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Matrix² Coils in Embolization of Intracranial Aneurysms: 1-Year Outcome and Comparison with Bare Platinum Coil Group in a Single Institution

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ORIGINAL
RESEARCHS.W. Youn
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BACKGROUND AND PURPOSE: The endosaccular occlusion by using BPC has been useful in the treatment of intracranial aneurysms, but its limited durability remains a deep-seated drawback. The Matrix² coil, one of the bioactive-coated coils, had been developed to improve this limited durability. To evaluate durability of Matrix² coils after embolization of intracranial aneurysms, we retrospectively compared 1-year outcomes with that of BPC groups.

MATERIALS AND METHODS: A group of 121 aneurysms in 114 patients were embolized by using Matrix² coils between April 2006 and September 2008. The BPC group consisted of 151 aneurysms in 137 patients embolized by using BPCs alone between October 2007 and October 2008. The initial outcomes including packing densities, occlusion grades, and periprocedural complications, and the 1-year outcomes on MR angiography were retrospectively compared between the 2 groups.

RESULTS: The Matrix² coil group and BPC group with similar baseline demographic characteristics revealed comparable initial outcomes. The rates of overall recurrence, major recanalization, and retreatment were 17.4%, 14.0%, and 10.7% versus 7.3%, 5.3%, and 4.6%, respectively ($P = .066$). However, the rates of subgroups with aneurysm volumes between 50 and 200 mm³ were 23.7%, 13.1%, and 10.5% versus 2.2%, 0%, and 0% ($P = .022$), respectively. The rates of subgroups with packing attenuation <30% were 38.3%, 31.9%, and 23.4% versus 13.3%, 11.7%, and 10% ($P = .025$), respectively. There were no differences in packing attenuation ($P = .152$), initial occlusion grade ($P = .098$), and 1-year outcomes ($P = .209$) according to the length of Matrix² coils used.

CONCLUSIONS: Overall, initial and 1-year outcomes of the Matrix² coil group were comparable to those of the BPC group. However, in certain subgroups of aneurysm volume and packing attenuation, the 1-year durability of Matrix² coils was inferior to that of the BPC group.

ABBREVIATIONS: BPC = bare platinum coil; DSA = digital subtraction angiography; INR = interventional neuroradiology; TOF = time-of-flight

The endosaccular occlusion of intracranial aneurysms by using detachable platinum coils has been useful to deal with both ruptured and unruptured intracranial aneurysms.¹⁻⁵ However, it has shown limited durability, which remains a deep-seated drawback of coil embolization.^{6,7} For durable aneurysm occlusion, the instant thrombosis that develops immediately after coiling between coil meshwork is not sufficient, and the organization into granulation tissue is essential to complete aneurysm occlusion.^{8,9} For organization of thrombus on coils, various modifications have been tried, and the platinum coil coated with polyglycolic/polylactic acid (Matrix; Boston Scientific, Natick, Massachusetts) was 1 of the bioactive-coated coils designed to reinforce these healing reactions. Polyglycolic/polylactic acid is a bioabsorbable polymer that was used to coat coil surfaces, and it improved clot organization inside the cavity and promoted thicker neointimal tissue formation at the orifice in rabbit and canine aneurysm models.¹⁰⁻¹² But there have been clinical reports that the

durability of the Matrix coil is comparable to or even worse than that of bare coils,¹³⁻¹⁸ because the miscarried elution of coated materials without intra-aneurysmal clot organization might cause the defect of coil meshwork.¹⁸ Thus, the Matrix² coil was developed, and the ratio between polymer coating and core coils was modified by reducing the dosage of polyglycolic/polylactic acid from 70% in the old Matrix to 30% in the new Matrix² (Fig 1). However, long-term data on the clinical effectiveness of this new coated coil are lacking.^{19,20}

This retrospective study evaluated the 1-year outcomes of Matrix² coils on the durability of endosaccular occlusion by comparing these with historical controls of BPCs in a single institution.

Materials and Methods**Patients and Aneurysms**

Aneurysms were retrospectively enrolled from the INR data base of our institution into which all patients undergoing endovascular treatment of intracranial aneurysms were registered, according to the following criteria: 1) intracranial aneurysms treated by endosaccular coiling alone were included, but the coil embolization for dissecting aneurysm/pseudoaneurysm, thrombosed aneurysm, or parent artery sacrifice were excluded; 2) the combination with BPCs was allowed as long as the length of Matrix² coils was >20% of total coil length used, but the use of other coated coils, including HydroCoils (MicroVention Terumo, Aliso Viejo, California), was excluded; and

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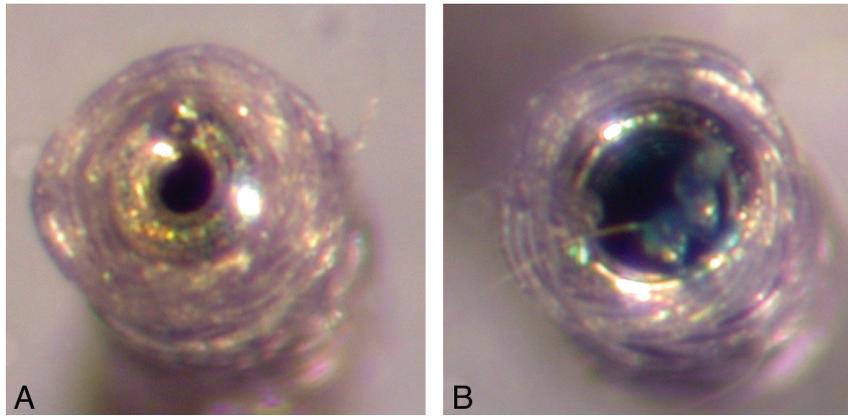


Fig 1. Matrix and Matrix² coils. The polyglycolic/polylactic acid coating of the Matrix² coil (B), with 30% of total coil volume, was reduced from the initial Matrix (A), with 70%, to prevent miscarried elution.

Table 1: Comparison of demographic characteristics and initial coiling outcomes

	Matrix ² Coil Group	BPC Group	P Value ^a
Aneurysms (patients)	121 (114)	151 (137)	
Age, mean ± SD (yr)	55.5 ± 11.2	57.6 ± 11.1	.136
Female, no. (%)	88 (72.7)	103 (68.2)	.418
Unruptured aneurysms, no. (%)	97 (80.2)	127 (84.1)	.148
Circulation, anterior:posterior, no. (%)	110:11 (90.9)	136:15 (90.1)	.839
Aneurysm volume (mm ³), mean ± SD	129.5 ± 268.4	95.9 ± 204.6	.243
Initial occlusion grade, complete obliteration, no. (%)	81 (66.9)	96 (63.6)	.688
Initial occlusion grade, residual neck, no. (%)	33 (27.3)	48 (31.8)	
Initial occlusion grade, residual aneurysm, no. (%)	7 (5.8)	7 (4.6)	
Packing density (%), mean ± SD	32.4 ± 7.9	31.2 ± 7.3	.181
Thromboembolism, overall, no. (%)	13 (10.7)	9 (6.0)	.181
Thromboembolism, symptomatic, no. (%)	1 (0.8)	2 (1.3)	1.0
Perforation or leakage, no. (%)	1 (0.8)	2 (1.3)	1.0
Coil protrusion, no. (%)	2 (1.7)	8 (5.3)	.193

^a P value <.05 is significant.

3) initial treatment of aneurysms was included, but repeated embolization or treatment for postsurgical residual sac was excluded. In total, 121 aneurysms in 114 patients who underwent endosaccular coiling by using Matrix² coils between April 2006 and September 2008 were eventually included for this study (Table 1). During the same period, 714 aneurysms in 626 patients were treated with coil embolization (201 aneurysms in 168 patients between April and December 2006, 266 aneurysms in 233 patients during 2007, and 247 aneurysms in 225 patients between January and September 2008). The Matrix² group was composed of 32 male and 82 female patients (age, 55.5 ± 11.2 years [mean ± SD]; range, 25–78 years). There were 97 unruptured aneurysms. Of 24 ruptured aneurysms, there were 10 with Hunt and Hess grade II, 13 with grade III, and 1 with grade IV. There was no aneurysm with Hunt and Hess grade I. We located 90.9% (110/121) of the aneurysms in the anterior circulation. The locations were internal carotid artery, 50; posterior communicating artery, 21; middle cerebral artery, 12; anterior communicating artery, 24; anterior cerebral artery, 3; and posterior circulation, 11, including 7 basilar tip, 1 basilar trunk, 1 posterior cerebral artery, 1 superior cerebellar artery, and 1 vertebral artery.

The control group also was identified from the INR data base of our institution into which all patients undergoing endovascular treatment of intracranial aneurysm were registered. There were 151 aneurysms in 137 patients (34 men and 103 women; age, 57.6 ± 11.1 [mean ± SD]; range, 34–80 years); these patients underwent endosaccular coiling by using BPCs alone between October 2007 and Oc-

tober 2008. There were 127 unruptured aneurysms. The Hunt and Hess grades of the other 24 aneurysms presenting with subarachnoid hemorrhage were grade II, 15; grade III, 6; and grade IV, 3. We located 90.1% (136/151) of the aneurysms in the anterior circulation, consisting of 67 internal cerebral artery, 15 posterior communicating artery, 31 anterior communicating artery, 10 anterior cerebral artery, and 13 middle cerebral artery. The 15 in the posterior circulation consisted of 10 basilar tip, 2 basilar trunk, 1 superior cerebellar artery, and 2 vertebral artery. Written informed consent for the interventional treatment was mandatory in all patients and our institutional review board approved this retrospective comparison study.

Endovascular Treatment

Endosaccular coiling and DSA were performed by using a biplanar angiographic unit (Integris Allura; Phillips Medical Systems, Best, the Netherlands). Matrix² coils were preferentially used for the initial framing, packing, and finishing. In case of packing difficulties with Matrix² coils, BPCs were chosen among GDC (Boston Scientific), MicroPlex (MicroVention), and TruFill-DCS (Cordis Neurovascular, Miami Lakes, Florida). Before coiling, Matrix² coils required preparation by flushing with normal saline. The neck remodeling techniques using multiple microcatheters, balloon, or stent, if needed, were combined to stabilize the coil frame and to control coil loop protrusion. In cases with unruptured aneurysm, the patients were given aspirin (325 mg) and clopidogrel (Plavix, 75 mg) the night

before the procedure and systemic heparinization (loading dose of 3000 U followed by 1000 U/hr) during procedure. In ruptured aneurysm, systemic heparin was administered upon the operator's case by case decision which varied between no use and maintenance dosage after ensuring protected dome with coil packing. Systemic heparinization was discontinued at the end of the procedure. The coiling was completed with immediate angiographic controls, including frontal, lateral, and magnified working projection and 3D rotational images. The grade of aneurysm occlusion was assessed on the basis of a modified 3-point Raymond scale with consensus of 2 observers (S.W.Y., M.H.H.): "complete obliteration" when no contrast agents could be demonstrated within the aneurysm, "residual neck" when contrast agent filled the neck portion inside the parent vessel-aneurysm interface, and "residual aneurysm" if contrast filling extended into the aneurysm fundus beyond the parent vessel-aneurysm interface.²¹

Calculation of Aneurysm Volume, Coil Volume, and Packing Attenuation

The aneurysm was assumed to be ellipsoid; aneurysm volume was estimated from the equation 4π (height/2) (length/2) (width/2)/3. Each diameter in 3 perpendicular axes was measured from 3D rotation angiography. Reconstruction of the 3D images by volume rendering was performed with the Integris 3D-RA release 3.2 software package (Philips Medical Systems). Coil volume for bare platinum coils and Matrix² coils was calculated by using the formula π (OD/2)² L, in which OD is the outer diameter of coil and L is the length of coil. The packing densities of the Matrix² coil group and bare coil group were then calculated by coil volume/aneurysm volume \times 100%.

Procedural Events

Procedure-related events including aneurysm perforation or leakage, thromboembolism, and coil protrusion or migration were assessed.

Follow-Up Imaging and Interpretation

Follow-up imaging protocols included MR angiography at 6 months and 1 year. Based on the source images of 3D TOF MR angiography and maximum-intensity projections that were produced from standard vertical and horizontal rotation by 15°, residual intra-aneurysmal flow on the follow-up MR angiography was graded as "recurrence" and was further evaluated by DSA. If increased aneurysm flow was >2 mm, which necessitates or is amenable to retreatment embolization, it was regarded as "major recanalization"; otherwise, it was regarded as "minor recanalization." The absence of intra-aneurysmal flow was graded as "stable occlusion."

Statistics

The parameters of the demographic characteristics of aneurysms, initial outcomes of endosaccular coiling, and 1-year follow-up outcomes were compared between the Matrix² coil group and the BPC group by contingency table or mean comparison. The initial occlusion grades and packing densities according to the subgroup of aneurysm volumes, and 1-year follow-up outcomes according to the subgroup of aneurysm volumes, initial occlusion grades, and packing densities, were compared by the same methods. All statistics were performed by using SPSS 12.0 (SPSS, Chicago, Illinois), and a *P* value $<.05$ was considered significant.

Results

Comparison of Aneurysm Volumes

The volume of the 121 aneurysms in the Matrix² coil group and 151 aneurysms in the BPC group was 129.5 ± 268.4 mm³ (mean \pm SD; range, 10–1420 mm³) and 95.9 ± 204.6 mm³ (range, 10–1740 mm³), respectively (*P* = .243; Table 1). Sixty-seven aneurysms (55.4%) of the Matrix² coil group and 90 aneurysms (59.6%) of the BPC group had a volume <50 mm³, 38 (31.4%) and 46 (30.5%) were between 50 and 200 mm³, and 16 (13.2%) and 15 (9.9%) were >200 mm³, respectively (*P* = .649).

Initial Outcomes of Endosaccular Coiling

Endosaccular coiling was performed by using a single microcatheter in 44 aneurysms of the Matrix² coil group (36.4%) and in 30 aneurysms of the BPC group (19.9%); by using multiple microcatheters in 33 aneurysms (27.3%) and 61 aneurysms (40.4%); by balloon remodeling in 34 aneurysms (28.1%) and 40 aneurysms (26.5%); and by assistance with stent placement in 10 (8.3%) aneurysms and 20 aneurysms (13.2%) in the Matrix² coil and BPC groups, respectively.

Immediate control DSA demonstrated complete obliteration in 66.9% of the Matrix² coil group (81/121) and 63.6% (96/151) of the BPC group, residual neck in 27.3% (33/121) and 31.8% (48/151), and residual aneurysm in 5.8% (7/121) and 4.6% (7/151), respectively. There was no difference in initial occlusion grade between the Matrix² coil group and BPC group in the subgroups of volume <50 , 50–200, and >200 mm³ (*P* = .688).

The packing attenuation of the Matrix² group and the BPC group was $32.4 \pm 7.9\%$ (mean \pm SD; range, 14%–60%) and $31.2 \pm 7.3\%$ (range, 12%–48%; *P* = .181), respectively. There was no difference in packing attenuation between the Matrix² coil group and the BPC group in the subgroups of volume <50 mm³, 50–200 mm³, and >200 mm³.

Thromboembolism occurred in the 10.7% (13/121) of the Matrix² group and 6.0% (9/151) of the BPC group (*P* = .181); 0.8% (1/121) and 1.3% (2/151) of each group had symptomatic thromboembolism (*P* = 1.0). There was 1 delayed subarachnoid hemorrhage (0.8%) in the Matrix² group and 2 perforations during coiling (1.3%) in the BPC group, 1 of which was without leakage (*P* = 1.0). Coil loop protrusion to parent artery lumen occurred in 1.7% (2/121) of the Matrix² group and 5.3% (8/151; including a coil migration that was retrieved) of the BPC group (*P* = .193), which was managed with bail-out stent placement.

Durability of Aneurysm Occlusion

MR angiography at 6-months and 1-year was acquired in all patients of both groups, and DSA was performed in only 26 aneurysms (26/121) in the Matrix² group (5 stable occlusions, 21 overall recurrences, 17 major recanalizations [17/21] and 13 retreatments [13/17]) and 20 aneurysms (20/151) in the BPC group (9 stable occlusions, 11 overall recurrences, 8 major recanalizations [8/11], and 7 retreatments [7/8]). Among 17 aneurysms with major recanalizations (17/21) in the Matrix² group, 13 aneurysms were retreated. And in the BPC group, 7 aneurysms were retreated among 8 aneurysms with major recanalizations (8/11). Five major recanalizations of the

Table 2: One-year follow-up outcomes of Matrix² group and BPC group based on aneurysm volumes, initial occlusion grades, and packing density

	Matrix ² Coil, No. (%)				BPC, No. (%)				P Value
	No.	Stable Occlusion	Overall Recurrence		No.	Stable Occlusion	Overall Recurrence		
			Major Recanalization	Retreatment			Major Recanalization	Retreatment	
All aneurysm volumes	121	100 (82.6)	21 (17.4)		151	140 (92.7)	11 (7.3)		.066
			17 (14.0)	13 (10.7)			8 (5.3)	7 (4.6)	
Volume <50 mm ³	67	64 (95.5)	3 (4.5)		90	86 (95.6)	4 (4.4)		.404
			3 (4.5)	2 (3.0)			2 (2.2)	0 (0)	
Volume 50–200 mm ³	38	29 (76.3)	9 (23.7)		46	45 (97.8)	1 (2.2)		.022 ^a
			5 (13.1)	4 (10.5)			0 (0)	0 (0)	
Volume >200 mm ³	16	7 (43.8)	9 (56.3)		15	9 (60)	6 (40)		.642
			9 (56.3)	7 (43.8)			6 (40)	5 (33.3)	
Initial occlusion grade			9 (11.1)				4 (4.2)		
Complete obliteration	81	72 (88.9)	6 (7.4)		96	92 (95.8)	1 (1.0)		.092
			6 (7.4)	6 (7.4)			5 (10.4)	1 (1.0)	
Residual neck	33	25 (75.8)	8 (24.2)		48	43 (89.6)	5 (10.4)		.160
			7 (21.2)	5 (15.2)			5 (10.4)	5 (10.4)	
Residual aneurysm	7	3 (42.9)	4 (57.1)		7	5 (71.4)	2 (28.6)		.558
			4 (57.1)	2 (28.6)			2 (28.6)	1 (14.3)	
Packing density			18 (38.3)				8 (13.3)		
PD <30%	47	29 (61.7)	15 (31.9)		60	52 (86.7)	7 (11.7)		.025 ^a
			15 (31.9)	11 (23.4)			1 (2)	6 (10)	
PD 30–35%	32	30 (93.7)	2 (6.3)		49	48 (98.0)	1 (2)		.327
			2 (6.3)	2 (6.3)			1 (2)	1 (2)	
PD >35%	42	41 (97.6)	1 (2.4)		42	40 (95.2)	2 (4.8)		.557
			0 (0)	0 (0)			0 (0)	0 (0)	

^a P value <.05.

Matrix² group and 3 major recanalizations of the BPC group were confirmed on the DSA performed <6 months after initial coiling.

The incidences of overall recurrence, major recanalization, and retreatment of the Matrix² group and the BPC group were 17.4% (21/121) versus 7.3% (11/151), 14.0% (17/121) versus 5.3% (8/151), and 10.7% (13/121) versus 4.6% (7/151), respectively ($P = .066$; Table 2). Those aneurysms in the subgroup with a volume <50 and >200 mm³ were not different between the Matrix² coil and the BPC group. However, those aneurysms with a volume between 50 and 200 mm³ were 23.7% (9/38) versus 2.2% (1/46), 13.1% (5/38) versus 0%, and 10.5% (4/38) versus 0%, respectively ($P = .022$).

The overall recurrence, major recanalization, and retreatment of the Matrix² coil and the BPC groups in the subgroups of initial occlusion grade were not different.

The overall recurrence, major recanalization, and retreatment of the Matrix² coil and the BPC groups in the subgroups of packing attenuation 30%–35% and >35% were not different. However, those with packing attenuation <30% were 38.3% (18/47) versus 13.3% (8/60), 31.9% (15/47) versus 11.7% (7/60), and 23.4% (11/47) versus 10% (6/60), respectively ($P = .025$).

The mean percentage length of Matrix² coils was 71.1% (range, 16%–100%). For the 3 subgroups of lengths of Matrix² coils that we used (Table 3), there were no differences in mean packing attenuation ($P = .152$), initial occlusion grade ($P = .098$), and 1-year follow-up outcomes ($P = .209$).

Discussion

There were no adverse side reactions that were related to coating material, eg, meningitis²² and perianeurysmal edema.^{23–25} The incidence of residual neck slightly increased along with the increment of the percentage of length of Matrix² coils, but it was not statistically significant. The technical disadvantages of Matrix coils have been adapted by the operator; the compartmentalization during coiling of multilobulated aneurysm could be overcome by microcatheter repositioning, and the friction and the stiffness during coiling were not severe enough to affect the initial results of coiling with the Matrix² coils when compared with previous reports about Matrix coils.^{26–28}

The durability of aneurysm occlusion has been a major concern since the introduction of treatment of endosaccular occlusion by using detachable coils. Cognard et al²⁹ reported that 14% of aneurysms (20/148) with initial complete occlu-

Table 3: Initial and 1-year follow-up outcomes according to length of Matrix² coils used

Length of Matrix ² Coils	<50%	50%–100%	100%	P Value ^a
Aneurysm no. (%)	35 (28.9)	47 (38.8)	39 (32.2)	
Mean aneurysm volume (mm ³)	168.5 ± 296.2	114.7 ± 237.3	112.3 ± 280.7	.597
Mean packing density (%)	30.2 ± 7.4	33.2 ± 6.4	33.5 ± 9.6	.152
Initial occlusion grade, no. (%)				
Complete obliteration	25 (71.4)	35 (74.4)	21 (53.8)	.098
Residual neck	7 (20.0)	12 (25.5)	14 (35.9)	
Residual aneurysm	3 (8.6)	0 (0.0)	4 (10.3)	
1-year follow-up outcomes, no. (%)				
Stable occlusion	25 (71.4)	42 (89.4)	33 (84.6)	.209
Overall recurrence	10 (28.6)	5 (10.6)	6 (15.4)	
Major recanalization	8 (22.9)	5 (10.6)	4 (10.3)	
Retreatment	5 (14.3)	4 (8.5)	4 (10.3)	

^a P value <.05 is significant.

sion recurred during a follow-up period between 3 and 30 months. Murayama et al³⁰ reported that the overall recanalization rate of aneurysm occluded by using detachable platinum coils during their 11 years of observation was 20.9%, with slight improvement from 26.1% for the initial 5 years to 17.2% for the remaining 6 years.

Durable aneurysm occlusion requires the organization of the clot into granulation tissue between the coil meshwork and re-endothelialization at the aneurysm neck on the surface of the coil mass. To accelerate tissue reaction, bioactive polyglycolic/poly-lactic acid copolymer-coated Matrix coils were invented; coil diameter was increased to 0.03 cm (0.012 inch), and the platinum coil was coated with a bioactive polymer with a 3:7 ratio. The fibrous intercoil granulation response in the aneurysmal cavity and the production of thicker neointimal tissue at the orifice were identified in the canine bifurcation aneurysm model.¹² However, in many reports, the packing attenuation was not improved, and overall recurrence rate ranged from 14.3% to 57.4%.^{13–15,17,26,27,31,32} Because the combination of excessive polymer and less coil mass was considered as the cause of polymer absorption without healing reaction, resulting in recanalization,¹⁸ in Matrix² coils the platinum coil was coated with a bioactive polymer with a 7:3 ratio.

Our outcomes of the Matrix² coil group were in agreement with the analysis of D'Agostino et al,²⁰ who reported a 23.7% recanalization rate, including 3.9% major recanalization, on 6-month follow-up, and 36.8% recanalization rate, including 15.8% major recanalization, on 1-year follow up among 100 aneurysms treated with the Matrix² coil.²⁰ However, our outcomes were worse than midterm angiographic outcomes of Ishii et al,¹⁹ who reported 9.4% recanalization rate, including 0% in small aneurysms with small necks, 5.6% in small aneurysms with wide necks, and 15.4% in large aneurysms, among 53 aneurysms treated with the Matrix² coil. In our study, the positive effect of the Matrix² coil was not seen, considering that the percentage length of the Matrix² coil used did not make a difference in the 1-year follow-up outcomes. Instead, the aneurysm volume, initial occlusion grade, and packing attenuation were shown to be associated with higher recanalization rates, as also was seen in several BPC studies.^{33,34}

We retrospectively compared the Matrix² coil group to the historical controls of the BPC group, both of which were treated with the homogeneous coiling technique in the single institution during the uniform follow-up period. During the

research period, there was no established strategy for coil selection among Matrix², BPC, or other coils and their combined use, and different types of bioactive coils were not used in the same aneurysm. Location and size of the aneurysm did not dictate the type of coil to be chosen. Matrix² coils were chosen mostly as the filling coil. However, there are several limitations in our study other than being a retrospective study. First, we included a large number of small-sized and unruptured aneurysms, which might have biased favorable outcomes. Second, our follow-up imaging was based on 3D TOF MR angiography, and only selected patients with suspected major recanalization underwent DSA. However, this strategy seems to be valid because detection of recurrence within the coiled aneurysm on MR angiography has shown similar results on DSA, and most missed recurrence is of very small size, <2 mm, that does not warrant retreatment.^{35–37} Third, baseline MR angiography was not conducted immediately after coiling, and the interval change in aneurysm occlusion grade between immediate control and follow-up MR angiography could not be assessed. Fourth, there were some cases of susceptibility artifact by coil mass. However, the source images of MR angiography were carefully reviewed for the evaluation of aneurysm neck, and the anatomic result was clarified in most cases.^{36,37}

Conclusions

The endosaccular occlusion of intracranial aneurysms by using Matrix² coils was feasible and safe, with similar compact packing, degree of occlusion, and complication in comparison with BPCs in our single institution experience. However, the 1-year durability of aneurysm occlusion by the use of Matrix² coils was inferior to that of BPCs in the specific subgroups of aneurysm volume and packing attenuation. Considering cost-effectiveness and technical demands, there would be little benefit provided by the use of Matrix² coils over BPCs.

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