

# Predictive Factors of Bifurcation Stenting

Young-Hak Kim, MD, PhD,

Department of Cardiology, University of Ulsan College of  
Medicine, Asan Medical Center, Seoul, Korea

# Traditional Predictive Factors

## *Several Biological and Mechanical Factors*

- Diabetes mellitus
- Renal failure
- DES type
- Stenosis in the side branch (SB)
- Bifurcation angle
- Single-stent vs. two-stent technique
- Multiple stents
- Final kissing balloon inflation
- IVUS-guidance
- Use of non-compliant balloon
- Operator's experience

# Contents

- Procedural factors in Crush stenting
- Bifurcation angle measured by 3D QCA

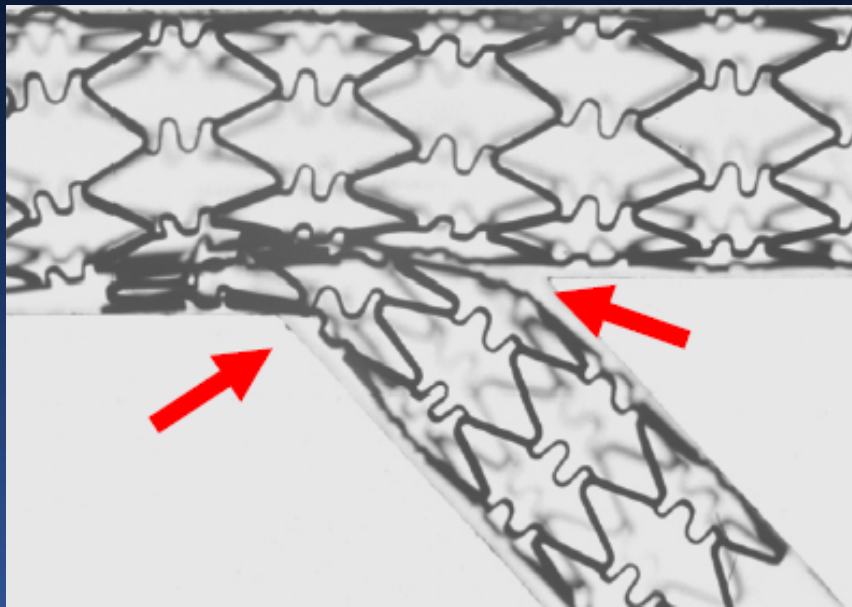
# Contents

- Procedural factors in Crush stenting
- Bifurcation angle measured by 3D QCA

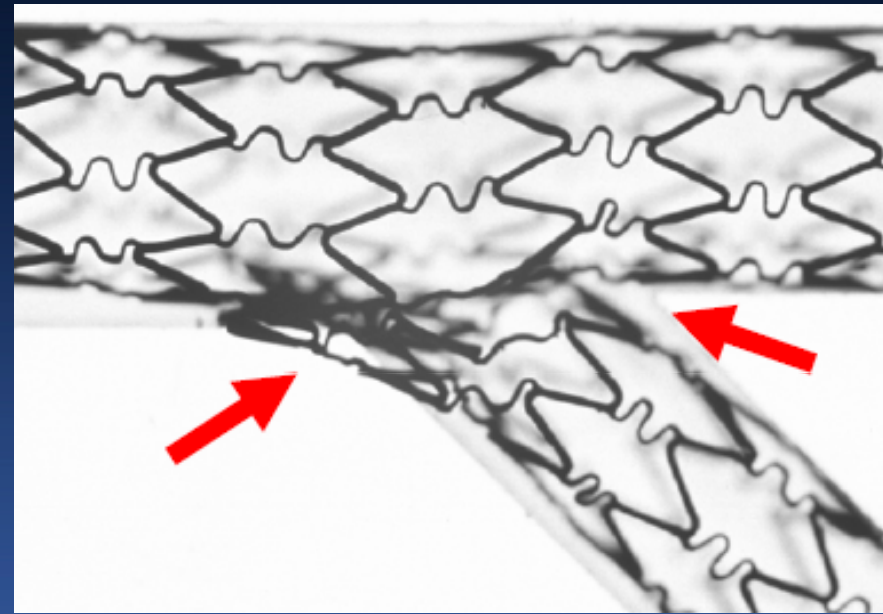
# Importance of Kissing in Bench

To avoid under-expansion or inapposition

Before FKB

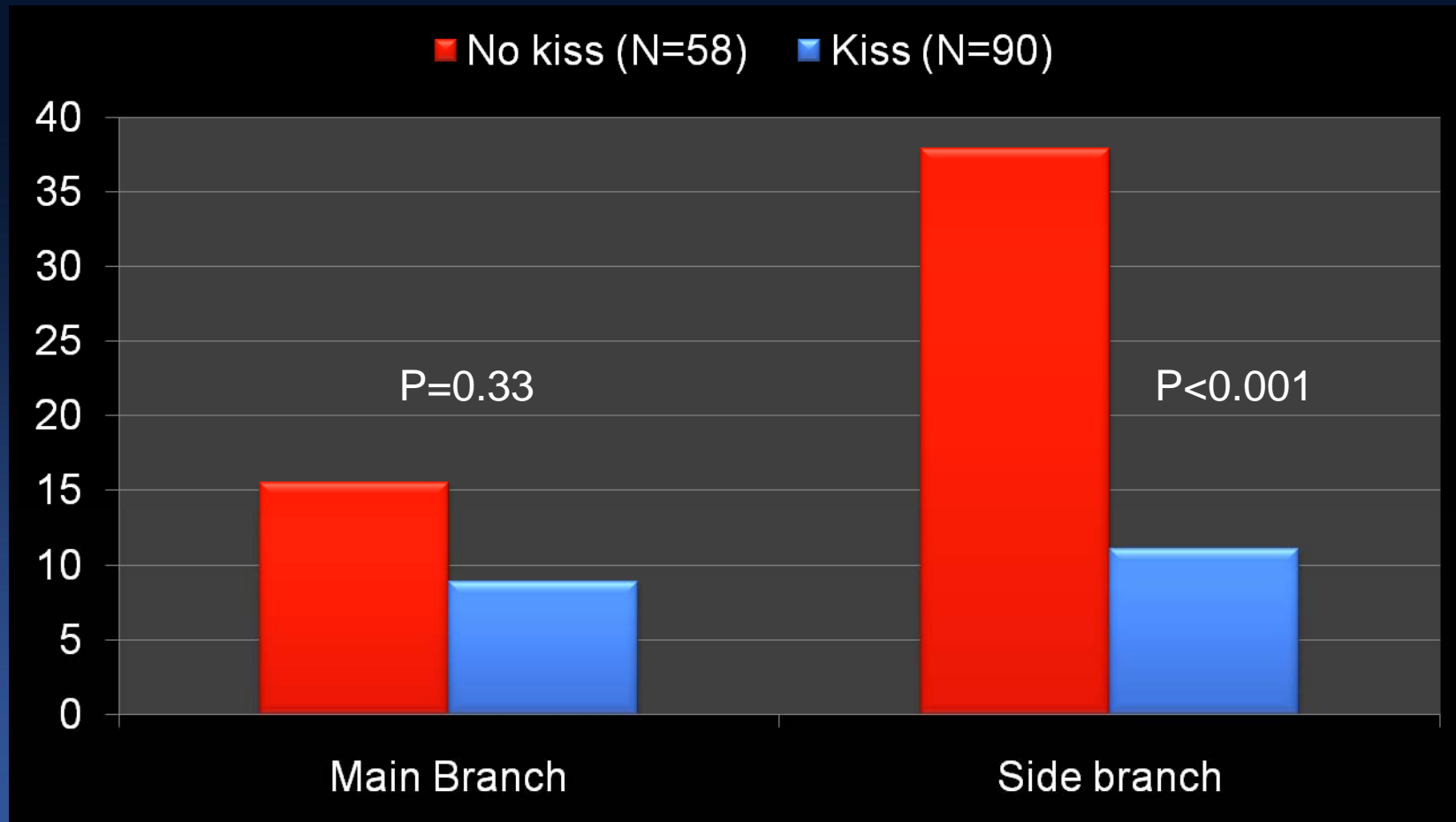


After FKB



# Clinical Importance of Kissing

## Reduction of Restenosis



Ge L et al. J Am Coll Cardiol 2005;46:613

# Studies of Crush Stenting

Author	No.	Type	FKB	IVUS	MACE	ST
Ge L et al <sup>1</sup>	181	Classic	64%	< 10%	26.5% (9M)	2.8%
Colombo A et al <sup>2</sup> (CACTUS)	177	Classic	92%		15.8% (6M)	1.7%
Galassi AR et al <sup>3</sup>	199	Mini-crush	88%		20.6%(25M)	1.0%
Moussa I et al <sup>4</sup>	120	Classic	88%		13.0% (6M)	1.7%
HS David et al <sup>5</sup> (BBC)	169	Classic	72%		15.2% (9M)	-
Erglis A et al <sup>6</sup> (NORDIC2)	209	Classic	85%		4.3% (6M)	-
Chue CD et al <sup>7</sup>	100	Classic	75%		28% (3Y)	-

1. J Am Coll Cardiol 2005;46:613

3. J Am Coll Cardiol Interv 2009;2:185

5. Circulation. 2010;121:1235

7. Cath Cardiovasc Interv 2010;75:605

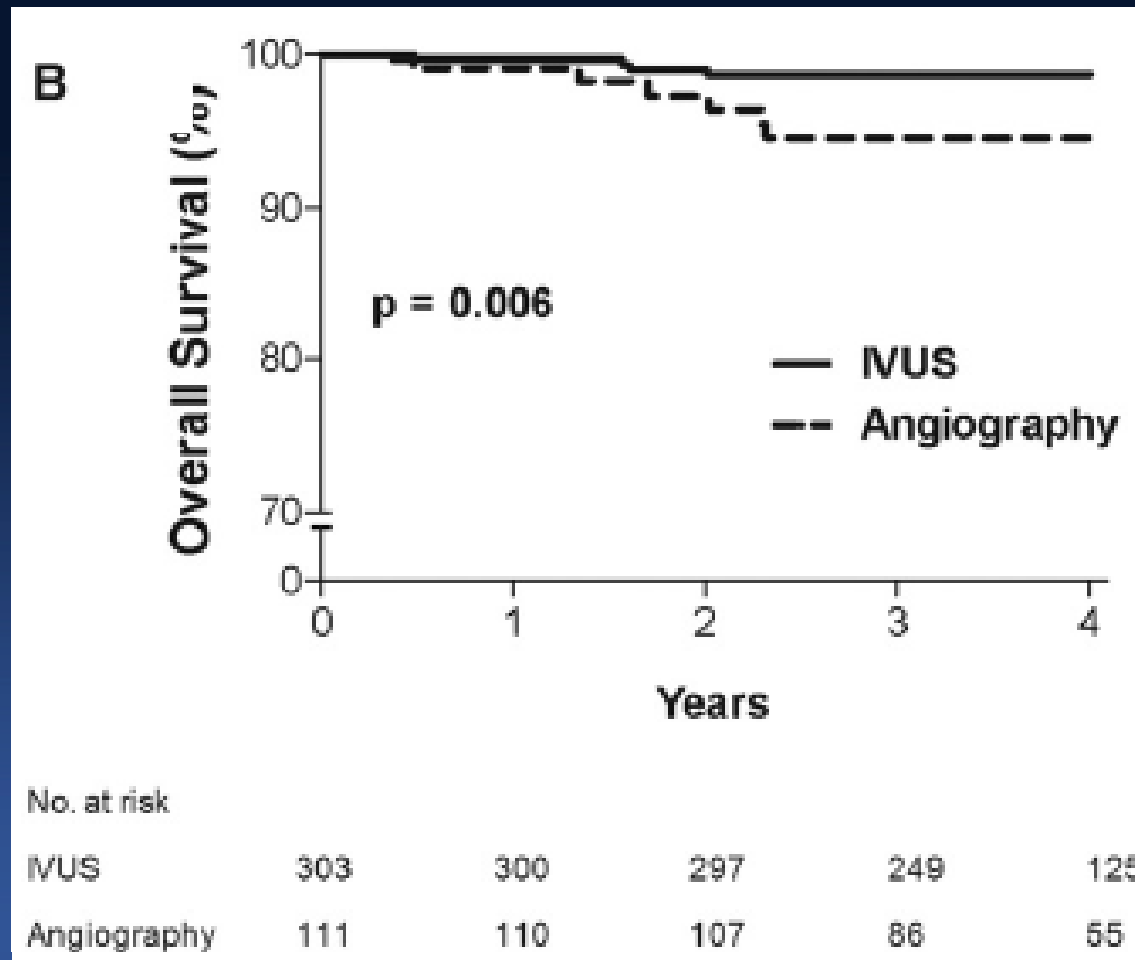
2. Circulation. 2009;119:71

4. Am J Cardiol 2006;97:1317

6. Circ Cardiovasc Interv. 2009;2:27

# 4-Year Mortality in AMC Bifurcation Registry

## 473 IVUS-guidance vs. 285 Angio-guided





# Adjusted Hazard Ratios by IVUS-Guidance

Outcome	Overall group		DES group		BMS group	
	HR (95% CI)	p	HR (95% CI)	p	HR (95% CI)	p
Death	<b>0.31</b> (0.13-0.74)	<b>0.008</b>	<b>0.24</b> (0.06-0.86)	<b>0.03</b>	0.41 (0.13-1.26)	0.12
Stent thrombosis	0.48 (0.16-1.43)	0.19	0.35 (0.08-1.64)	0.18	1.09 (0.22-5.34)	0.92
TLR	1.47 (0.79-2.71)	0.21	0.92 (0.38-2.25)	0.86	2.27 (0.99-5.25)	0.05

# Predictive Factors after Crush

- From 2003, 404 patients who were treated with DES using the Crush technique under the IVUS-guidance for 415 native bifurcation coronary lesions in Asan Medical Center were collected.
- Patients who received primary angioplasty for acute ST-elevation MI were excluded.

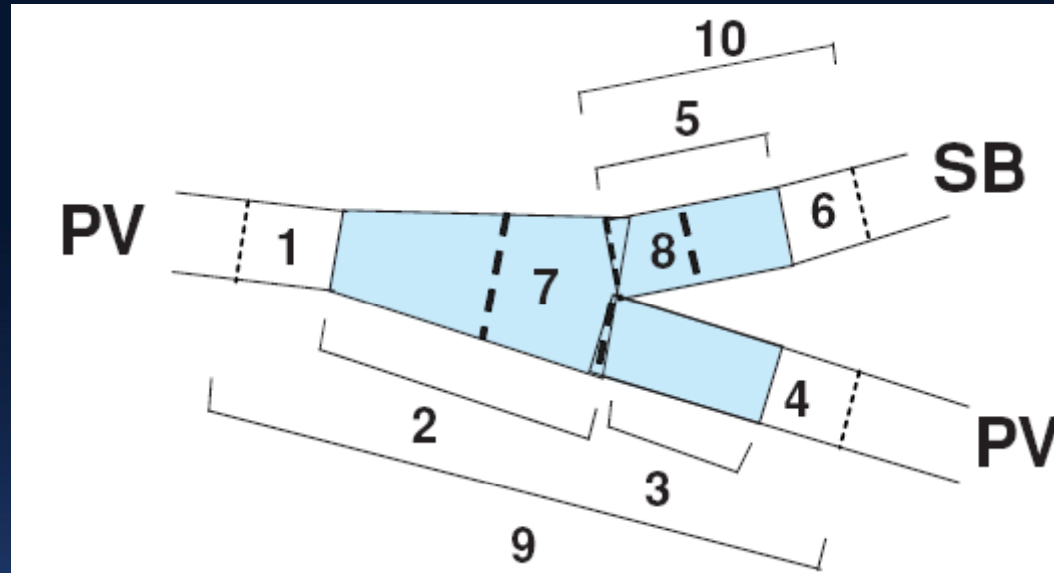
# Techniques

- The Crush technique was performed for true bifurcation lesions.
- A final kissing balloon (FKB) dilatation was attempted in all lesions.
- IVUS-guidance was also attempted in all lesions.
- Non-compliant balloon has been used for optimal stent expansion during post-stent dilatation at the operators' discretion.
- In particular, use of non-compliant balloon in the side branch has been preferred since 2008 in our center.

# End point and Follow-up

- The primary outcome of interest was the major adverse cardiac event (MACE) including all-cause death, myocardial infarction (MI), and target vessel revascularization (TVR).
- MI was defined as either complications at the index admission (defined as new pathologic Q waves after index treatment) or spontaneous MI.
- TVR was defined as any revascularization with either PCI or CABG for the treated vessels.

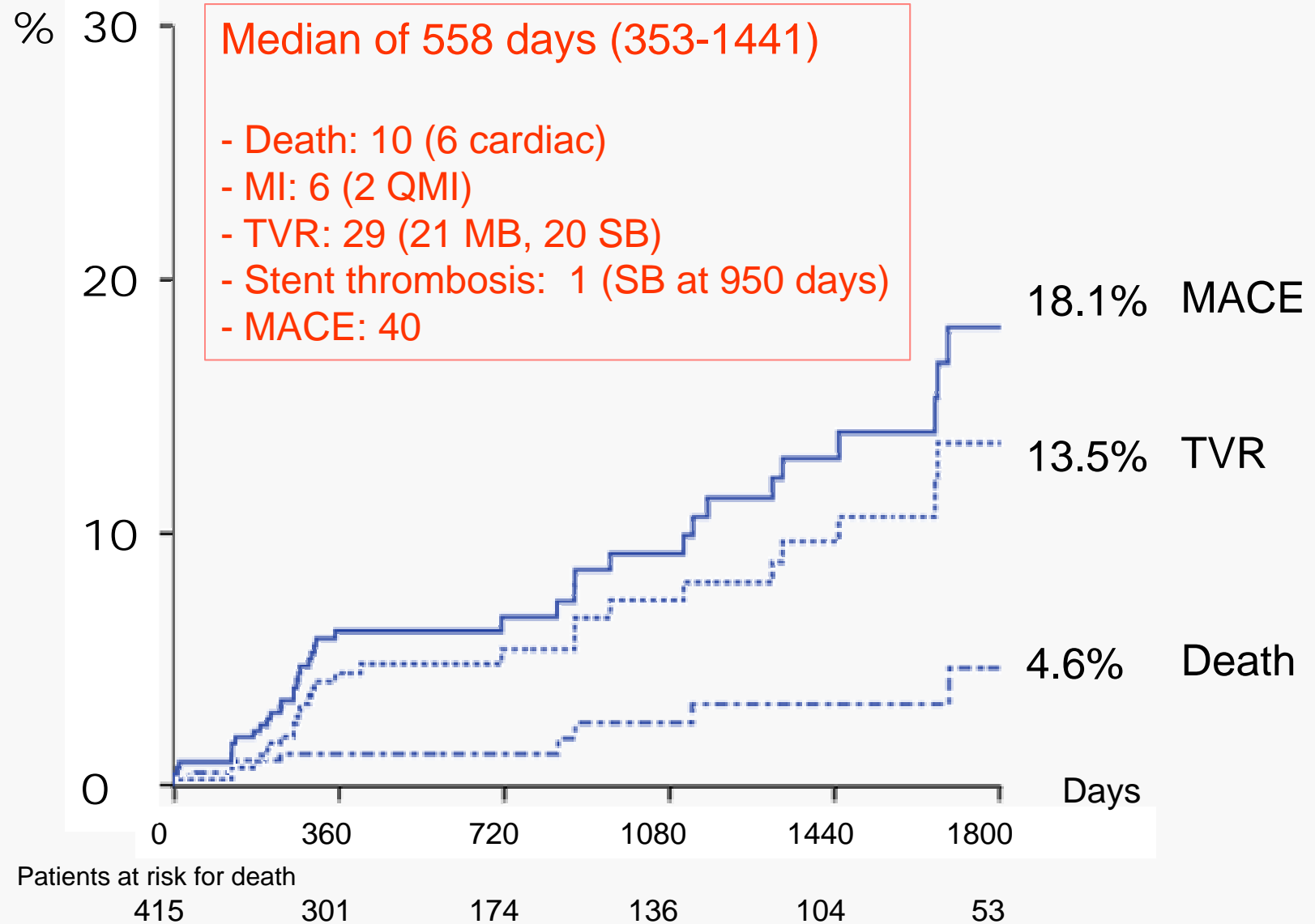
# Angiographic Analysis in the Core Lab



1. Proximal edge (5 mm)
2. Proximal main stent
3. Distal main stent
4. Distal edge main (5 mm)
5. SB stent
6. Distal edge side (5 mm)
7. Polygon of confluence
8. Ostium of SB (5 mm)
9. MB stent + edges
10. SB stent + distal edge

- Angiographic analysis was performed in 10 segments according to the dedicated bifurcation measurement technique (Rancharitar et al. EuroInterv. 2008;3:553) using the bifurcation software (CASS 5.4).
- The proximal main branch (MB) included segments 1 and 2.
- Distal MB and side branch (SB) included 3 and 4, and 6, respectively.

# 5-Year Incidence of Events



# Baseline Clinical Characteristics

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
Age, years	62.0 (54.0, 68.0)	62.5	62.0	0.854
Male	311 (74.9)	30 (75.0)	281 (74.9)	0.993
<b>Diabetes mellitus</b>	<b>137 (33.3)</b>	<b>21 (52.5)</b>	<b>116 (30.9)</b>	<b>0.008</b>
Hypertension	237 (57.1)	28 (70.0)	209 (55.7)	0.083
Smoking	110 (26.5)	7 (17.5)	103 (27.5)	0.175
<b>Dyslipidemia</b>	<b>252 (60.7)</b>	<b>15 (37.5)</b>	<b>237 (63.2)</b>	<b>0.002</b>
Renal failure	6 (1.4)	0	6 (1.6)	1.000
Prior PCI	62 (14.9)	8 (20.0)	54 (14.4)	0.345
Prior CABG	9 (2.2)	1 (2.5)	8 (2.1)	0.602

# Baseline Clinical Characteristics

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
Prior MI	24 (5.8)	2 (5.0)	22 (5.9)	1.000
Prior stroke	21 (5.1)	0	21 (5.6)	0.245
Family history	63 (15.2)	7 (17.5)	56 (14.9)	0.645
Peripheral disease	14 (3.4)	2 (5.0)	12 (3.2)	0.632
Clinical diagnosis				0.701
Stable angina	272 (65.5)	24 (60.0)	248 (66.1)	
Unstable angina	120 (28.9)	13 (32.5)	107 (28.5)	
MI	23 (5.5)	3 (7.5)	20 (5.3)	
Ejection fraction, %	60.0 (57.0, 63.3)	62.0	60.0	0.188



# Procedures

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
Intra-aortic pump	17 (4.1)	1 (2.5)	16 (4.3)	1.000
DCA	10 (2.4)	2 (5.0)	8 (2.1)	0.249
Thrombus aspiration	2 (0.5)	0	2 (0.5)	1.000
Rotablation	1 (0.2)	0	1 (0.3)	1.000
Post-stent balloon				
MB	396 (95.4)	35 (87.5)	361 (96.3)	0.027
SB	397 (95.7)	36 (90.0)	361 (96.3)	0.084
<b>FKB</b>	<b>392 (94.5)</b>	<b>32 (80.0)</b>	<b>360 (96.0)</b>	<b>0.001</b>
Non-compliant balloon				
<b>MB</b>	<b>194 (46.7)</b>	<b>11 (27.5)</b>	<b>183 (48.8)</b>	<b>0.012</b>
<b>SB</b>	<b>159 (38.3)</b>	<b>9 (22.5)</b>	<b>150 (40.0)</b>	<b>0.030</b>

N(%) and Median (interquartile range)

# Stent Implantation

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
Used DES				0.237
Sirolimus	309 (74.5)	34 (85.0)	275 (73.3)	
Paclitaxel	13 (3.1)	2 (5.0)	11 (2.9)	
Zotarolimus	18 (4.3)	1 (2.5)	17 (4.5)	
Everolimus	75 (18.1)	3 (7.5)	72 (19.2)	
Max. device, mm				
MB	3.84 (3.71, 4.20)	3.84	3.83	0.191
SB	3.09 (2.90, 3.33)	3.10	3.03	0.502
Max. pressure, atm				
MB	18.0 (14.0, 20.0)	17.0	18.0	0.770
SB	16.0 (12.0, 18.0)	16.0	14.0	0.112

# Used Stents

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
<b>Number of stents</b>				
MB	2.0 (1.0, 2.0)	1.0	2.0	0.368
SB	1.0 (1.0, 1.0)	1.0	1.0	0.939
<b>Mean stent size, mm</b>				
MB	3.33 (3.17, 3.50)	3.50	3.25	0.680
SB	2.75 (2.75, 3.00)	3.00	2.75	0.128
<b>Total stent length, mm</b>				
MB	41.0 (28.0, 56.0)	33.0	41.0	0.425
SB	23.0 (18.0, 28.0)	23.0	23.0	0.946
Angiographic F/U	305 (73.5)	33 (82.5)	272 (72.5)	0.175

# Baseline Angiography

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
Diseased vessels				0.758
1 vessel	147 (35.4)	17 (42.5)	130 (34.7)	
2 vessel	158 (38.1)	13 (32.5)	145 (38.7)	
3 vessel	110 (26.5)	10 (25.0)	100 (26.7)	
Location				0.151
Left anterior	256 (61.7)	18 (45.0)	238 (63.5)	
Left circumflex	16 (3.9)	2 (5.0)	14 (3.7)	
Right coronary	6 (1.4)	1 (2.5)	5 (1.3)	
<b>Left main</b>	<b>137 (33.0)</b>	<b>19 (47.5)</b>	<b>118 (31.5)</b>	
MEDINA class				0.283
1:0:0	4 (1.0)	0	4 (1.1)	
0:1:0	13 (3.1)	1 (2.5)	12 (3.2)	
1:1:0	22 (5.3)	1 (2.5)	21 (5.6)	
<b>1:1:1</b>	<b>242 (58.3)</b>	<b>18 (45.0)</b>	<b>224 (59.7)</b>	
<b>0:0:1</b>	<b>15 (3.6)</b>	<b>3 (7.5)</b>	<b>12 (3.2)</b>	
<b>1:0:1</b>	<b>39 (9.4)</b>	<b>5 (12.5)</b>	<b>34 (9.1)</b>	
<b>0:1:1</b>	<b>80 (19.3)</b>	<b>12 (30.0)</b>	<b>68 (18.1)</b>	

N(%)

# QCA before Procedure

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
<b>Lesion length, mm</b>				
MB	30.6 (21.4, 41.2)	28.7	30.9	0.592
SB	13.3 (8.7, 18.9)	14.0	13.3	0.939
<b>Proximal MB</b>				
Reference, mm	3.49 (3.19, 3.86)	3.47	3.50	0.467
MLD, mm	1.57 (1.21, 2.05)	1.67	1.56	0.180
DS, mm	54.6 (44.7, 63.8)	54.0	54.8	0.116
<b>Distal MB</b>				
Reference, mm	3.09 (2.81, 3.40)	3.11	3.09	0.910
MLD, mm	1.40 (1.04, 1.78)	1.40	1.40	0.359
DS, mm	54.6 (44.9, 66.3)	53.0	54.7	0.219
<b>SB</b>				
Reference, mm	2.90 (2.57, 3.24)	3.04	2.87	0.106
MLD, mm	1.44 (1.11, 1.81)	1.38	1.45	0.445
DS, mm	50.5 (37.7, 61.1)	52.3	50.1	0.121
<b>Angle, Pre, °</b>				
Proximal	144 (126, 158)	138	145	0.424
Distal	53 (39, 71)	55	53	0.642
Median (interquartile range)				

# QCA after Procedure

	Overall	MACE (+)	MACE (-)	p
Lesions	415	40	375	
<b>Proximal MB</b>				
MLD, in-stent, mm	3.10 (2.80, 3.39)	3.11	3.10	0.952
DS, in-stent, %	9.3 (4.4, 15.6)	7.64	9.4	0.804
<b>Stent length, mm</b>	<b>14.2 (11.2, 19.3)</b>	<b>11.96</b>	<b>14.7</b>	<b>0.024</b>
<b>Distal MB</b>				
MLD, in-stent, mm	2.64 (2.40, 2.90)	2.71	2.64	0.366
DS, in-stent, %	16.7 (4.4, 15.8)	8.7	11.0	0.523
Stent length, mm	17.7 (10.9, 29.8)	17.2	17.8	0.796
<b>SB</b>				
MLD, ostium, mm	2.57 (2.31, 2.90)	2.66	2.56	0.185
<b>MLD, in-stent, mm</b>	<b>2.30 (2.09, 2.59)</b>	<b>2.47</b>	<b>2.29</b>	<b>0.047</b>
DS, ostium, %	10.2 (5.0, 17.0)	12.0	9.8	0.585
DS, in-stent, %	10.8 (4.8, 18.1)	12.4	10.7	0.770
Stent length, mm	14.7 (10.0, 20.0)	17.1	14.5	0.497
Median (interquartile range)				

# QCA at Follow-up

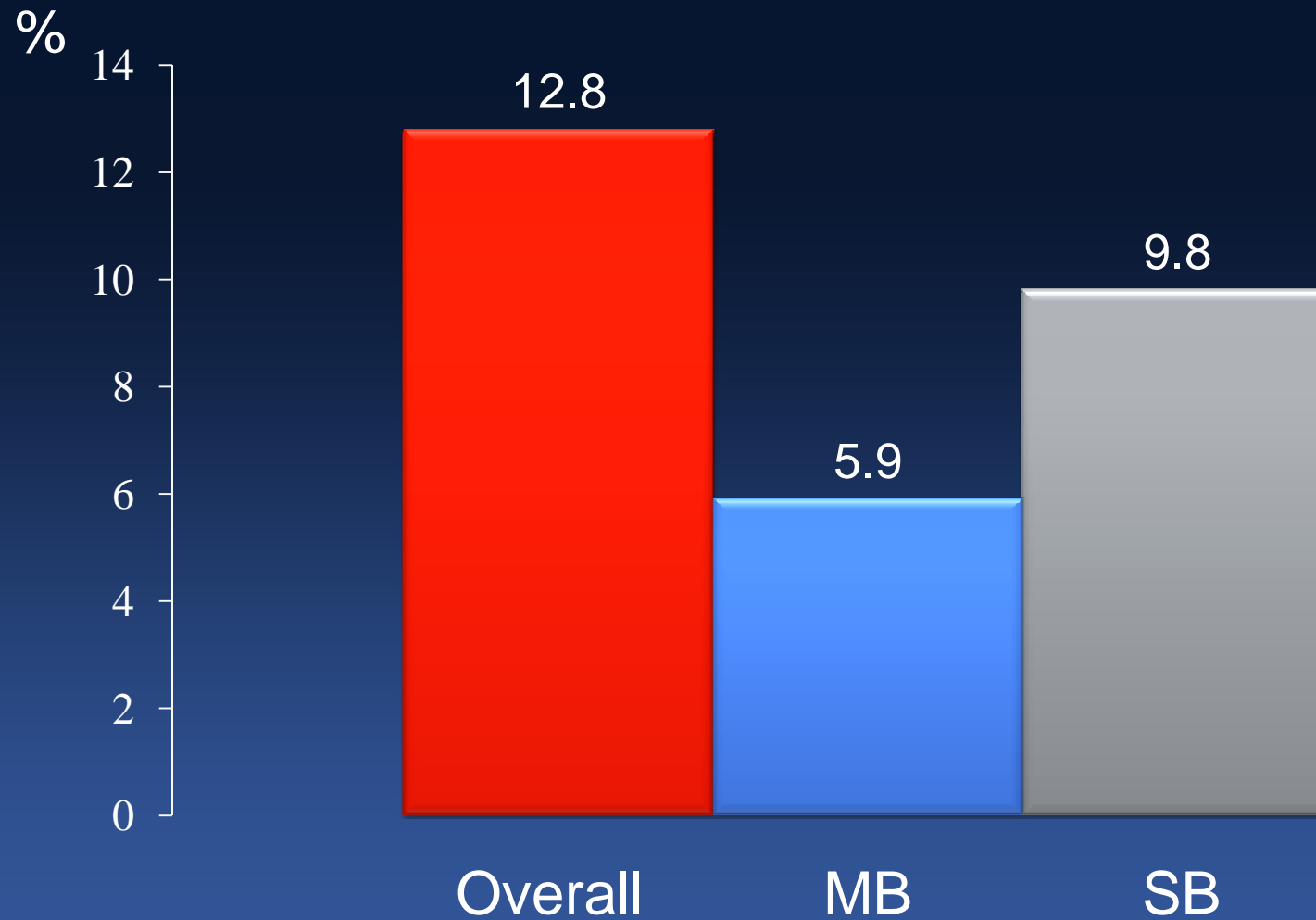
	Overall	MACE (+)	MACE (-)	p
Lesions	305	33	272	
<b>Proximal MB</b>				
MLD, in-stent, mm	2.92 (2.62, 3.25)	2.78	2.95	0.114
DS, in-stent, %	14.4 (7.0, 22.5)	19.0	13.8	0.051
<b>Distal MB</b>				
MLD, in-stent, mm	2.53 (2.20, 2.77)	2.39	2.54	0.035
DS, in-stent, %	15.6 (9.2, 25.0)	18.9	15.6	0.165
<b>SB</b>				
MLD, ostium, mm	2.30 (1.98, 2.67)	2.19	2.31	0.045
MLD, in-stent, mm	2.09 (1.83, 2.40)	2.03	2.09	0.067
DS, ostium, %	20.1 (9.9, 30.3)	29.0	20.0	0.010
DS, in-stent, %	21.7 (11.7, 32.7)	33.0	21.4	0.006

# Late Luminal Loss (mm)

Lesions	Overall	MACE (+)	MACE (-)	p
	305	33	272	
<b>Proximal MB</b>				
In-stent	0.14 (-0.07, 0.43)	0.20	0.13	<b>0.025</b>
In-segment	0.14 (-0.10, 0.43)	0.20	0.13	<b>0.034</b>
<b>Distal MB</b>				
In-stent	0.18 (-0.04, 0.41)	0.35	0.15	<b>0.014</b>
In-segment	0.06 (-0.16, 0.33)	0.20	0.05	<b>0.055</b>
<b>SB</b>				
Ostium	0.28 (0.01, 0.54)	0.43	0.27	<b>0.032</b>
In-stent	0.22 (0.00, 0.43)	0.34	0.21	<b>0.023</b>
In-segment	0.13 (-0.12, 0.35)	0.39	0.11	<b>0.001</b>



# Restenosis Rate



# Restenosis (Main Branch)

	Overall	MACE (+)	MACE (-)	p
Lesions	305	33	272	
Restenosis	12.8	57.6	7.4	<0.001
MB	5.9	36.4	2.2	<0.001
Location				
Proximal edge	2 (11.1)	2 (16.7)	0	
In-stent	<b>14 (77.8)</b>	8 (66.7)	6 (100)	
Distal edge	2 (11.1)	2 (16.7)	0	
Pattern				0.343
Focal, Gap	0	0	0	
Edge	3 (16.7)	3 (25.0)	0	
Body	<b>10 (55.6)</b>	5 (41.7)	5 (83.3)	
Multifocal	0	0	0	
Diffuse	2 (11.1)	2 (16.7)	0	
Proliferative	1 (5.6)	1 (8.3)	0	
Total occlusion	2 (11.1)	1 (8.3)	1 (16.7)	

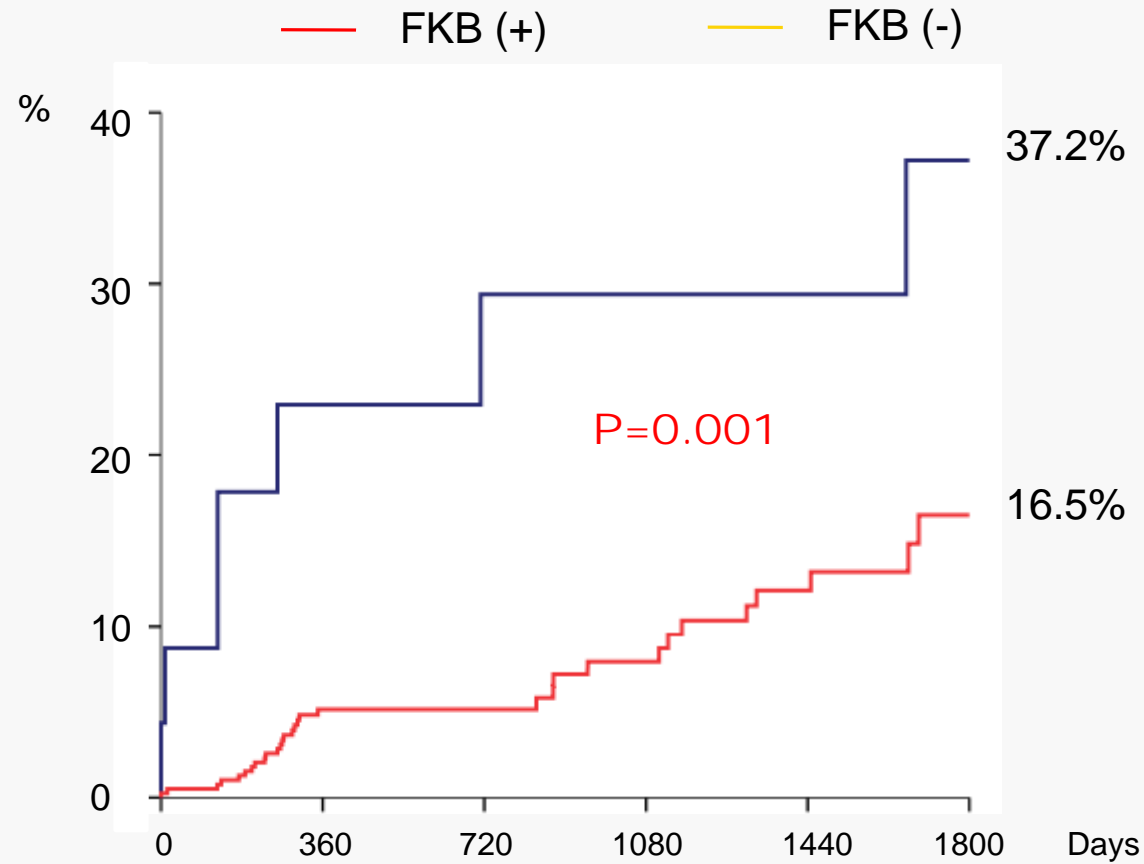
# Restenosis (Side Branch)

	Overall	MACE (+)	MACE (-)	p
Lesions	305	33	272	
Restenosis	39 (12.8)	19 / 33 (57.6)	20 / 272 (7.4)	<0.001
SB	30 (9.8)	13 / 33 (39.4)	17 / 272 (6.3)	<0.001
Location				
Ostium	<b>9 (30.0)</b>	4 (30.8)	5 (29.4)	
In-stent	<b>25 (83.3)</b>	10 (76.9)	15 (88.2)	
Distal edge	2 (6.7)	1 (7.7)	1 (5.9)	
Pattern				0.428
Focal, Gap	0	0	0	
Edge	3 (10.0)	2 (15.4)	1 (5.9)	
Body	<b>22 (73.3)</b>	8 (61.5)	14 (82.4)	
Multifocal	1 (3.3)	1 (7.7)	0	
Diffuse	1 (3.3)	1 (7.7)	0	
Proliferative	0	0	0	
Total occlusion	3 (10.0)	1 (7.7)	2 (11.8)	

# Predictors of MACE by Cox Models

	Univariate analysis			Multivariate analysis		
	HR	95 % CI	p	HR	95 % CI	p
Diabetes mellitus	2.25	1.21, 4.19	0.011	<b>2.48</b>	<b>1.32, 4.65</b>	<b>0.005</b>
Left main stenosis	1.75	0.94, 3.26	0.078	-	-	-
FKB	0.28	0.13, 0.63	0.002	<b>0.24</b>	<b>0.11, 0.55</b>	<b>0.001</b>

# MACE btw FKB vs. Non-FKB



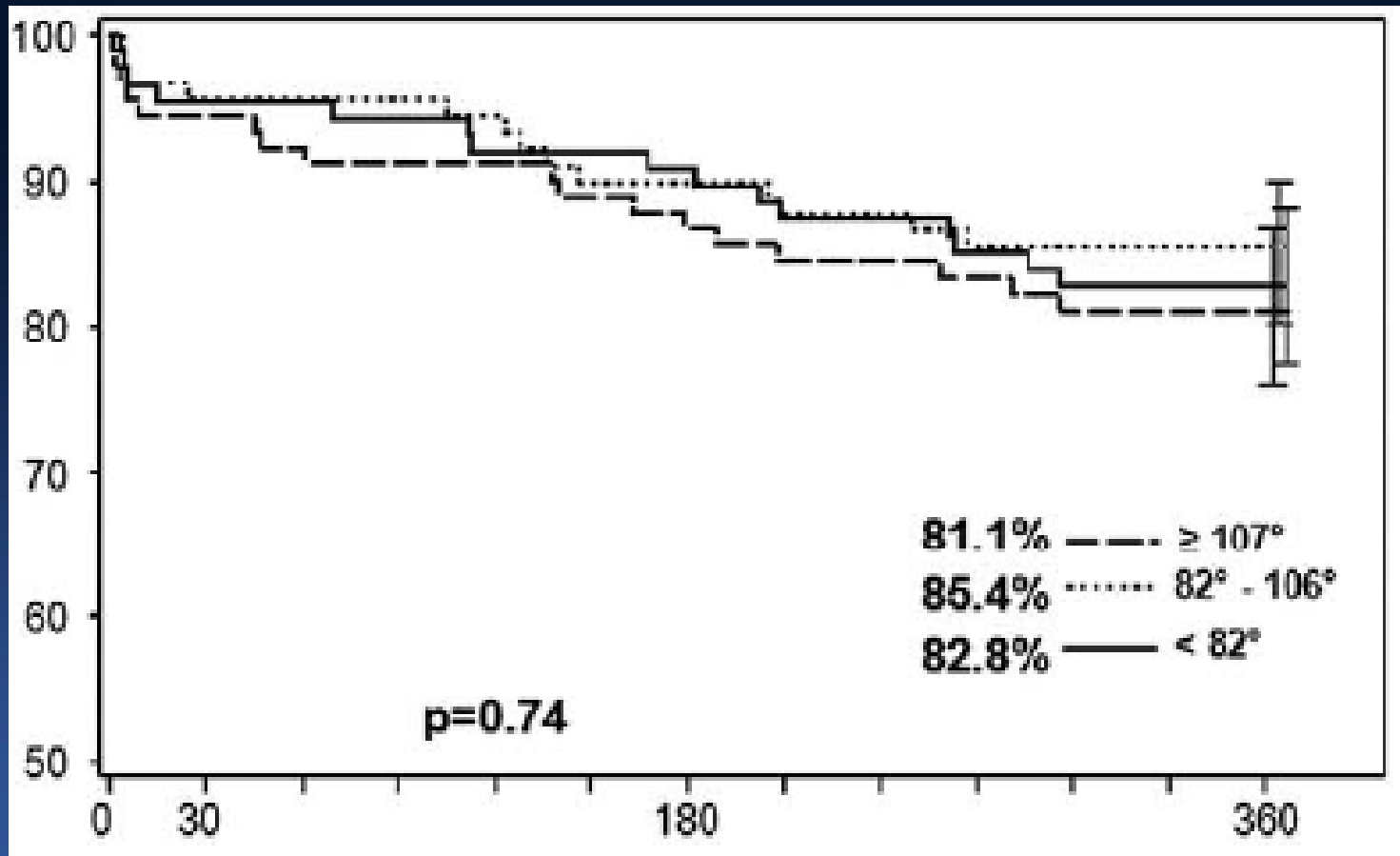
Patients at risk

FKB (+)	415	274	155	117	85	38
FKB (-)	23	14	11	10	10	8

# Contents

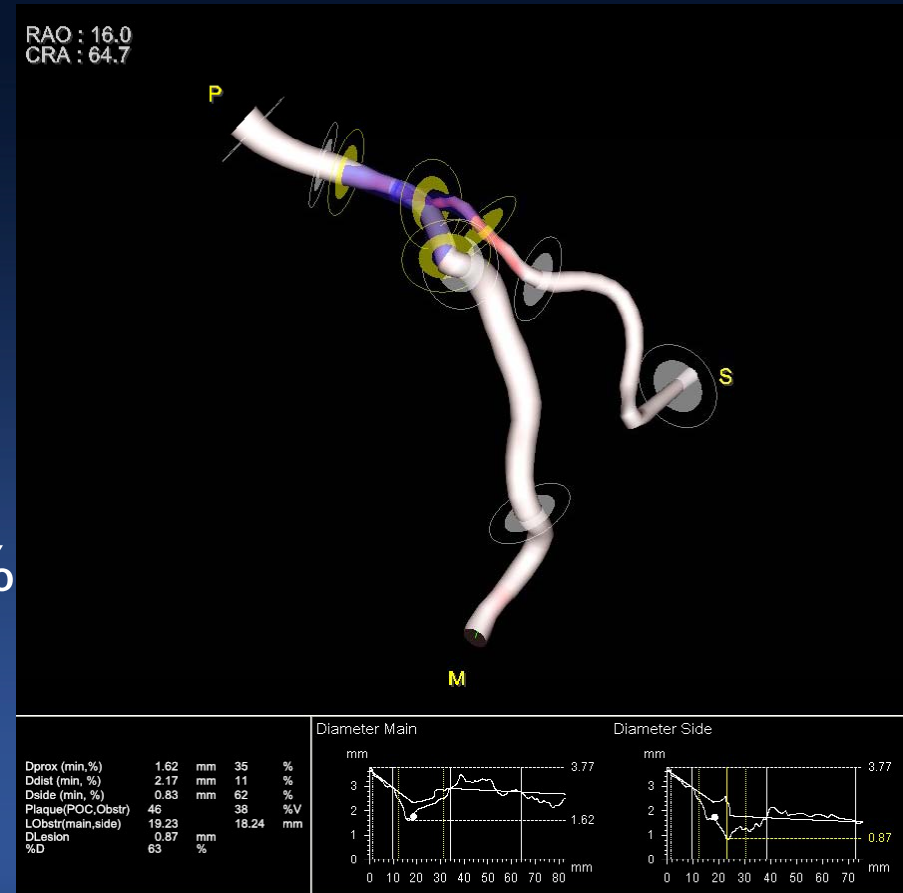
- Procedural factors in Crush stenting
- Bifurcation angle measured by 3D QCA

# 1-Year MACCE Rate according to Distal Angle for 354 SYNTAX LM Patients



# Impact of 3-D Bifurcation Angle in LM PCI

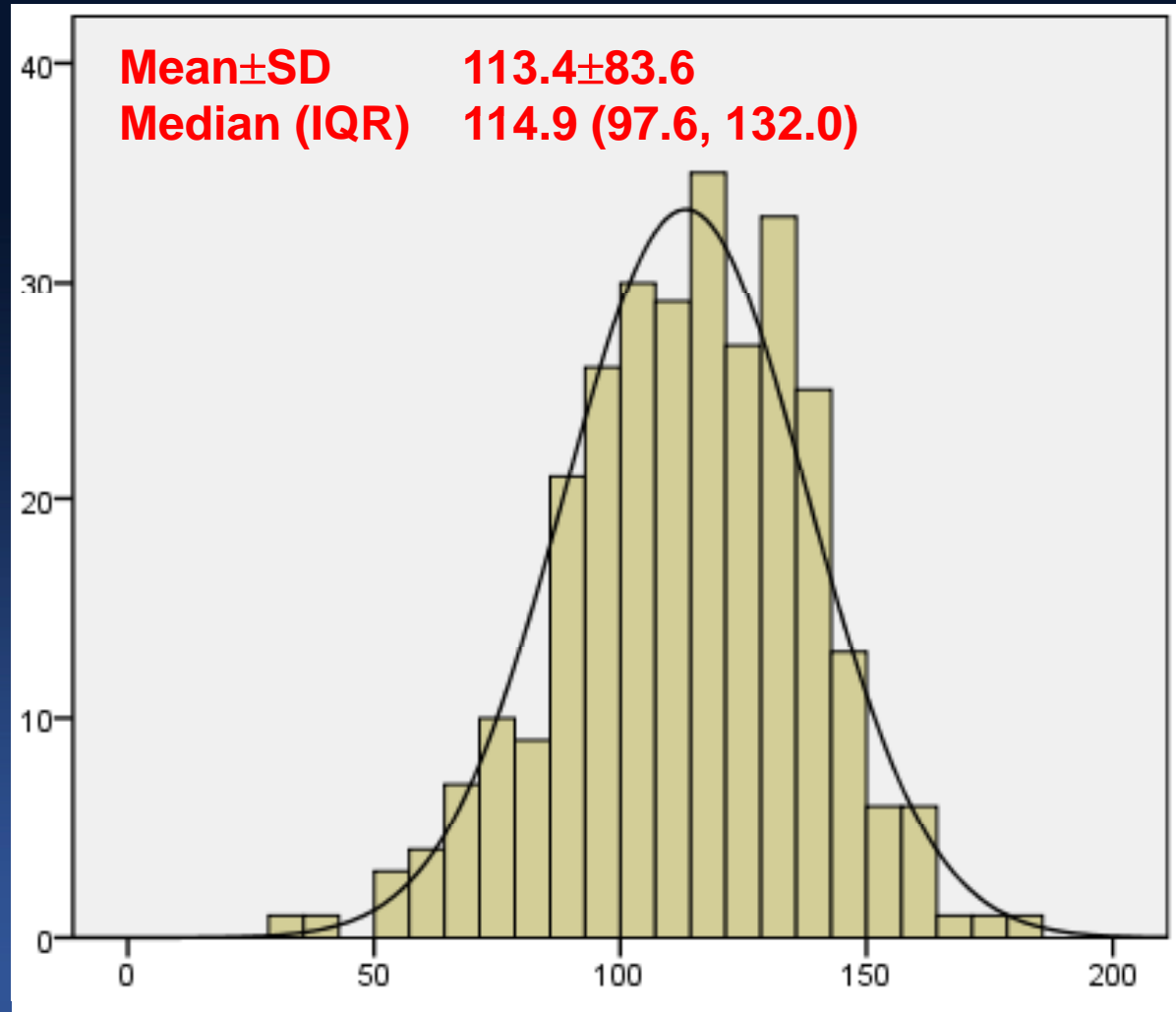
- 3-D bifurcation angle was retrospectively evaluated 289 patients with LM stenosis who were treated with PCI using DES.
- Two-stent technique in 17%
- Single-stent technique in 83%





# Proximal Angle before Procedure

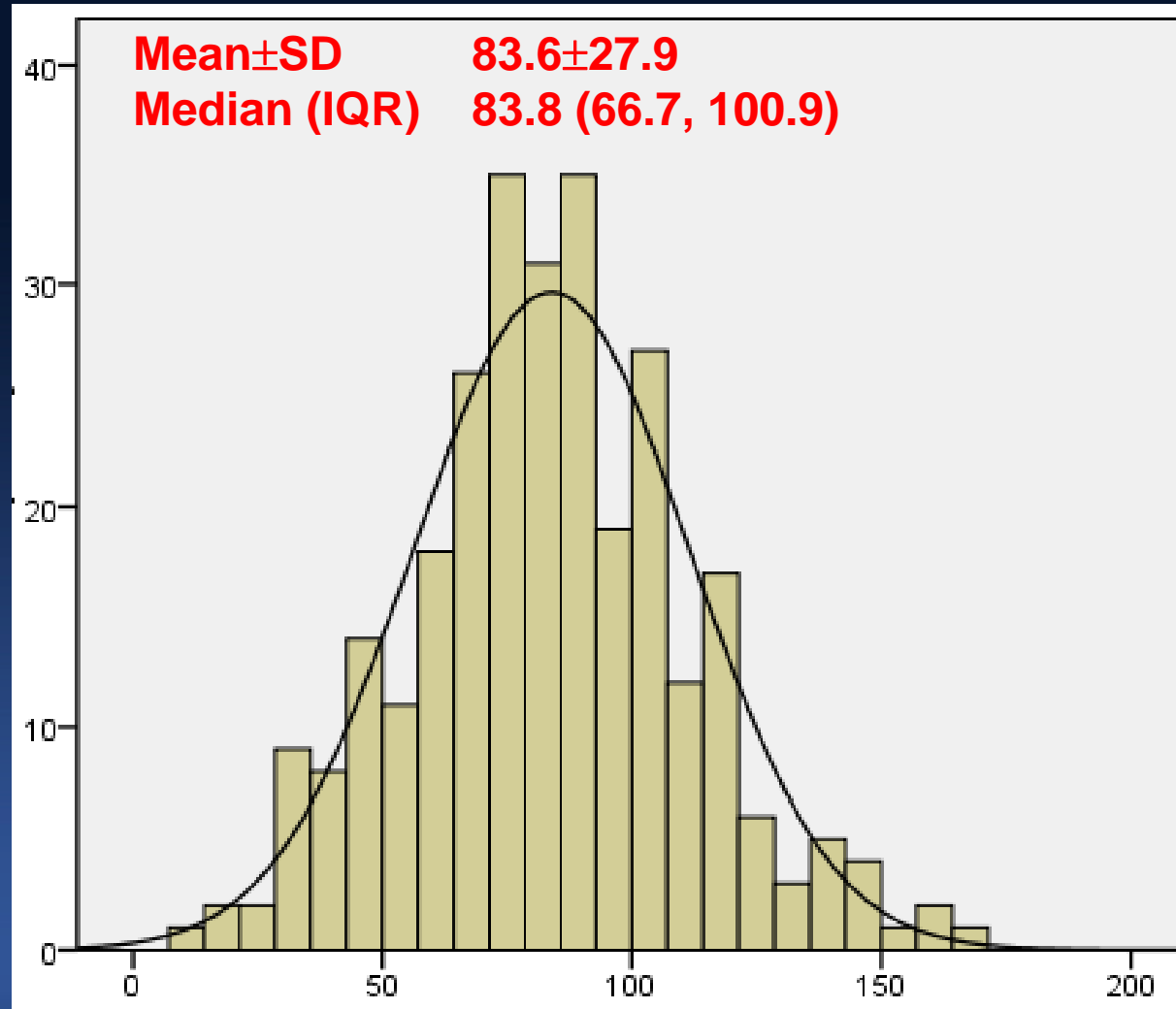
Frequency



Angle °

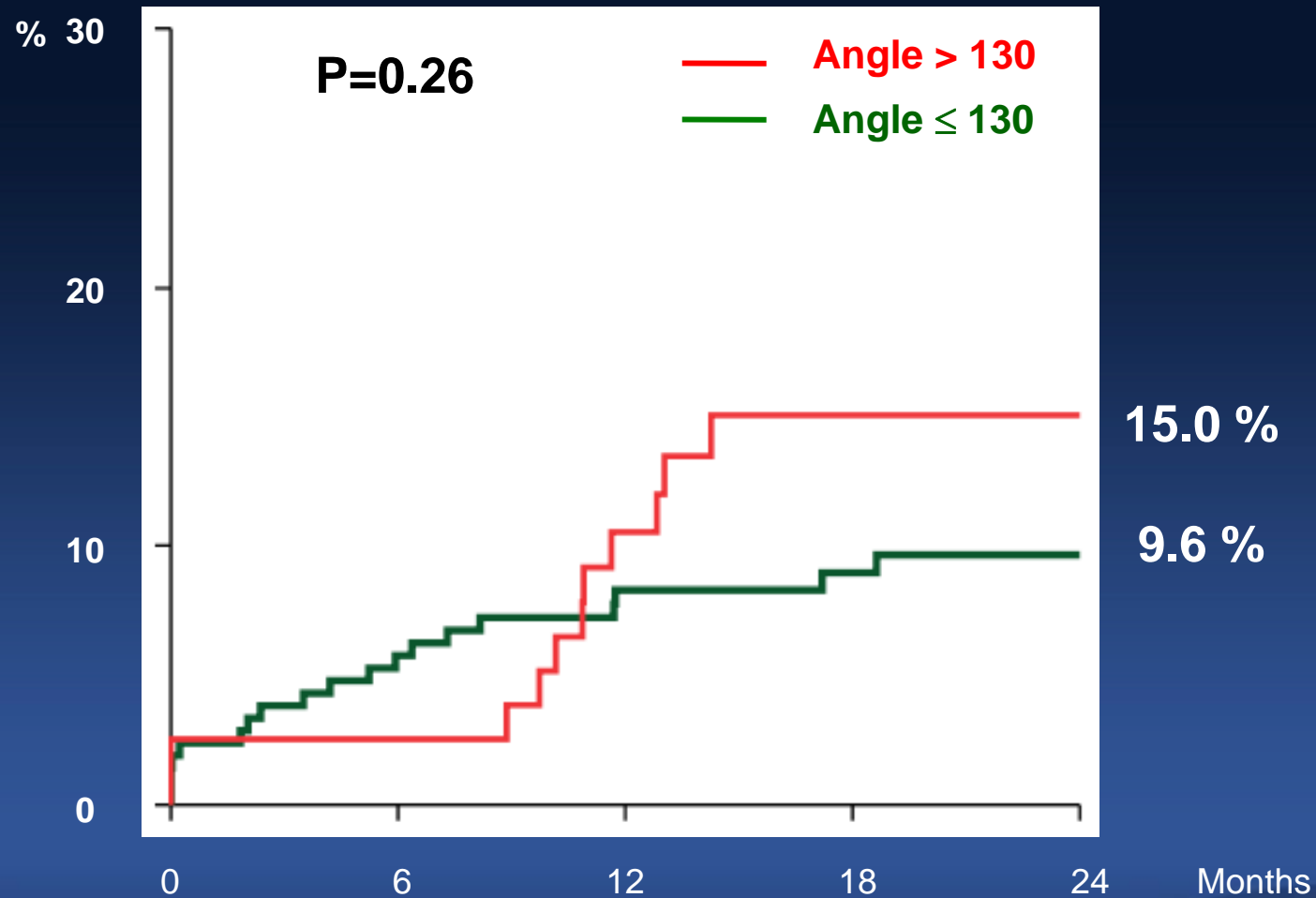
# Distal Angle before Procedure

Frequency

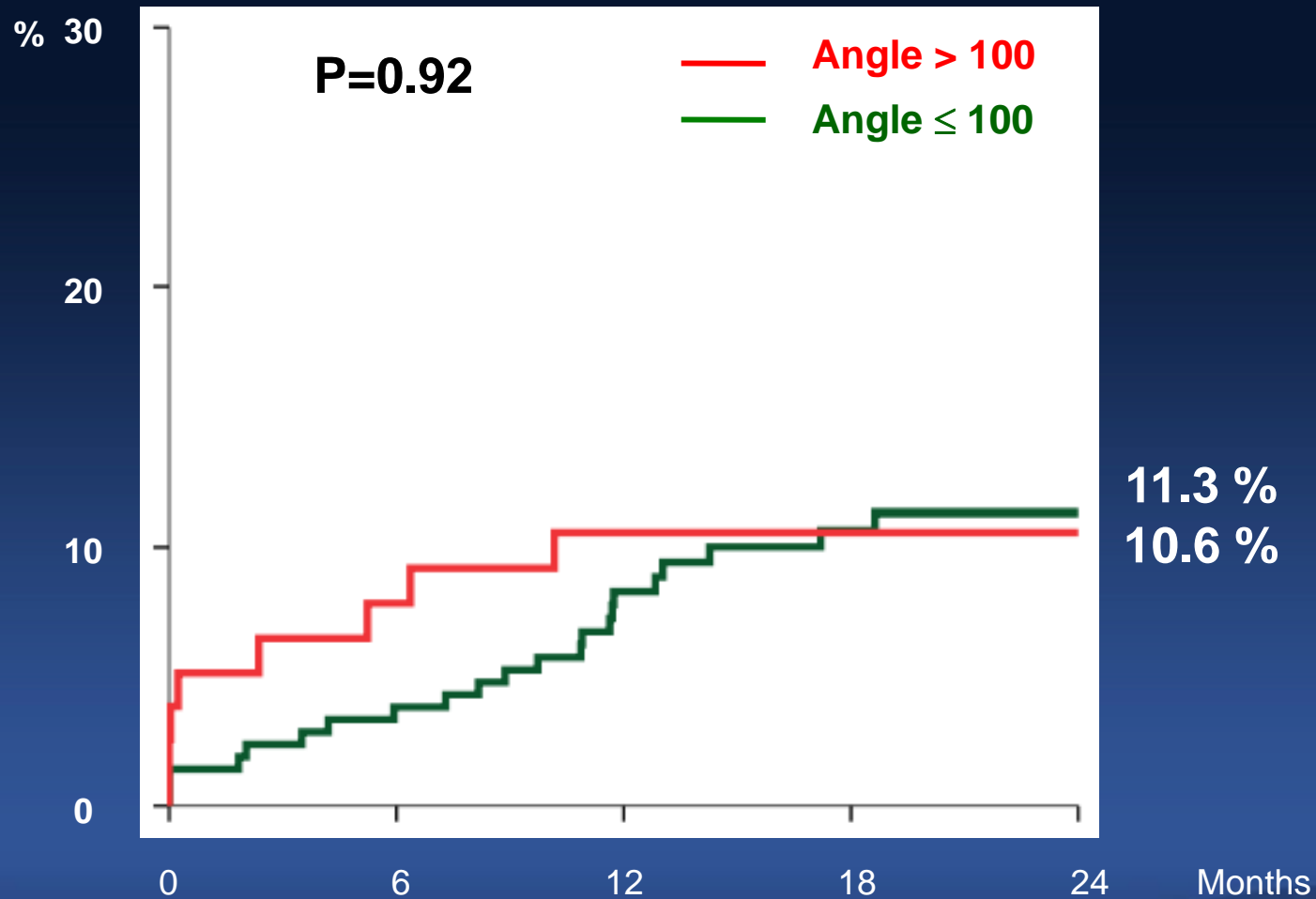


Angle °

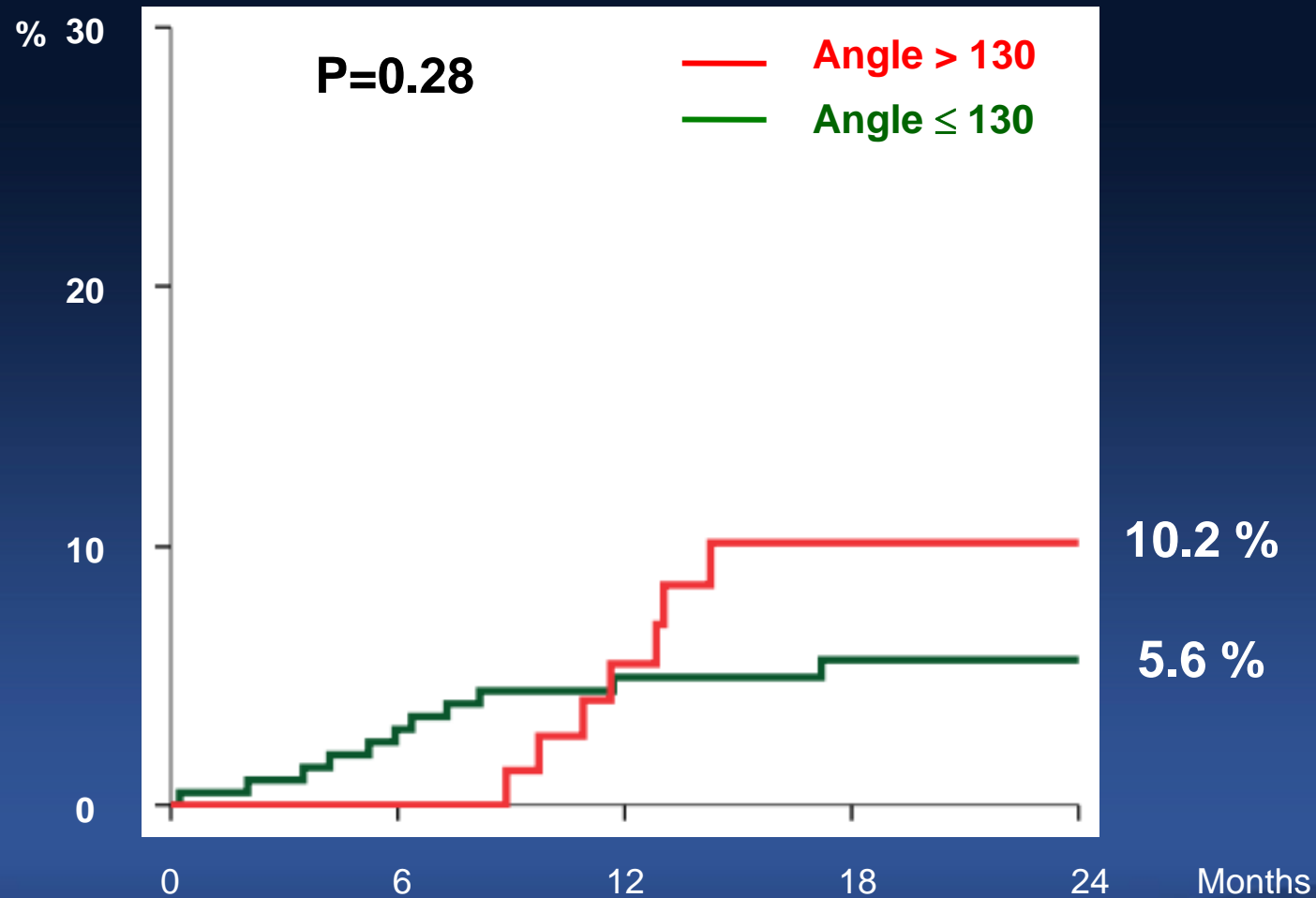
# 2-Year MACCE According to the Proximal Angle



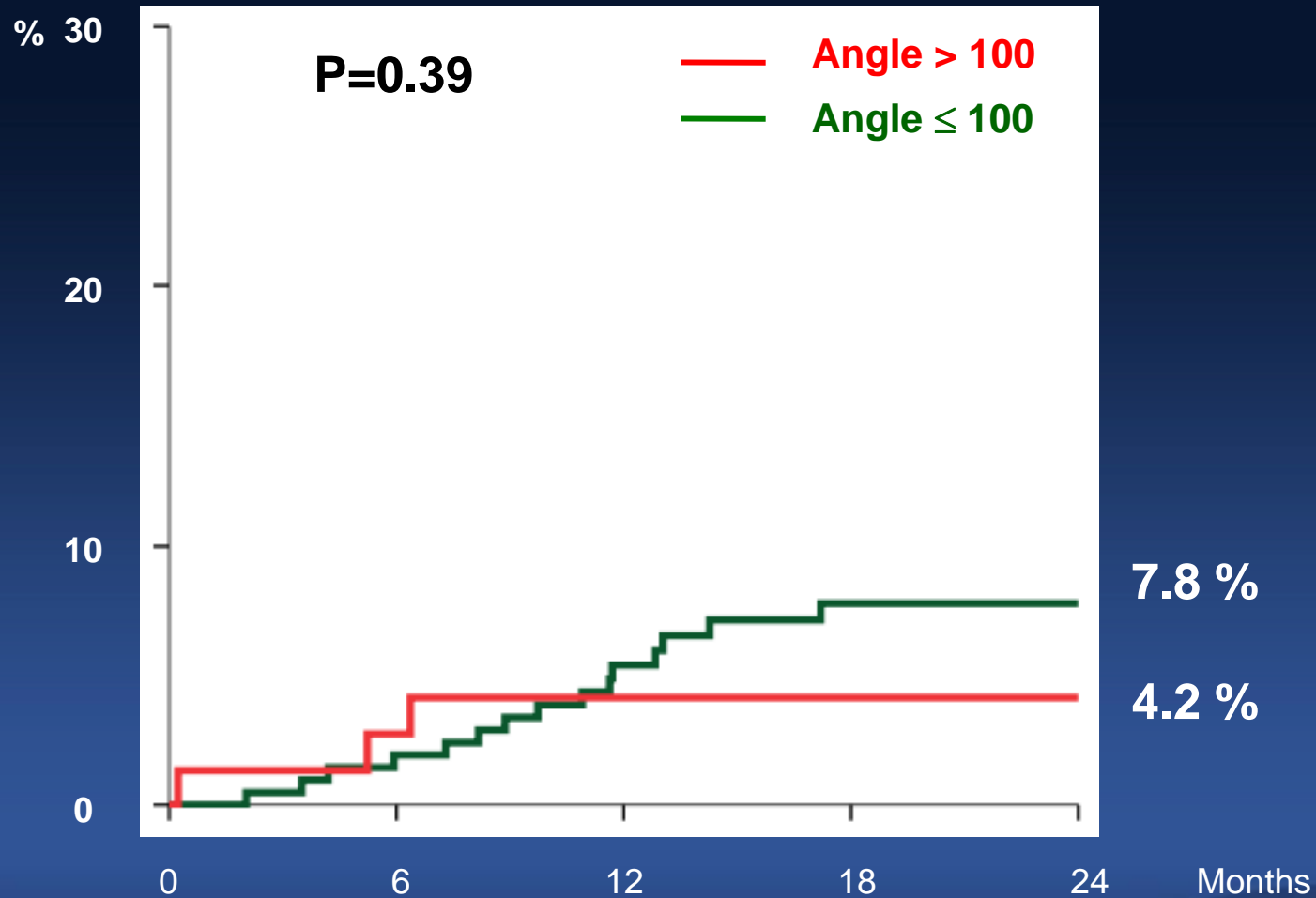
# 2-Year MACCE According to the Distal Angle



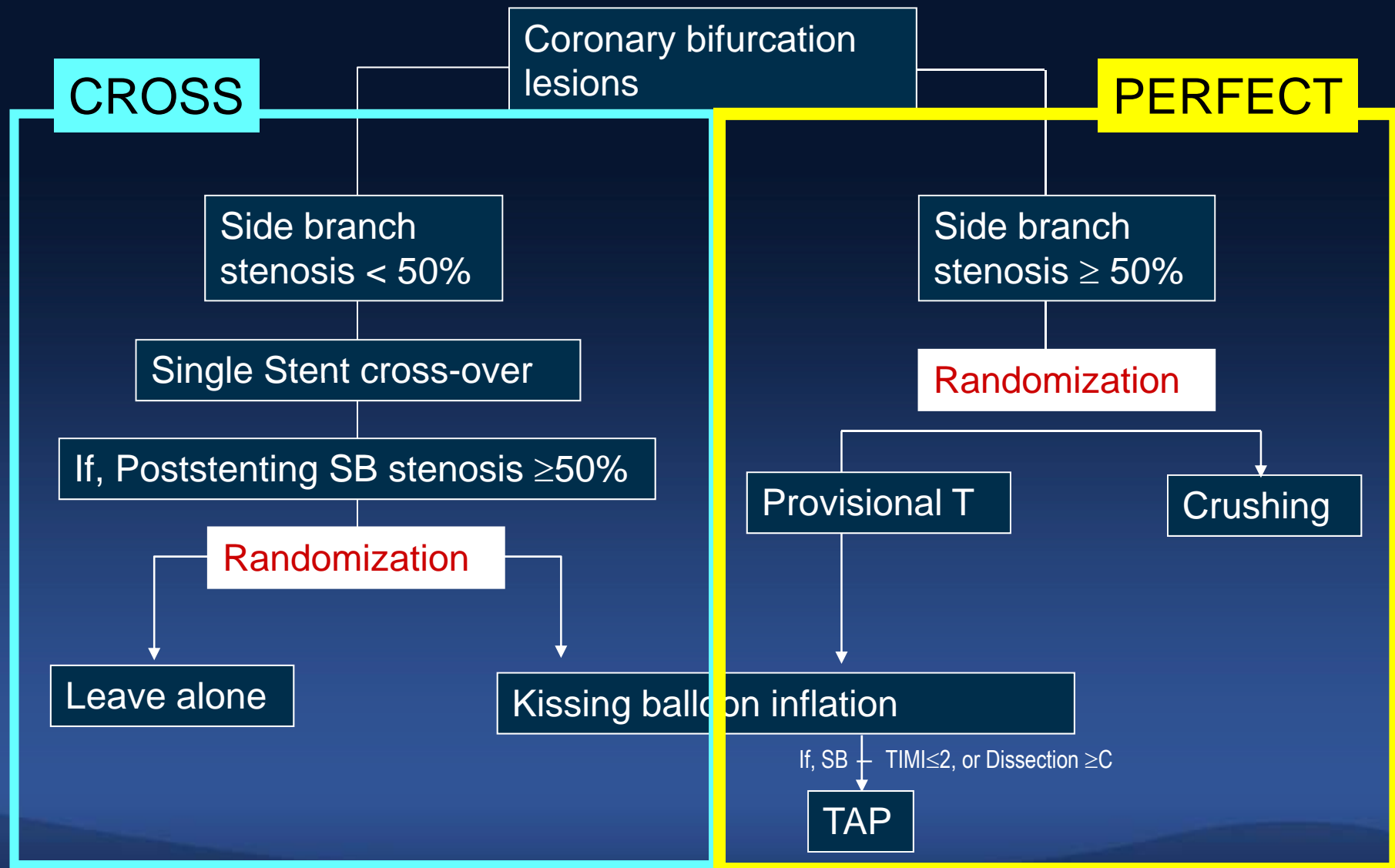
# 2-Year Ischemia-driven TVR According to the Proximal Angle



# 2-Year Ischemia-driven TVR According to the Distal Angle



# Ongoing CROSS & PERFECT Trials



# CROSS For SB

Bifurcation without SB stenosis by angiography

**Any DES**  
(N=600)

After MV stenting

SB DS  $\geq$  50% & TIMI 3 flow

2<sup>nd</sup> Randomization

• Stratified by sites

TIMI  $\leq$  2 flow

Registry

1. Treatment at the operator's discretion

SB DS < 50% & TIMI 3 flow

Registry

1. IVUS exam in MV
2. FFR in SB (selected sites)

**Kissing balloon group**  
(N=150)

1. FFR in SB before kissing balloon
2. Rewire into SB
3. Kissing balloon inflation

**Leave it alone group**  
(N=150)

1. IVUS exam in MV
2. FFR in SB (selected sites)

SB DS < 70% & TIMI 3  
Dissection none or  $\leq$  class B

1. IVUS in MV
2. FFR in SB (selected sites)

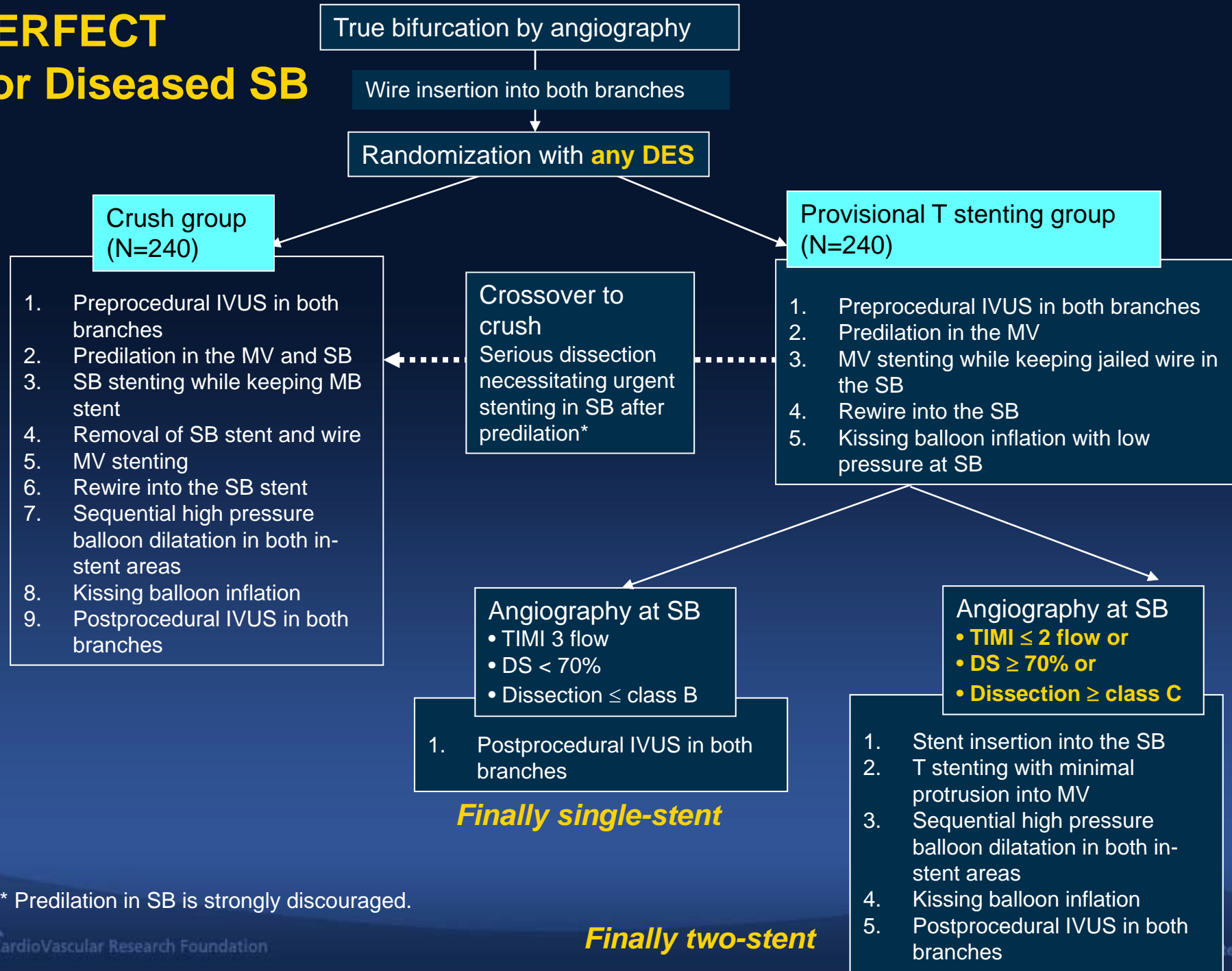
SB DS  $\geq$  70% or TIMI  $\leq$  2 or  
Dissection  $\geq$  class C

1. FFR in SB (selected sites)
2. Provisional T stenting in SB \*
3. IVUS in both branches

\* The decision can not be influenced by the value of FFR.

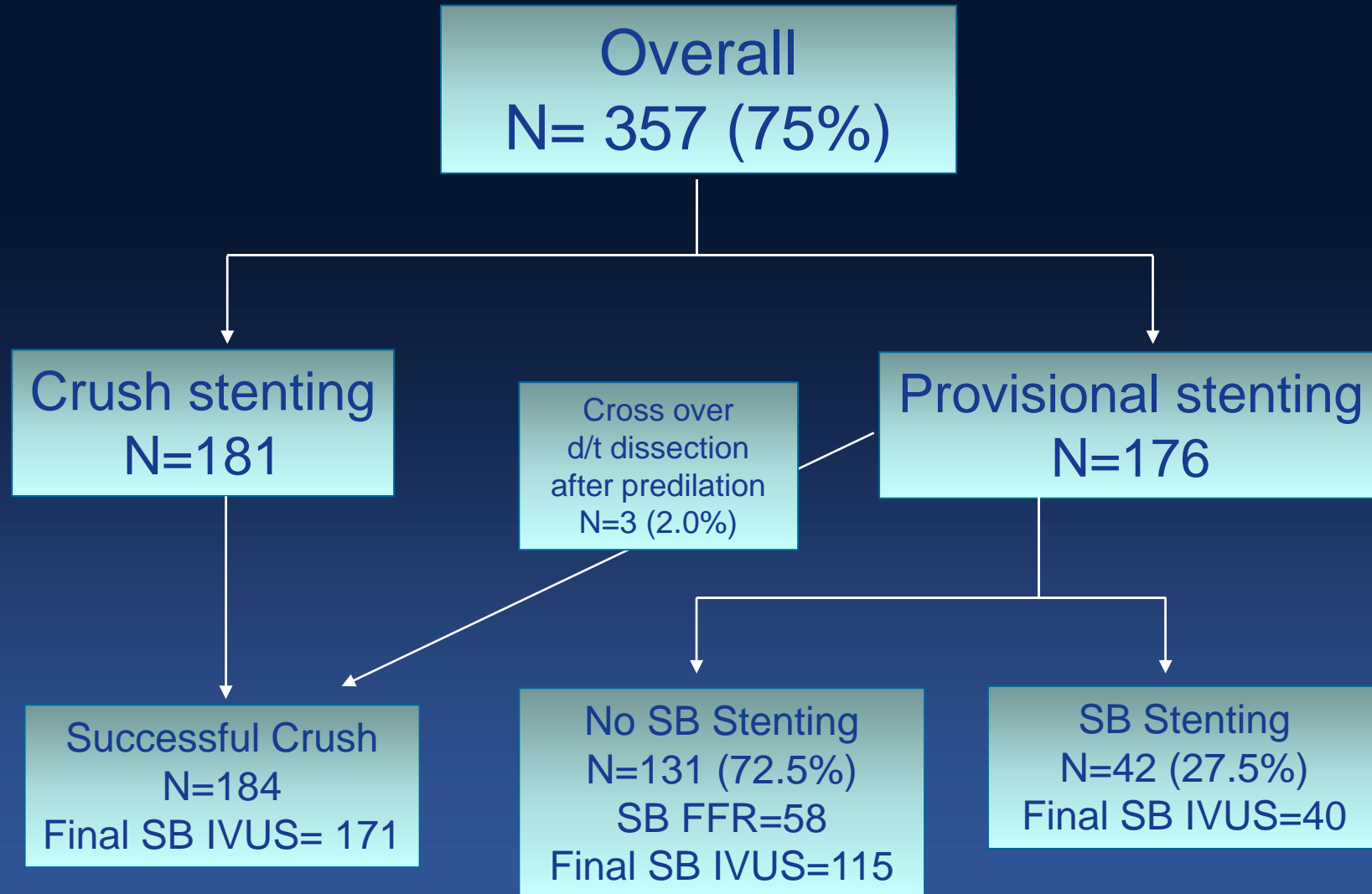


# PERFECT For Diseased SB



\* Predilation in SB is strongly discouraged.

# PERFECT Cases (Apr 2011)



# Conclusions

- Long-term outcomes of the Crush technique for native bifurcation lesions were favorable when FKB was successfully performed under the guidance of IVUS.
- However, the benefit of non-compliant balloon at post-stent balloon dilatation was not evidenced in this cohort.
- In our LM cohort, bifurcation angle measured by 3D QCA was not associated with long-term clinical outcomes.
- Further studies are required to assess the impact of angiographic characteristics, diverse stenting techniques and devices on long-term clinical outcomes in PCI for bifurcation lesions.