during the eight months follow-up period (3.3% versus 4.4% and 4.4% versus 3.3%, respectively). We also compared two subgroups of failed FC insertion (19 of TG and 26 of MH). The number of angled catheters was significantly higher in the failed TG group than in the failed MH group.

CONCLUSION: There was no statistically significant difference between the clinical and radiological outcomes of TG and MH used as FC. However, in the FC insertion failure subgroups, the number of angled catheters was significantly higher in the TG failed group than in the MH failed. It was experimentally confirmed that the angle change of microcatheter tip with a large angle was large; however, further studies are required.

KEYWORDS: Intracranial aneurysm, Coil embolization, Detachable coils, Finishing coil, Comparative studies

INTRODUCTION

Coil embolization is a major therapeutic option for intracranial aneurysms, which attempts to prevent the aneurysm form rupturing and reduce the chances of recurrence (6,21). To achieve successful embolization and prevent a recurrence, dense coil packing of the aneurysm sac is required, therefore, proper selection of coils (sizes, shapes, and structural characteristics) should be done for every coil embolization stage; framing, filling, and finishing (4,7). In the final stage, a very soft and small size coil, referred to as finishing coil (FC), is usually selected to achieve the densest possible coil packing (16).

Currently, companies are manufacturing different types of coils with varying characteristics. In general, embolization coils have multiple structures; primary, secondary and tertiary structures. The primary structure is a thin and thread-like stock wire mostly of platinum alloy. The primary structure is the wound around a mandrel in a coil or a spring to make the secondary structure. Then the secondary structure is shaped into any three-dimensional shapes (tertiary configurations),
such as a helix, sphere, or other complex shapes. These
coil structures are transferred to the aneurysm sac through
a microcatheter by a delivery wire and detached in various
ways (5,24).
Coil configuration affects the inherent characteristics such as
the size, and softness/stiffness, and therefore the packing
density. Although these factors are known to influence clinical
outcomes, there are no studies on the impact of coil designs
on clinical outcomes. In particular, there is little research on
how these factors affect the insertion of FC in the final stage.
FCs are commonly used in complicated situations where they
are inserted into a coil mass already formed by previously
placed coils. In some cases, they are inserted into spaces
smaller than their original size (23,25).
In this study, to evaluate the impact of coil design on the
clinical outcomes, for the first time, we compared the clinical
outcomes of coil embolization between Target 360 nano (TG)
(Stryker, Fremont, CA, USA) and Microplex hypersoft 3D (MH)
(Mirovention Terumo, Tustin, CA, USA). The size and length
of the two coils were the same as those of the FCs. We also
considered other factors that could have an effect on the
outcomes.

**MATERIAL and METHODS**

**Study Population and Data Collection**

From January 2018 to December 2020, a total of 528 patients
with 595 intracranial aneurysms underwent coil embolization
at our institution. In this cohort, we included 243 cases of coil
embolization using TG and MV coils as FCs (the same size-
1 mm x 2 cm). Non-saccular type aneurysms such as oncot-
ic, dissecting, and blood blister-like aneurysms, and cases in
which other sizes or products other than the TG and MV coils
were used as FC were excluded. Medical records were re-
viewed retrospectively to assess the patients’ related factors
such as age, sex, hypertension, diabetes mellitus, dyslipid-
emia, smoking history, subarachnoid hemorrhage (SAH), loca-
tion of aneurysms, and postoperative complications. We also
reviewed the surgical records for operation-related factors
such as the number and type of coils, the type of microcath-
eters, the use of intracranial stents, and other events during
the procedure. This study was approved by the Institutional
Review Board of the author’s institution.

**Ethical approval and consent to participate:** The present
study was approved by the local ethical committee and
institutional review board (IRB No. MSH-2021001). Informed
consent was obtained from all patients.

**Endovascular Procedures**

In our institution, all the coil embolization procedures were
performed under general anesthesia, and a cerebral angiography
and three-dimensional rotational image reconstruction were
performed to determine the shapes and sizes (width, depth,
and neck) of aneurysms using an Artis Q biplane or Artis zee
biplane (Siemens healthineers, Erlangen, Germany). Except in
cases of a ruptured aneurysm, after the femoral sheath was
inserted, 2500 to 3000IU of unfractionated heparin was initial-
ly injected intravenously depending on the patient's weight,
and an additional dose of 1000IU was administered every 1
hour while monitoring activated clotting time. The emboliza-
tion coil intervention procedure for each cerebral aneurysm
was performed by four skilled endovascular neurosurgeons
(SU.K, J.H) certified by the Korean Neuroendovascular soci-
ety (KoNES). During the procedure, the aneurysmal sac was
filled as densely as possible. In case of unexpected problems
during the procedure, appropriate measures were taken with
the operators’ discretion. Such measures included inserting
additional coils after reversal of heparin with protamine sul-
fate in case of premature rupture or attempting to dissolve an
acute thrombus with tirofiban in the thromboembolic events.

**Angiographic Result and Clinical Outcome**

The final angiographic results after the coil embolization were
classified into three categories according to Roy Raymond
scale; complete occlusion, residual neck, and residual sac.
The complete occlusion and residual neck were defined as
successful occlusion (12). The procedure was defined as ‘failure’
when the microcatheter dropped out while inserting the
FC or an attempt to fill the FC was unsuccessful. Packing
density (PD) was calculated using the AngioCals app, based
on the shape and size of the aneurysm, as well as the type
and size of coils. The PD was measured before and after
FC insertion. Unexpected events during the procedure,
such as premature rupture and acute thrombus formation,
were classified as procedural complications and confirmed
by the medical records and postoperative imaging studies.
Subsequent cerebral vessel studies confirmed whether
postoperative embolism, recurrence, and retreatment of
aneurysms during the follow-up period (Figure 1).

**Angled Catheter**

The experiment was conducted to verify the differences
between the TG and MH coils based on the angle of the
microcatheter tips. Two coils of the same size (1 mm x 2
cm), were inserted into the microcatheters, Excelsior SL-10
(Stryker, Fremont, CA, USA) of different tip angles (straight,
pre-shaped 45, pre-shaped 90, pre-shaped S, and pre-shaped
J) and each microcatheter angle was measured 10 times. As
shown in Table I and Figure 2, the difference between the
tip angles changes as the TG and MH pass through each
catheter was calculated as the mean and standard deviation
and displayed in a graph. And in this study, we defined the
pre-shaped S and pre-shape J microcatheters based on the
angle difference of more than 30 degrees between the two
coils, and steam-shaping microcatheters based on angulated
forms such as pig-tail, S-shaped, and J-shaped like the group
wise an angled catheter.

**Statistical Analysis**

Statistical analysis was performed using SPSS version 25.0
(IBM Corporation, Armonk, NY, USA). Continuous variables
were presented as means and standard deviations compared
between the two groups using Fisher’s exact or chi-square test
as appropriate. The categorical variables were analyzed using
Student t-test or the Mann-Whitney U test as appropriate. The
propensity score matching (PSM) was done to compensate
for the group-wise imbalances in the baseline characteristics that could potentially skew the results. Reflecting the angled catheter and stent-assisted coiling, PSM for each patient was performed within the R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) using the nearest neighbor package for optimal 1:1 matching. A probability value <0.05 was considered statistically significant. Odd ratios (OR) and their 95% CIs were also reported.

### RESULTS

#### Baseline Characteristics of Patients and Aneurysm

A total of 243 aneurysms cases were collected analyzed in this study. The mean age of the study population was 61.2 ± 10.6 years (range 29 to 84 years) and 188 patients 77.4% were female. The mean volume of the aneurysms was 28.9 ± 36.3 mm³ (range 2.44 to 353.26). Clinical parameters were distributed as follows: hypertension, 120 (49.4%); diabetes...
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Comparison of Total Population and PSM Group Results of Coil Embolization Using Different Finishing Coils

To evaluate the difference between the clinical outcomes of different FCs, we compared the results of two groups using two different types of coils of the same size (1 mm x 2 cm), TG (n=152) and MH (n=91) as FCs. There were no statistically significant differences between the patients’ age, sex, other clinical factors, and location and size of cerebral aneurysms in the two groups. There was also no significant difference in the PD of TG, and MH groups before inserting the FC (approximately 31%). However, procedural factors such as angled catheter and using an intracranial stent showed statistically significant difference. The number of cases that used angled catheter to insert FC was higher in the TG group (43.9%) than the MH group (29.7%), (p=0.023), while the number of cases that underwent stent-assisted embolization was higher in the MH group than in the TG group (64.8% versus 50%, p=0.024).

Since there was a significant difference in the use of angled catheter results and stent, between the two groups, we formed new groups of 91 subjects from each group by matching 1:1 propensity scores, and the above factors were compared and analyzed again (Table II). There were no statistically significant differences in age, sex, clinical factors, and procedural factors including angled catheter and use of

Figure 2: A comparison of angle change of the microcatheter tip during the coil insertion, Microcatheter used an Excelsior SL-10 preshaped 90 (Stryker, Fremont, CA, USA). Control group (A) to (E) (straight, pre-shaped 45, pre-shaped 90, pre-shaped S, and pre-shaped J); (a-1) to (e1) the angle changes when inserting Target 360 nano 1 mm x 2 cm (Stryker, Fremont, CA, USA) into each microcatheters; (a-2) to (e-2) the angle changes when inserting Microplex hypersoft 3D 1 mm x 2 cm (Mirovention Terumo, Tustin, CA, USA) into each microcatheters.
**Table II: Baseline Characteristics Before and After Propensity Score Matching in Coil Embolization Using Two Different Finishing Coils**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total population</th>
<th>Propensity score matching (n=182)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=243)</td>
<td><em>(Target: n=152)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Microplex: n=91)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>p</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Target: n=182)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>(Microplex: n=91)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>p</em></td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.2 ± 10.6</td>
<td>60.4 ± 10.6</td>
</tr>
<tr>
<td>Female</td>
<td>188 (77.4%)</td>
<td>117 (77%)</td>
</tr>
<tr>
<td>HTN</td>
<td>120 (49.4%)</td>
<td>77 (50.7%)</td>
</tr>
<tr>
<td>DM</td>
<td>40 (16.5%)</td>
<td>21 (13.8%)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>41 (16.9%)</td>
<td>29 (19.1%)</td>
</tr>
<tr>
<td>Smoking</td>
<td>38 (15.6%)</td>
<td>24 (15.8%)</td>
</tr>
<tr>
<td>SAH</td>
<td>28 (11.5%)</td>
<td>20 (13.2%)</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td>0.938</td>
</tr>
<tr>
<td>ACA</td>
<td>47 (19.3%)</td>
<td>31 (20.4%)</td>
</tr>
<tr>
<td>MCA</td>
<td>35 (15.2%)</td>
<td>22 (14.5%)</td>
</tr>
<tr>
<td>ICA</td>
<td>149 (61.3%)</td>
<td>93 (61.2%)</td>
</tr>
<tr>
<td>BA, VA</td>
<td>10 (4.1%)</td>
<td>6 (3.9%)</td>
</tr>
<tr>
<td>Aneurysm volume (mm³)</td>
<td>28.9 ± 36.3</td>
<td>25.2 ± 24.0</td>
</tr>
<tr>
<td>Angled catheter</td>
<td>91 (37.4%)</td>
<td>58 (43.9%)</td>
</tr>
<tr>
<td>Stent-assisted coiling</td>
<td>135 (55.6%)</td>
<td>76 (50.0%)</td>
</tr>
<tr>
<td>PD before FC (%) (A)</td>
<td>31.0 ± 10.9</td>
<td>31.5 ± 10.9</td>
</tr>
<tr>
<td>PD after FC (%) (B)</td>
<td>36.5 ± 13.2</td>
<td>37.7 ± 13.7</td>
</tr>
<tr>
<td>B-A</td>
<td>5.6 ± 6.5</td>
<td>6.1 ± 7.2</td>
</tr>
</tbody>
</table>

**HTN:** Hypertension, **DM:** Diabetes mellitus, **SAH:** Subarachnoid hemorrhage, **ACA:** Anterior cerebral artery, **MCA:** Middle cerebral artery, **ICA:** Internal carotid artery, **BA:** Basilar artery, **VA:** Vertebral artery, **PD:** Packing density, **FC:** Finishing coil

The statistically significant values are presented in bold (p<0.005).

There was no difference between the two coils in complications related to the procedure and embolisms as confirmed by the postoperative imaging study, 3.3% versus 4.4%, and 23.1% versus 25.3%. In addition, there was no significant difference in the recurrence and retreatment of aneurysms between the two groups during a follow-up period of approximately 8 months.

**Subgroup Analysis: Comparisons of Clinical Outcomes Between Two Finishing Coil Insertion Failure Groups Using Different Coils**

Table IV showed the results of a subgroups comparison of 45 cases in which FC insertion failed, TG (n=19), and MH (n=26). Although not related to other factors, the SAH and angled catheter showed significant differences between the two coils. Specifically, the angled catheter accounted for 57.9% (11 out of 19) in the failed TG group and 28.6% (7/26) in the failed MH group, and angled catheter was approximately 4 times more in the failed TG group than in the failed MH group (p=0.036).
Table III: Clinical and Radiological Outcomes After Propensity Score Matching

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=182)</th>
<th>Target (n=91)</th>
<th>Microplex (n=91)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful occlusion</td>
<td>160 (87.9%)</td>
<td>81 (89.0%)</td>
<td>79 (86.8%)</td>
<td>0.649</td>
</tr>
<tr>
<td>FC Fail</td>
<td>45 (24.7%)</td>
<td>19 (20.9%)</td>
<td>26 (28.6%)</td>
<td>0.229</td>
</tr>
<tr>
<td>Procedural complication</td>
<td>7 (3.8%)</td>
<td>3 (3.3%)</td>
<td>4 (4.4%)</td>
<td>0.700</td>
</tr>
<tr>
<td>Embolism</td>
<td>44 (24.2%)</td>
<td>21 (23.1%)</td>
<td>23 (25.3%)</td>
<td>0.729</td>
</tr>
<tr>
<td>Recurrence</td>
<td>7 (3.8%)</td>
<td>4 (4.4%)</td>
<td>3 (3.3%)</td>
<td>0.700</td>
</tr>
<tr>
<td>Retreat</td>
<td>7 (3.8%)</td>
<td>4 (4.4%)</td>
<td>3 (3.3%)</td>
<td>0.700</td>
</tr>
<tr>
<td>F/U duration (months)</td>
<td>8.0 ± 6.0</td>
<td>8.5 ± 6.4</td>
<td>7.6 ± 5.7</td>
<td>0.309</td>
</tr>
</tbody>
</table>

FC: Finishing coil, F/U: Follow-up.

Table IV: Subgroup Analysis: Analysis of Finishing Coil Failure Risk Factor for the Two Coils

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total population</th>
<th>Target (n=19)</th>
<th>Microplex (n=26)</th>
<th>p [Odds ratio (95%CI)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>64.1 ± 11.1</td>
<td>64.4 ± 10.3</td>
<td>64.0 ± 12.0</td>
<td>0.905</td>
</tr>
<tr>
<td>Female</td>
<td>36 (80.0%)</td>
<td>15 (78.9%)</td>
<td>21 (80.8%)</td>
<td>0.880</td>
</tr>
<tr>
<td>HTN</td>
<td>28 (62.2%)</td>
<td>11 (57.9%)</td>
<td>17 (65.4%)</td>
<td>0.609</td>
</tr>
<tr>
<td>DM</td>
<td>8 (17.8%)</td>
<td>4 (21.1%)</td>
<td>4 (15.4%)</td>
<td>0.623</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>9 (20.0%)</td>
<td>5 (26.3%)</td>
<td>4 (15.4%)</td>
<td>0.365</td>
</tr>
<tr>
<td>Smoking</td>
<td>6 (13.3%)</td>
<td>2 (10.5%)</td>
<td>4 (15.4%)</td>
<td>0.636</td>
</tr>
<tr>
<td>SAH</td>
<td>3 (6.7%)</td>
<td>3 (15.8%)</td>
<td>0 (0.0%)</td>
<td>0.036</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
<td>0.660</td>
</tr>
<tr>
<td>ACA</td>
<td>7 (15.6%)</td>
<td>3 (15.8%)</td>
<td>4 (15.4%)</td>
<td></td>
</tr>
<tr>
<td>MCA</td>
<td>6 (13.3%)</td>
<td>1 (5.3%)</td>
<td>5 (19.2%)</td>
<td></td>
</tr>
<tr>
<td>ICA</td>
<td>30 (66.7%)</td>
<td>14 (73.7%)</td>
<td>16 (61.5%)</td>
<td></td>
</tr>
<tr>
<td>BA, VA</td>
<td>2 (4.4%)</td>
<td>1 (5.3%)</td>
<td>1 (3.8%)</td>
<td></td>
</tr>
<tr>
<td>Aneurysm volume (mm³)</td>
<td>33.6 ± 43.1</td>
<td>27.4 ± 33.9</td>
<td>38.1 ± 48.9</td>
<td>0.416</td>
</tr>
<tr>
<td>Angled catheter</td>
<td>18 (40.0%)</td>
<td>11 (57.9%)</td>
<td>7 (26.9%)</td>
<td>0.036 [0.268 (0.076−0.942)]</td>
</tr>
<tr>
<td>Stent-assisted coiling</td>
<td>32 (71.1%)</td>
<td>15 (78.9%)</td>
<td>17 (65.4%)</td>
<td>0.321</td>
</tr>
<tr>
<td>PD before FC (%)</td>
<td>35.7 ± 11.1</td>
<td>37.1 ± 11.9</td>
<td>34.7 ± 10.7</td>
<td>0.473</td>
</tr>
<tr>
<td>Successful occlusion</td>
<td>39 (86.7%)</td>
<td>17 (89.5%)</td>
<td>22 (84.6%)</td>
<td>0.636</td>
</tr>
<tr>
<td>Procedural complication</td>
<td>1 (2.2%)</td>
<td>0 (0.0%)</td>
<td>1 (3.8%)</td>
<td>0.387</td>
</tr>
<tr>
<td>Embolism</td>
<td>13 (28.9%)</td>
<td>5 (26.3%)</td>
<td>8 (30.8%)</td>
<td>0.745</td>
</tr>
<tr>
<td>Recurrence</td>
<td>1 (2.2%)</td>
<td>1 (5.3%)</td>
<td>0 (0.0%)</td>
<td>0.237</td>
</tr>
<tr>
<td>Retreat</td>
<td>1 (2.2%)</td>
<td>1 (5.3%)</td>
<td>0 (0.0%)</td>
<td>0.237</td>
</tr>
<tr>
<td>Complication</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1.000</td>
</tr>
<tr>
<td>F/U duration (months)</td>
<td>6.5 ± 5.8</td>
<td>8.2 ± 6.5</td>
<td>5.2 ± 5.0</td>
<td>0.085</td>
</tr>
</tbody>
</table>


The statistically significant values are presented in bold (p<0.005).
## DISCUSSION

Currently, there are several papers investigating the clinical outcomes of different first coil insertions including the effects of physical properties of coil materials on the successful insertion, (6,18,24) but there are only a few papers on FCs other than those meant for experiments and on specific commercial products (2,16). To the best of our knowledge, this is the first study to compare clinical results of two different commercial coils of the same size and similar propensity as FC.

Previous studies on the effects of size and characteristics of embolization coils used the size and shape of cerebral aneurysms and the length of the aneurysms’ neck as the analytical factors (8,10). However, since the aim of this study was to compare the performance of two different coils used as FCs, PD was used as a standard measure to evaluate the effects of coil characteristics on its effectiveness in filling the aneurysm sac. FC Insertion is the final step in the coil embolization, and very soft and small-sized coils are preferred in order to achieve the densest possible coil packing of the aneurysm sac (7). The final PD can be increased by filling the remaining empty space in the cerebral aneurysm sac with more FC, and in the present study, we found that this could increase the PD by approximately 5% more in our study. High-density coil packing can improve the outcome of aneurysm occlusion and prevent recurrence of aneurysms (8). There was no compaction occurred during a 6 months follow-up with 24% coil packing (20). There was no significant difference in the hemodynamics with different coil configurations for 30% coil density (14). But, in this study, cases of aneurysm recurrence (about 4%) were observed in a final PD of 37%, so further research is needed.

Our present study compared the clinical outcomes between two embolization coils, TG and MH, when used as FCs. Based on our study results there was no significant difference in the clinical or radiologic outcomes between the two groups. The results of our study showed 88% successful occlusion including complete occlusion and residual neck, and a 3.8% procedure complication rate; this was similar to the findings of previous studies, 90%, and 4-8%, respectively (1,3,17,22). During an 8-month follow-up period, 3.8% aneurysm recurrence was observed; treatment outcomes were not lagging compared to 7-20% reported in other studies, and fortunately, no serious morbidity or mortality was observed (2,11,15).

Although there was no statistically significant difference in the clinical and radiological outcomes of the TG and MH groups, the results of the two groups were statistically corrected using PSM, because the PD before FC insertion was about 3% higher in the TG group and the FC insertion failure rate was 8% higher in the MH group, translating to a significant difference in PD after FC insertion between the TG and MH groups.

The ability to insert the coil into the aneurysm is affected by the softness of the coil. In the present study coil softness was calculated using the following theoretical equation (24):

$$K = \frac{D1^4G}{8D2^2n}; \text{Stiffness} = \frac{D1^4}{D2^2}$$

Where, D1 is the coil wire diameter, G is the shear modulus of the coil wire, D2 is the primary outer diameter, n is the number of turns per unit distance. TG and MH which were used as FCs in this study had similar propensities in detailed specifications, such as the same size of stock wire (0.00125 inches), and the same size of the primary coil outer diameter (0.01 inches). In addition, both coils were secondary coils of the same size and length with a spherical three-dimensional structure, and the K value of the two coils obtained from the above equation was the same (2.4411x10^-6). Therefore there was no difference in the clinical and radiologic outcomes of the two coils under similar conditions calibrated with PSM.

However, in a subgroup analysis of 45 cases (a quarter of the total population) of failed FC insertion, a significant difference was found in the use of angled catheter between the two coils. The detachable coil consisted of a coil part that fills the aneurysm, a delivery wire that conveys it through a microcatheter, and a junction that connects the two parts and separates them in various ways. The characteristics of these parts vary among products (Table V) and with different characteristics having different effects on the flexibility and pushability of the wires by having differently influence on the coils and microcatheters interactions (19).

The microcatheter kickback phenomenon encountered in the final stage of coil embolization is influenced by the vessel diameter and tortuosity, as well as the delivery wire-related factors, and the coil factors such as the diameter of the stock wire and a stretch-resistant structure (7,13). In a previous study, this phenomenon was thought to be due to a counterforce against the catheter by the prolapsed coil tail, and it was accompanied by straightening of the Stretch-resistant (SR) coil tail (19). As reported in previous studies conducted at our institution and studies, (7) it was confirmed that the coil passed through the microcatheter in an unconstrained free space, and the coil tail deformation was different for each catheter angle (7,9).

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Table V: Dimensions of the Coils Used as Finishing Coil: Wire Diameter (D1), Primary Coil (D2), Nominal Loop, Stretch-Resistant (SR) Filament, and Outer Diameter (OD)

<table>
<thead>
<tr>
<th>Coil</th>
<th>Wire diameter (D1, inch)</th>
<th>Primary coil OD (D2, inch)</th>
<th>Nominal loop OD (mm)</th>
<th>SR material</th>
<th>SR filament OD (inch) (2 strands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target 360 nano</td>
<td>0.00125</td>
<td>0.0100</td>
<td>3.634</td>
<td>Polypropylene</td>
<td>0.0014</td>
</tr>
<tr>
<td>Microplex hypersoft 3D</td>
<td>0.00125</td>
<td>0.0100</td>
<td>2.105</td>
<td>Polyethylene terephthalate</td>
<td>0.0022</td>
</tr>
</tbody>
</table>
In addition, in our present study, it was confirmed that a catheter with a larger pre-shaped angle tends to have a larger angle change, probably because the more the microcatheter bends, the greater the friction between the delivery wire and the microcatheter, thereby raising the resistance further, and the greater the difference between the force pushing the delivery wire and the force received at its end (19). The change in the microcatheter tip is influenced by the delivery wires and coil junctions whose design and characteristics vary among manufacturers. In the present study, this was thought to be responsible for the catheter angle change difference among the two coils, as shown in Figure 3. And this difference seems to correlate with the high percentage of the TG coil FC insertion failure.

There are several limitations to this study. First, the data used in this study were collected and analyzed retrospectively in a single institution. Also, there were some biases, such as differences in the skill levels between operators, differences in procedural techniques or materials used, and preferences for coil selection, although statistically corrected using the PSM. In this study, clinical and radiological outcome variables; the FC insertion failure, procedural complications, and the grade of aneurysm occlusion, were determined through a discussion between the authors, however, they may not be objective. The impact of different propensities of the two coils such as the coil shape, softness of delivery wire, materials and mechanism of a coil-wire junction, and the balance of these factors, may have been overlooked in this study. In addition, the sample size for the angled catheter experiment was small, and in the actual coil procedures, microcatheters other than the excelsior SL-10 and steam-shaping catheter were used. These microcatheters have not been experimentally verified. In this study, variables’ errors were also considered as a limitation and additional long-term follow-up through prospective multicenter, randomized controlled trials are required to confirm our results.

**CONCLUSION**

There were no significant differences in the clinical and radiological outcomes of TG and MH coils of the same size as FC. However, in the FC insertion failure subgroups, the number of angled catheter was significantly higher in TG coils than in MH coils. In the present study, we experimentally confirmed that there was a difference in the angle change of microcatheter tip between the two coils, with a greater change in a microcatheter with a large angle, however, additional long-term follow-up through prospective, multicenter, randomized controlled studies.

**Conflict of interest:** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

**Availability of data and materials:** The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

**AUTHORSHIP CONTRIBUTION**

Study conception and design: DHL, JH, SUK

Data collection: DSK, CWH

Analysis and interpretation of results: DHL, HZC

Draft manuscript preparation: DHL

Critical revision of the article: DHL

All authors (SUK, JH, DSK, CWH, HZC, DHL) reviewed the results and approved the final version of the manuscript.
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