Turk Neurosurg, 2022

Original Investigation

Received: 24.01.2022
Accepted: 25.02.2022

DOI: 10.5137/1019-5149.JTN.37336-22.1

Published Online: 30.11.2022

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

Sang Uk KIM[1], Joon HUH[1], Dal Soo KIM[1], Choon Woong HUH[1], Han Zo CHOI[2], Dong Hoon LEE[3]

[1]Myong-Ji St. Mary's Hospital, Department of Neurosurgery, Seoul, South Korea
[2]Kyung Hee University Hospital at Gangdong, Department of Emergency Medicine, Seoul, South Korea
[3]The Catholic University of Korea, St. Vincent's Hospital, Department of Neurosurgery, Suwon, South Korea

Corresponding author: Dong Hoon LEE ✉ nshoonydong@gmail.com

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 (8,21). 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),

Sang Uk KIM : 0000-0002-5195-1215
Joon HUH : 0000-0001-8504-1386
Dal Soo KIM : 0000-0003-2663-9163
Choon Woong HUH : 0000-0003-2765-8104
Han Zo CHOI : 0000-0001-9201-5223
Dong Hoon LEE : 0000-0002-3796-8707

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-1mm x 2 cm). Non-saccular type aneurysms such as oncotic, 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 reviewed retrospectively to assess the patients' related factors such as age, sex, hypertension, diabetes mellitus, dyslipidemia, smoking history, subarachnoid hemorrhage (SAH), location 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 microcatheters, 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 initially 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 embolization coil intervention procedure for each cerebral aneurysm was performed by four skilled endovascular neurosurgeons (SU.K, J.H) certified by the Korean Neuroendovascular society (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 sulfate 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

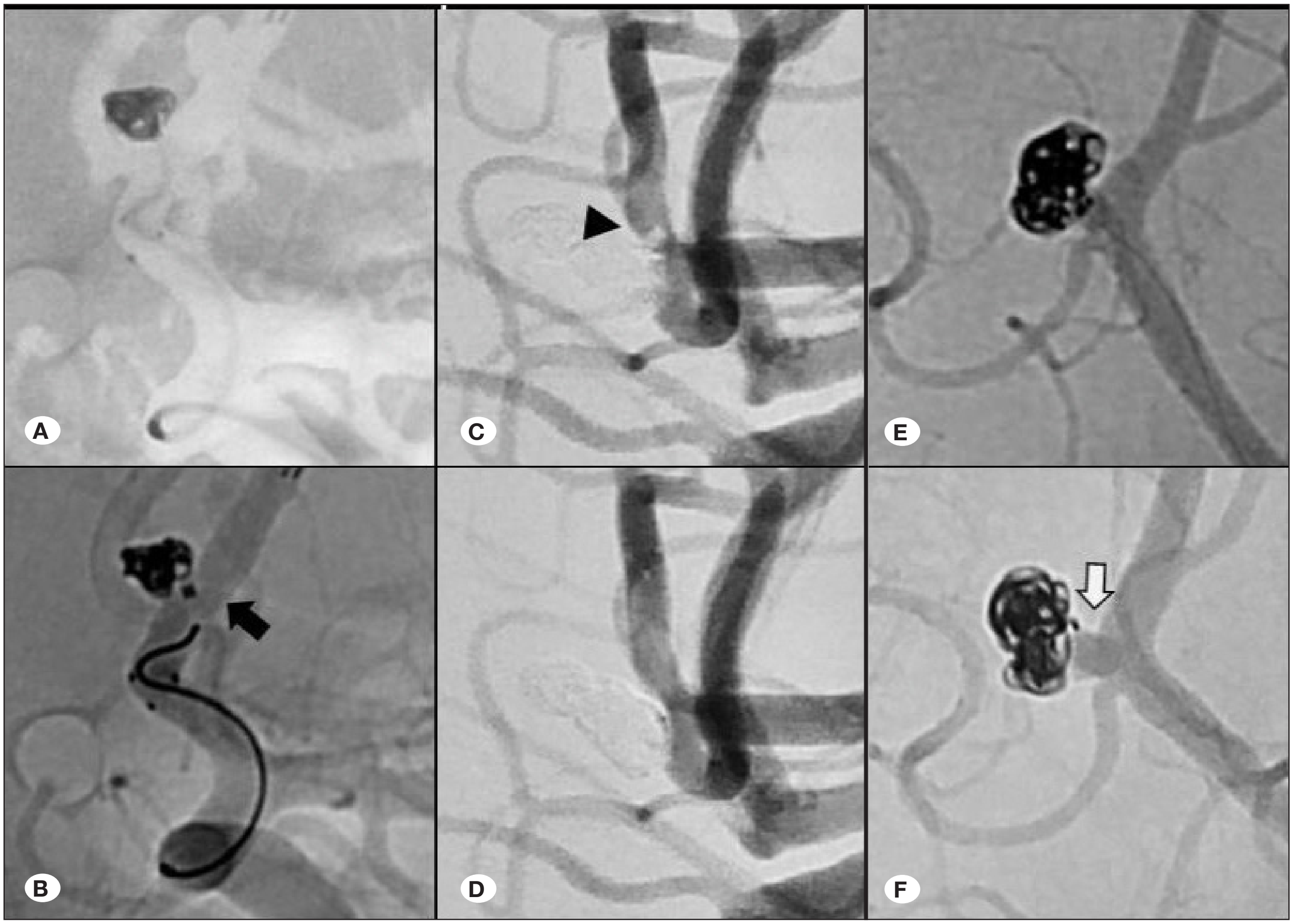

Figure 1: Before **(A)** and after **(B)** the final coil (FC) was inserted in the coil embolization of a 57-year-old woman, during the insertion of the FC, the microcatheter unexpectedly came out (black arrow) and the insertion failed, such cases were classified as 'failure', And in coil embolization of a 52-year-old male, acute thrombus formation (arrowhead) was confirmed on the post angiogram after FC insertion **(C)**, and the acute thrombus disappeared after intra-arterial injection of a tirofiban. **D)** This case was classified as a ' procedural complication'. After successful coil embolization of a 57-year-old woman **(E)**, regrowth of aneurysmal neck (white arrow) was observed during a follow-up examination, 18 months later, **(F)** and retreatment were performed. This case was classified as a 'recurrence' and 'retreatment".

Table I: The Difference in the Tip Angle Change for Different Types of Microcatheter Use with the Two Coils

	Straight	Pre-shaped 45	Pre-shaped 90	Pre-shaped S	Pre-shaped J
Target 360 nano	-6.0 ± 3.9	-1.5 ± 2.4	27 ± 4.8	122.5 ± 2.6	62.5 ± 8.2
Mciroplex hypersoft 3D	-6.3 ± 4.9	-13.0 ± 2.6	27 ± 7.9	33 ± 3.5	31.5 ± 9.1

**It was measured as (-) if it was bent forward from its original tip shape and as (+) if it was extended.*

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 mm^3 (range 2.44 to 353.26). Clinical parameters were distributed as follows: hypertension, 120 (49.4%); diabetes

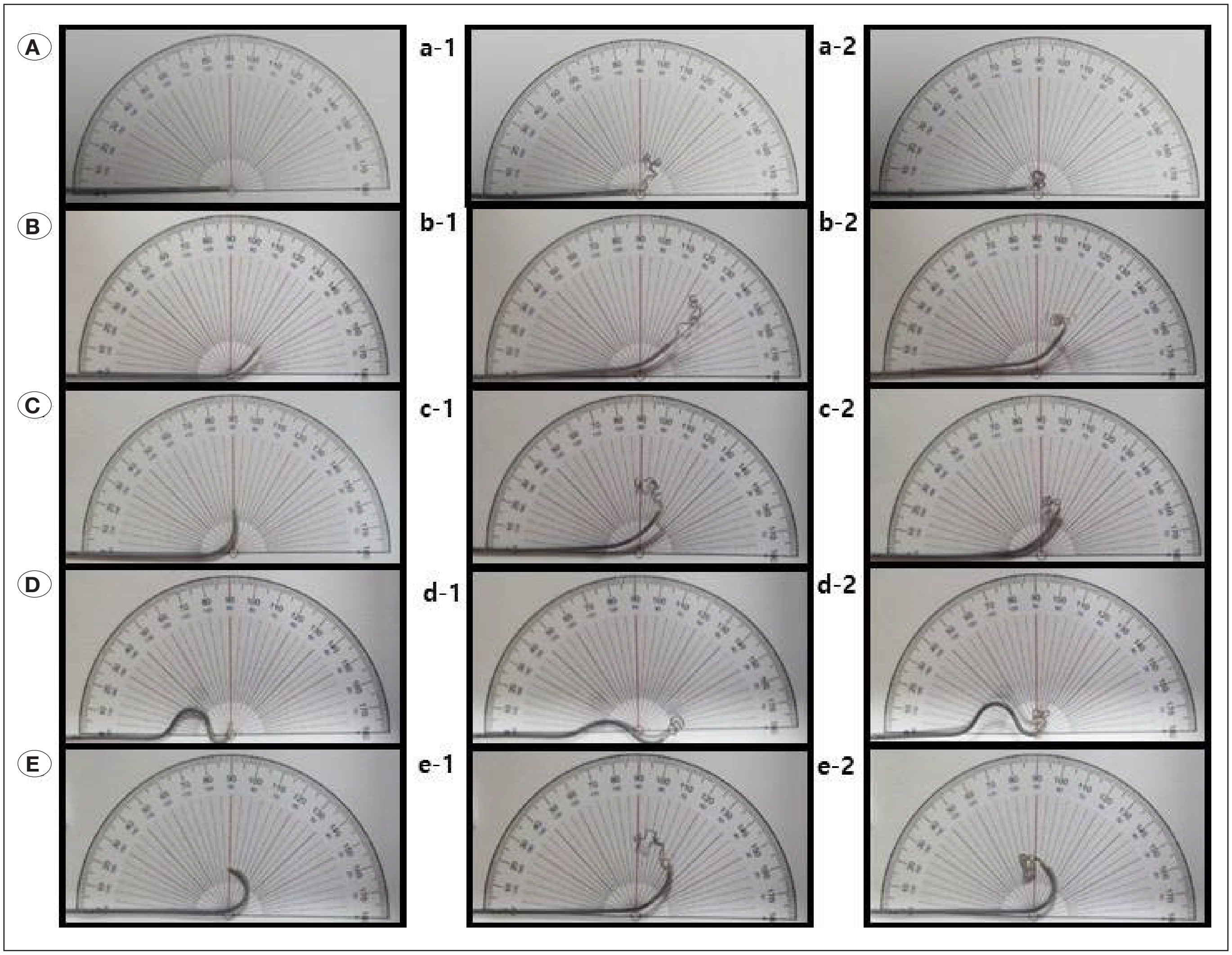

Figure 2: A comparison of angle change of the microcatheter tip during the coil insertion, Microcatheter used an Excelsior SL-10 preshaped 90 (Stryker, Fremont, CA, USA). Control group **(A)** to **(E)** (straight, pre-shaped 45, pre-shaped 90, pre-shaped S, and pre-shaped J); **(a-1)** to **(e1)** the 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 Microplexhypersoft 3D 1 mm x 2 cm (Mirovention Terumo, Tustin, CA, USA) into each microcatheters.

mellitus, 40 (16.5%); dyslipidemia 41 (16.9%); smoking 38 (15.6%), and SAH 28 (11.5%). 55.6% of the total embolization cases were performed using an intracranial stent, and 91 aneurysms sacs (37.4%) were with a bent tip microcatheter defined as an angled catheter. Baseline characteristics of patients and treated aneurysms are presented in Table II.

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

Table II: Baseline Characteristics Before and After Propensity Score Matching in Coil Embolization Using Two Different Finishing Coils

Variable	Total population				Propensity score matching (n=182)			
	(n=243)	Target (n=152)	Microplex (n=91)	p	(n=182)	Target (n=91)	Microplex (n=91)	p
Age (years)	61.2 ± 10.6	60.40 ± 10.6	62.4 ± 10.7	0.157	61.4 ± 11.0	60.3 ± 11.3	62.4 ± 10.7	0.208
Female	188 (77.4%)	117 (77%)	71 (78.0.6%)	0.850	142 (78.0%)	71 (78.0%)	71 (78.0%)	1.000
HTN	120 (49.4%)	77 (50.7%)	43 (47.3%)	0.607	90 (49.5%)	47 (51.6%)	43 (47.3%)	0.553
DM	40 (16.5%)	21 (13.8%)	19 (20.9%)	0.151	39 (21.4%)	20 (22.0%)	19 (20.9%)	0.857
Dyslipidemia	41 (16.9%)	29 (19.1%)	12 (13.2%)	0.235	27 (14.8%)	15 (16.5%)	12 (13.2%)	0.532
Smoking	38 (15.6%)	24 (15.8%)	14 (15.4%)	0.933	31 (17.0%)	17 (18.7%)	14 (15.4%)	0.554
SAH	28 (11.5%)	20 (13.2%)	8 (8.8%)	0.302	20 (11.0%)	12 (13.2%)	8 (8.8%)	0.343
Location				0.938				0.734
ACA	47 (19.3%)	31 (20.4%)	16 (17.6%)		35 (19.2%)	19 (20.9%)	16 (17.6%)	
MCA	35 (15.2%)	22 (14.5%)	15 (16.5%)		26 (14.3%)	11 (12.1%)	15 (16.5%)	
ICA	149 (61.3%)	93 (61.2%)	56 (61.5%)		111 (61.0%)	55 (60.4%)	56 (61.5%)	
BA, VA	10 (4.1%)	6 (3.9%)	4 (4.4%)		10 (5.5%)	6 (6.6%)	4 (4.4%)	
Aneurysm volume (mm^3)	28.9 ± 36.3	25.2 ± 24.0	35.1 ± 50.1	0.081	29.9 ± 39.4	24.7 ± 23.8	35.1 ± 50.1	0.076
Angled catheter	91 (37.4%)	58 (43.9%)	33 (29.7%)	***0.023***	76 (41.8%)	43 (47.3%)	33 (36.3%)	0.133
Stent-assisted coiling	135 (55.6%)	76 (50.0%)	59 (64.8%)	***0.024***	117 (64.3%)	58 (63.7%)	59 (64.8%)	0.877
PD before FC (%) (A)	31.0 ± 10.9	31.5±10.9	30.1± 11.0	0.323	31.6 ± 11.2	33.2 ± 11.4	30.1 ± 11.0	0.065
PD after FC (%) (B)	36.5 ± 13.2	37.7± 13.7	34.7± 12.2	0.087	37.0 ± 13.4	39.3 ± 14.1	34.7 ± 12.2	***0.020***
B-A	5.6 ± 6.5	6.1 ± 7.2	4.6 ± 5.0	***0.047***	5.3 ± 6.2	6.1 ± 7.2	4.6 ± 5.0	0.099

HTN: *Hypertension,* ***DM:*** *Diabetes mellitus,* ***SAH:*** *Subarachnoid hemorrhage,* ***ACA:*** *Aanterior 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).

stent between the two PSM groups. The difference in the PD before inserting FC between the TG and MH groups was not statistically significant 33.2%, and 30.1% respectively (p =0.065). However, the difference in the PD after inserting FC between the TG and MH groups was statistically significant, 9.3% and 34.7% respectively (p=0.02)

Clinical and Radiological Outcomes After Propensity Score Matching

As shown in Table III, there was no difference in the clinical and angiographic results of the two coils in the PSM groups, which corrected for two factors that could affect the coil embolization results.

In the TG and MH coils, successful occlusion, complete and residual neck based on the Roy Raymond scale, were 89% and 86.8%, and FC insertion failures were 20.9% and 28.6%, respectively; there was no significant difference between the two groups. 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 angular 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 26.9% (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

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

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

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

Variable	Total population			
	(n=45)	Target (n=19)	Microplex (n=26)	p [Odds ratio (95%CI)]
Age (years)	64.1 ± 11.1	64.4 ± 10.3	64.0 ± 12.0	0.905
Female	36 (80.0%)	15 (78.9%)	21 (80.8%)	0.880
HTN	28 (62.2%)	11 (57.9%)	17 (65.4%)	0.609
DM	8 (17.8%)	4 (21.1%)	4 (15.4%)	0.623
Dyslipidemia	9 (20.0%)	5 (26.3%)	4 (15.4%)	0.365
Smoking	6 (13.3%)	2 (10.5%)	4 (15.4%)	0.636
SAH	3 (6.7%)	3 (15.8%)	0 (0.0%)	***0.036***
Location				0.660
ACA	7 (15.6%)	3 (15.8%)	4 (15.4%)	
MCA	6 (13.3%)	1 (5.3%)	5 (19.2%)	
ICA	30 (66.7%)	14 (73.7%)	16 (61.5%)	
BA, VA	2 (4.4%)	1 (5.3%)	1 (3.8%)	
Aneurysm volume (mm^3)	33.6 ± 43.1	27.4 ± 33.9	38.1 ± 48.9	0.416
Angled catheter	18 (40.0%)	11 (57.9%)	7 (26.9%)	***0.036*** [0.268 (0.076~0.942)]
Stent-assisted coiling	32 (71.1%)	15 (78.9%)	17 (65.4%)	0.321
PD before FC (%)	35.7 ± 11.1	37.1 ± 11.9	34.7 ± 10.7	0.473
Successful occlusion	39 (86.7%)	17 (89.5%)	22 (84.6%)	0.636
Procedural complication	1 (2.2%)	0 (0.0%)	1 (3.8%)	0.387
Embolism	13 (28.9%)	5 (26.3%)	8 (30.8%)	0.745
Recurrence	1 (2.2%)	1 (5.3%)	0 (0.0%)	0.237
Retreat	1 (2.2%)	1 (5.3%)	0 (0.0%)	0.237
Complication	0 (0%)	0 (0%)	0 (0%)	1.000
F/U duration (months)	6.5 ± 5.8	8.2 ± 6.5	5.2 ± 5.0	0.085

CI: Confidence interval, ***HTN:*** Hypertension, ***DM:*** Diabetes mellitus, ***SAH:*** Subarachnoid hemorrhage, ***ACA:*** Aanterior 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).

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):

$$K = \frac{D1^4 G}{8 D2^3 n}; Stiffness \propto \frac{D1^4}{D2^3}$$

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 ($2.441(1\times10^{-6})$). 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 coils 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).

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)

Coil	Wire diameter (D1, inch)	Primary coil OD (D2, inch)	Nominal loop OD (mm)	SR material	SR filament OD (inch) (2 strands)
Target 360 nano	0.00125	0.0100	3.634	Polypropylene	0.0014
Microplex hypersoft 3D	0.00125	0.0100	2.105	Polyethylene terephthalate	0.0022

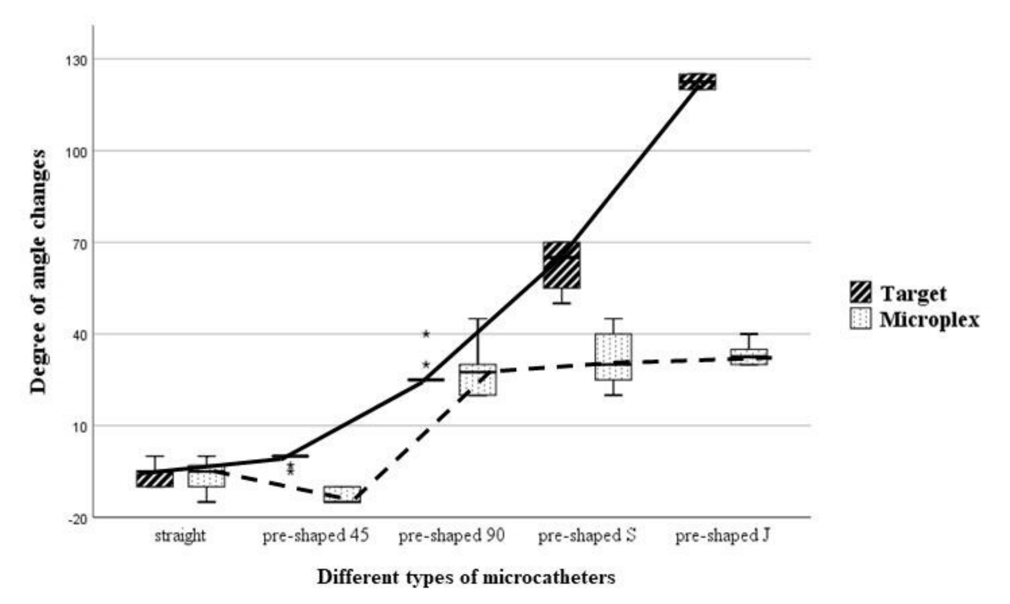

Figure 3: A graphical comparison of the difference in tip angles when inserting Target and Microplex coils into different types of microcatheters.

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.

REFERENCES

1. Bendok BR, Abi-Aad KR, Ward JD, Kniss JF, Kwasny MJ, Rahme RJ, Aoun SG, El Ahmadieh TY, El Tecle NE, Zammar SG, Aoun RJN, Patra DP, Ansari SA, Raymond J, Woo HH, Fiorella D, Dabus G, Milot G, Delgado Almandoz JE, Scott JA, DeNardo AJ, Dashti SR: The hydrogel endovascular aneurysm treatment trial (HEAT): A randomized controlled trial of the second-generation hydrogel coil. Neurosurgery 86:615-624, 2020
2. Brinjikji W, Amar AP, Delgado Almandoz JE, Diaz O, Jabbour P, Hanel R, Hui F, Kelly M, Layton KD, Miller JW, Levy E, Moran C, Suh DC, Woo H, Sellar R, Ho B, Evans A, Kallmes DF: GEL THE NEC: A prospective registry evaluating the safety, ease of use, and efficacy of the HydroSoft coil as a finishing device. J Neurointerv Surg 10:83-87, 2018
3. Cloft HJ: Hydrocoil for endovascular aneurysm occlusion (HEAL) study: Periprocedural results. AJNR Am J Neuroradiol 27:289-292, 2006
4. Cloft HJ, Kallmes DF: Aneurysm packing with HydroCoil Embolic System versus platinum coils: Initial clinical experience. AJNR Am J Neuroradiol 25:60-62, 2004
5. Dumont TM, Eller JL, Mokin M, Sorkin GC, Levy EI: Advances in endovascular approaches to cerebral aneurysms. Neurosurgery 74 Suppl 1:S17-31, 2014
6. Jeong W, Han MH, Rhee K: Effects of framing coil shape, orientation, and thickness on intra-aneurysmal flow. Med Biol Eng Comput 51:981-990, 2013
7. Kanenaka N, Sato H, Hiraoka F, Abe H, Torihashi K, Sora S: Comparative examination of finishing coils available in Japan. J Neuroendovascular Therapy 10:88-92, 2016
8. Kawanabe Y, Sadato A, Taki W, Hashimoto N: Endovascular occlusion of intracranial aneurysms with Guglielmi detachable coils: Correlation between coil packing density and coil compaction. Acta Neurochir (Wien) 143:451-455, 2001
9. Kim SU, Huh J, Lee HG, Jeong WJ, Kim DS, Huh CW, Choi HZ: Is a small coil more effective as a finishing coil for the embolization of intracranial aneurysms? Outcomes using GALAXY G3™ MINI micro-coils as finishing coils in a single center. Interv Neuroradiol 27:798-804, 2021
10. Knap D, Gruszczyńska K, Partyka R, Ptak D, Korzekwa M, Zbroszczyk M, Baron J: Results of endovascular treatment of aneurysms depending on their size, volume and coil packing density. Neurol Neurochir Pol 47:467-475, 2013
11. Lee JY, Seo JH, Cho YD, Kang HS, Han MH: Endovascular treatment of 429 anterior communicating artery aneurysms using bare-platinum coils: Clinical and radiologic outcomes at the long-term follow-up. J Korean Neurosurg Soc 57:159-166, 2015
12. Mascitelli JR, Moyle H, Oermann EK, Polykarpou MF, Patel AA, Doshi AH, Gologorsky Y, Bederson JB, Patel AB: An update to the raymond-roy occlusion classification of intracranial aneurysms treated with coil embolization. J Neurointerv Surg 7:496-502, 2015
13. Miyachi S, Izumi T, Matsubara N, Naito T, Haraguchi KI, Wakabayashi T: The mechanism of catheter kickback in the final stage of coil embolization for aneurysms: The straightening phenomenon. Interv Neuroradiol 16:353-360, 2010
14. Morales HG, Kim M, Vivas EE, Villa-Uriol MC, Larrabide I, Sola T, Guimaraens L, Frangi AF: How do coil configuration and packing density influence intra-aneurysmal hemodynamics? AJNR Am J Neuroradiol 32:1935-1941, 2011
15. Murayama Y, Nien YL, Duckwiler G, Gobin YP, Jahan R, Frazee J, Martin N, Viñuela F: Guglielmi detachable coil embolization of cerebral aneurysms: 11 years' experience. J Neurosurg 98:959-966, 2003
16. Ota K, Matsubara N, Miyachi S, Izumi T, Ito M, Asai T, Yamanouchi T, Wakabayashi T: Evaluation of the characteristics of various types of finishing coils for the embolization of intracranial aneurysms in an experimental model with radiolucent coils. Interv Neuroradiol 23:143-150, 2017
17. Qureshi AI, Luft AR, Sharma M, Guterman LR, Hopkins LN: Prevention and treatment of thromboembolic and ischemic complications associated with endovascular procedures: Part II--Clinical aspects and recommendations. Neurosurgery 46:1360-1375; discussion 1375-1366, 2000
18. Schirmer CM, Malek AM: Critical influence of framing coil orientation on intra-aneurysmal and neck region hemodynamics in a sidewall aneurysm model. Neurosurgery 67:1692-1702; discussion 1702, 2010
19. Shintai K, Matsubara N, Izumi T, Miyachi S, Yamada H, Marui N, Wakabayashi T: Experimental study of coil delivery wire insertion force in intracranial aneurysm embolization: Force discrepancy generated inside the microcatheter through that coil delivery wire passes. Nagoya J Med Sci 81:217-225, 2019
20. Sluzewski M, van Rooij WJ, Slob MJ, Bescós JO, Slump CH, Wijnalda D: Relation between aneurysm volume, packing, and compaction in 145 cerebral aneurysms treated with coils. Radiology 231:653-658, 2004
21. Tamatani S, Ito Y, Abe H, Koike T, Takeuchi S, Tanaka R: Evaluation of the stability of aneurysms after embolization using detachable coils: Correlation between stability of aneurysms and embolized volume of aneurysms. AJNR Am J Neuroradiol 23:762-767, 2002
22. Taschner CA, Chapot R, Costalat V, Machi P, Courthéoux P, Barreau X, Berge J, Pierot L, Kadziolka K, Jean B, Blanc R, Biondi A, Brunel H, Gallas S, Berlis A, Herbreteau D, Berkefeld J, Urbach H, Elsheikh S, Fiehler J, Desal H, Graf E, Bonafé A: Second-generation hydrogel coils for the endovascular treatment of intracranial aneurysms: A randomized controlled trial. Stroke 49:667-674, 2018
23. Taussky P, Kallmes DF, Cloft H: Mathematic analysis of incremental packing density with detachable coils: Does that last coil matter much? AJNR Am J Neuroradiol 33:E74-75, 2012
24. White JB, Ken CG, Cloft HJ, Kallmes DF: Coils in a nutshell: A review of coil physical properties. AJNR Am J Neuroradiol 29:1242-1246, 2008
25. Zhao R, Liu J, McComas S, Guo J, Girdhar G: In-vitro pliability assessment of embolization coils for intracranial aneurysm treatment. J Neurol Sci 406:116432, 2019