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The Mini-Crush Technique for the Treatment of Bifurcation and Trifurcation Coronary Lesions

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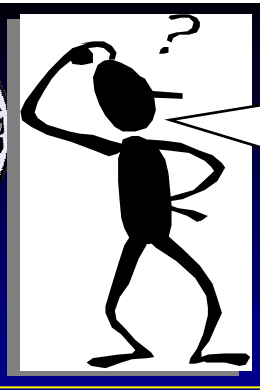
Coronary Bifurcation Lesions

- Treatment of coronary bifurcation lesions remains an issue in terms of procedural success, MACE, TLR, restenosis and stent thrombosis
- Optimal technique with DES (1 stent vs 2 stents, type of technique) is still a debate
- Randomized studies are scarce, not homogeneous and executed on a small scale
- Meta-analysis of these etherogeneous reports have proven quite impossible



Does The Side Branch Need Protection by a Stent?

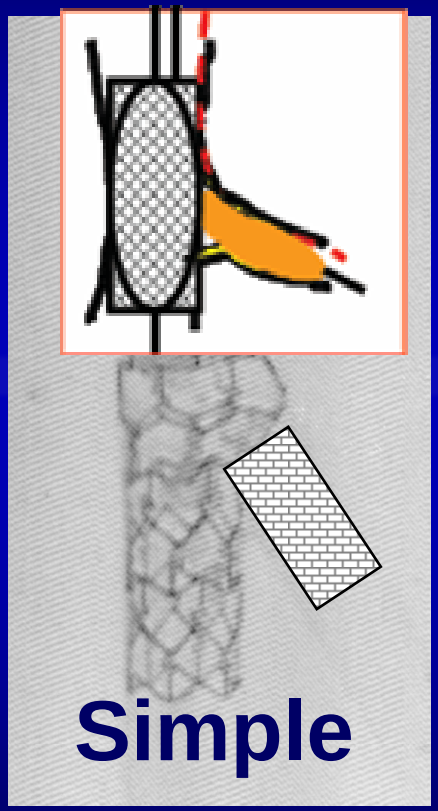
DEFINITELY ….YES!!!! ……

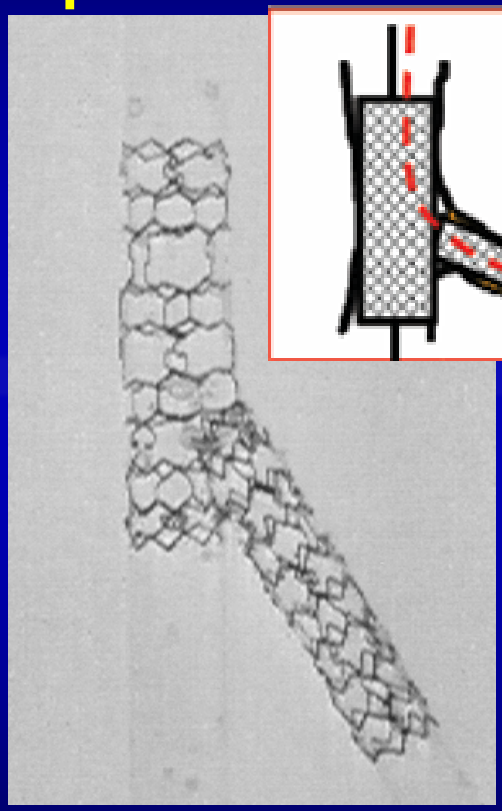
- if the side branch is a large vessel
- if the side branch comes out from the main with an acute angle
- if the ostium or the proximal segment of the side branch have a significant narrowing
- if the side branch is very difficult to be wired
- if the patient is a very high risk patient and the side branch appears relatively important
- if the main branch is severely narrowed with a lot of plaque burden

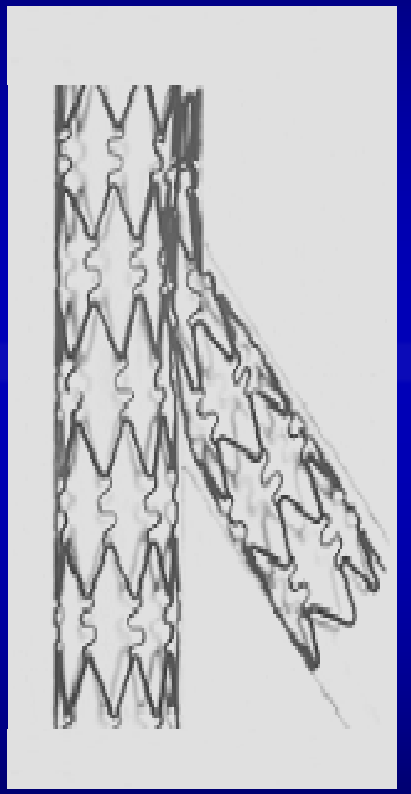
… sometimes a decision should be made only following predilatation of the main branch and of the side branch!

Treatments Are Not Equivalent

Technique can be divided into 2 strategies:







PTS

Provisional T Stenting

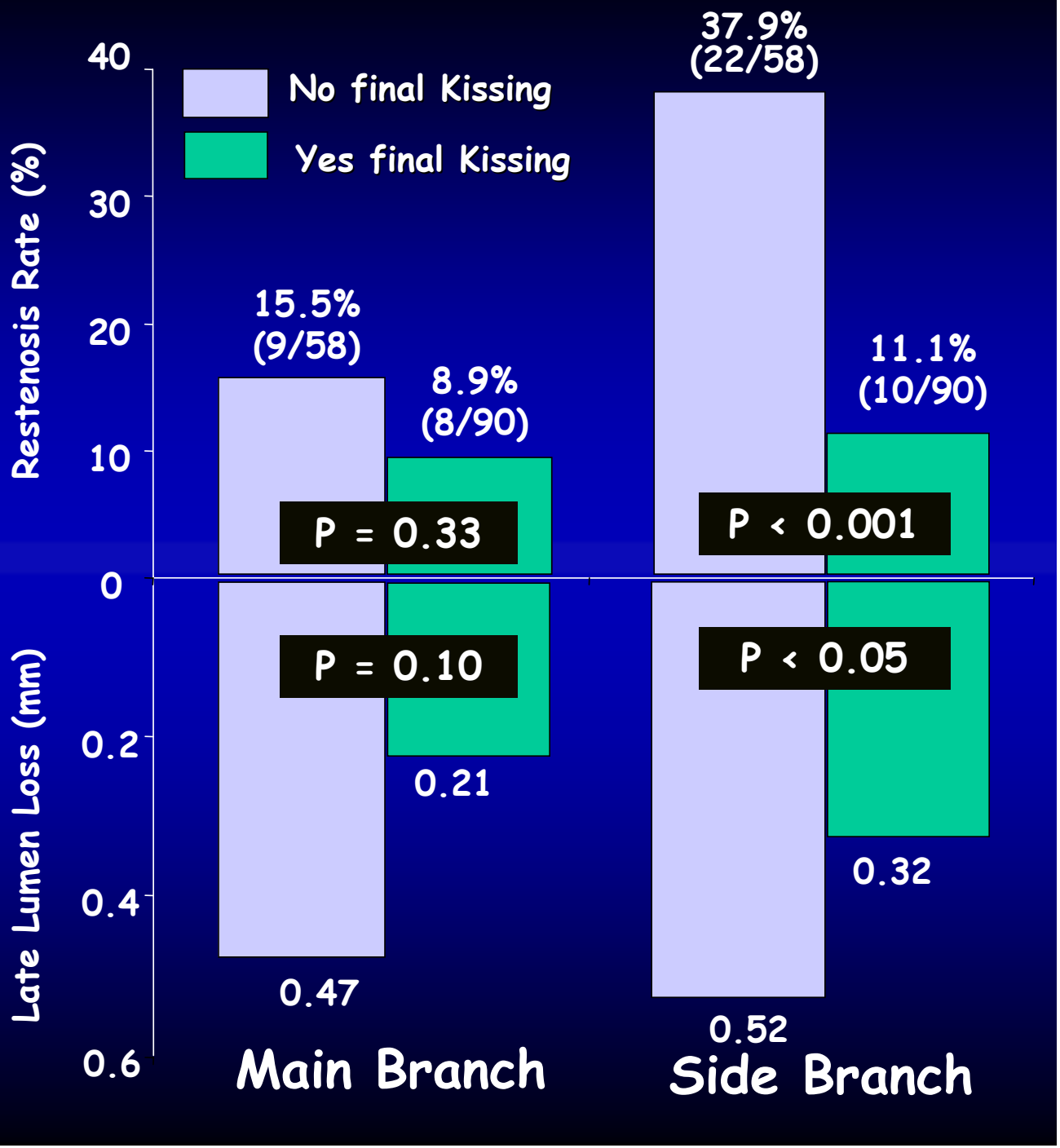
T stenting

Coulotte

Crush

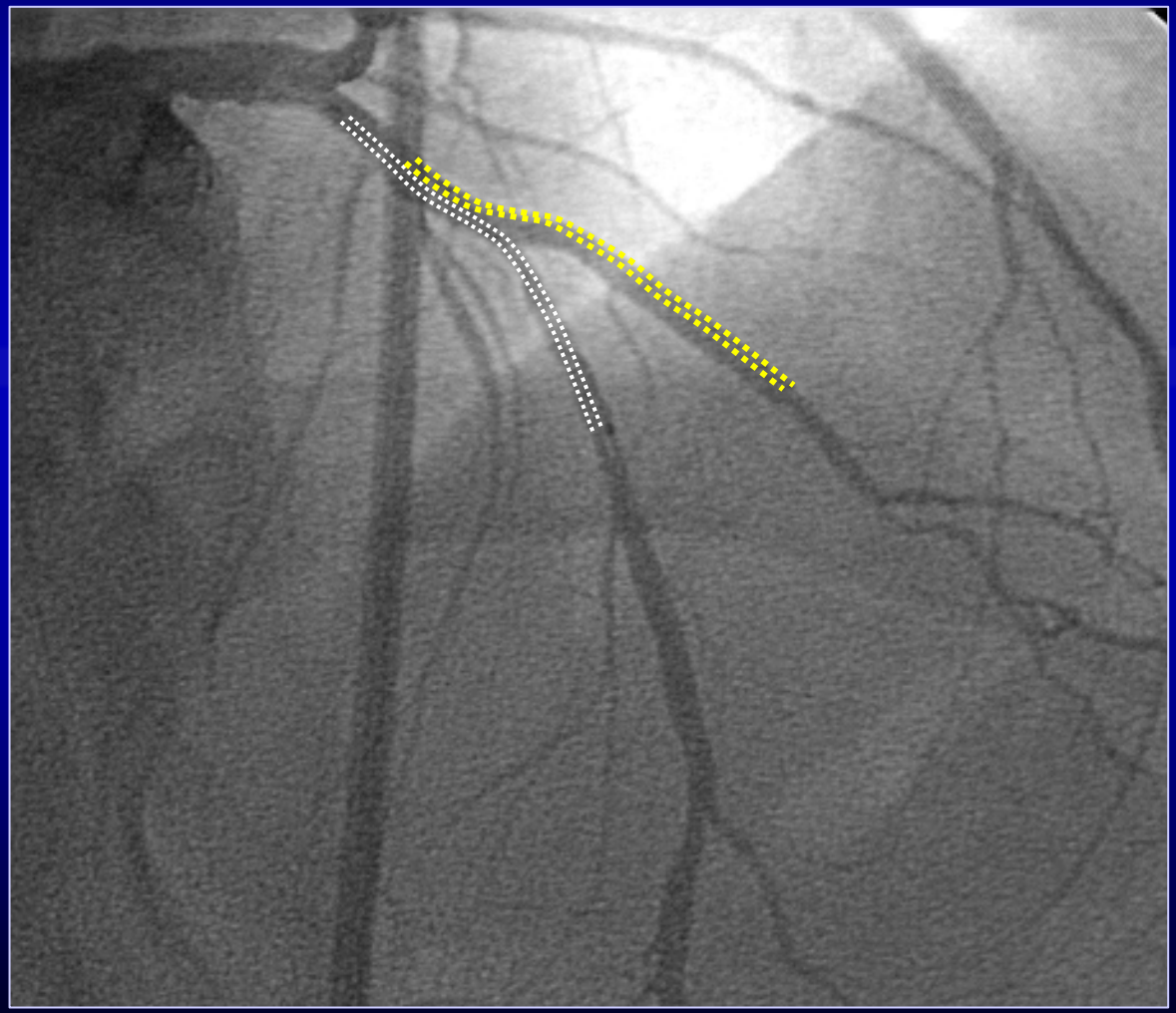
Result with Crush stenting according to performance of final kiss: restenosis and late loss are significantly reduced for the side branch

Ge et al. JACC 2005



Classic "Crush" Technique

Excessive Protrusion of Diagonal Stent in the LAD



"Crush" Technique

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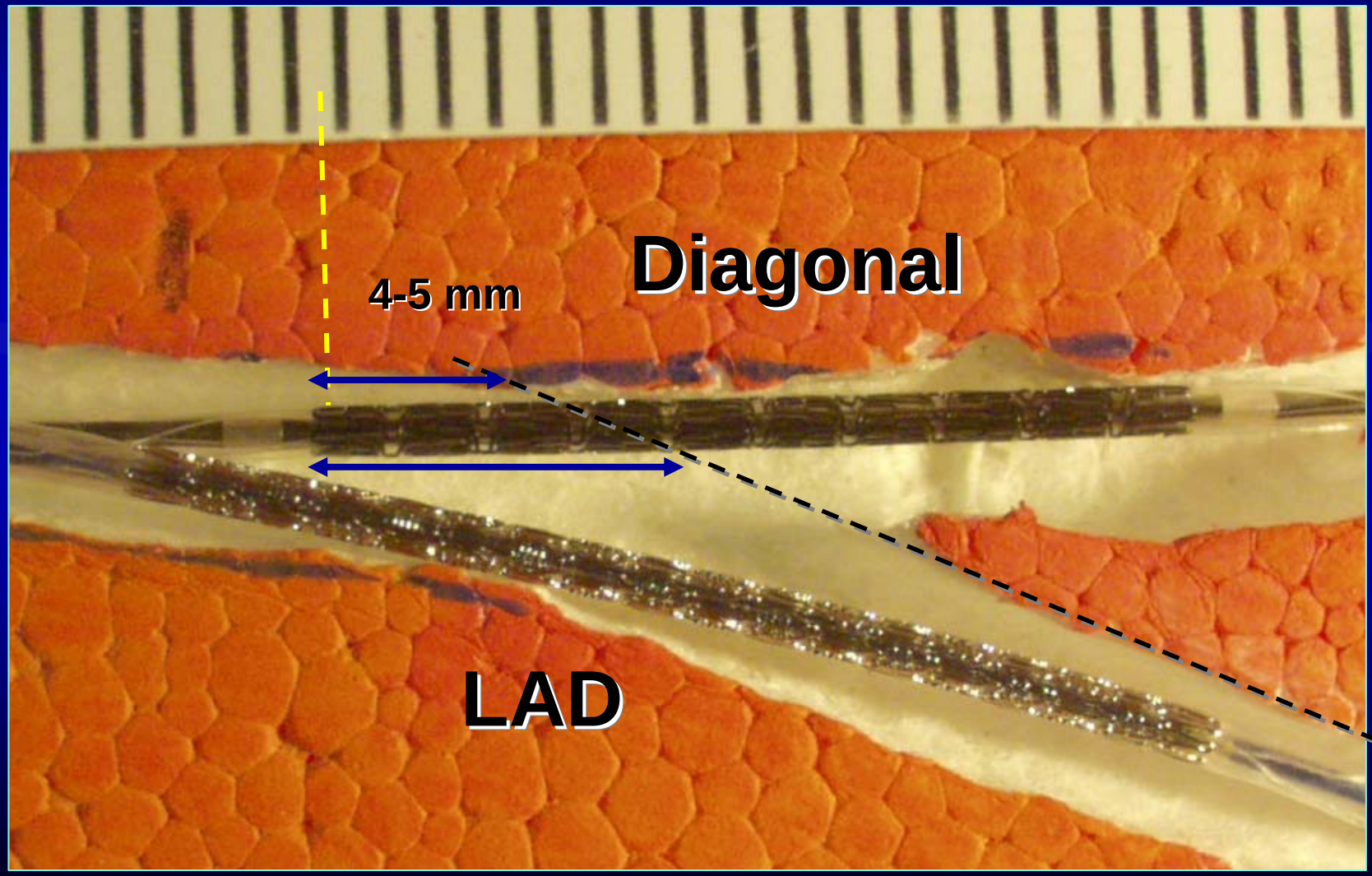

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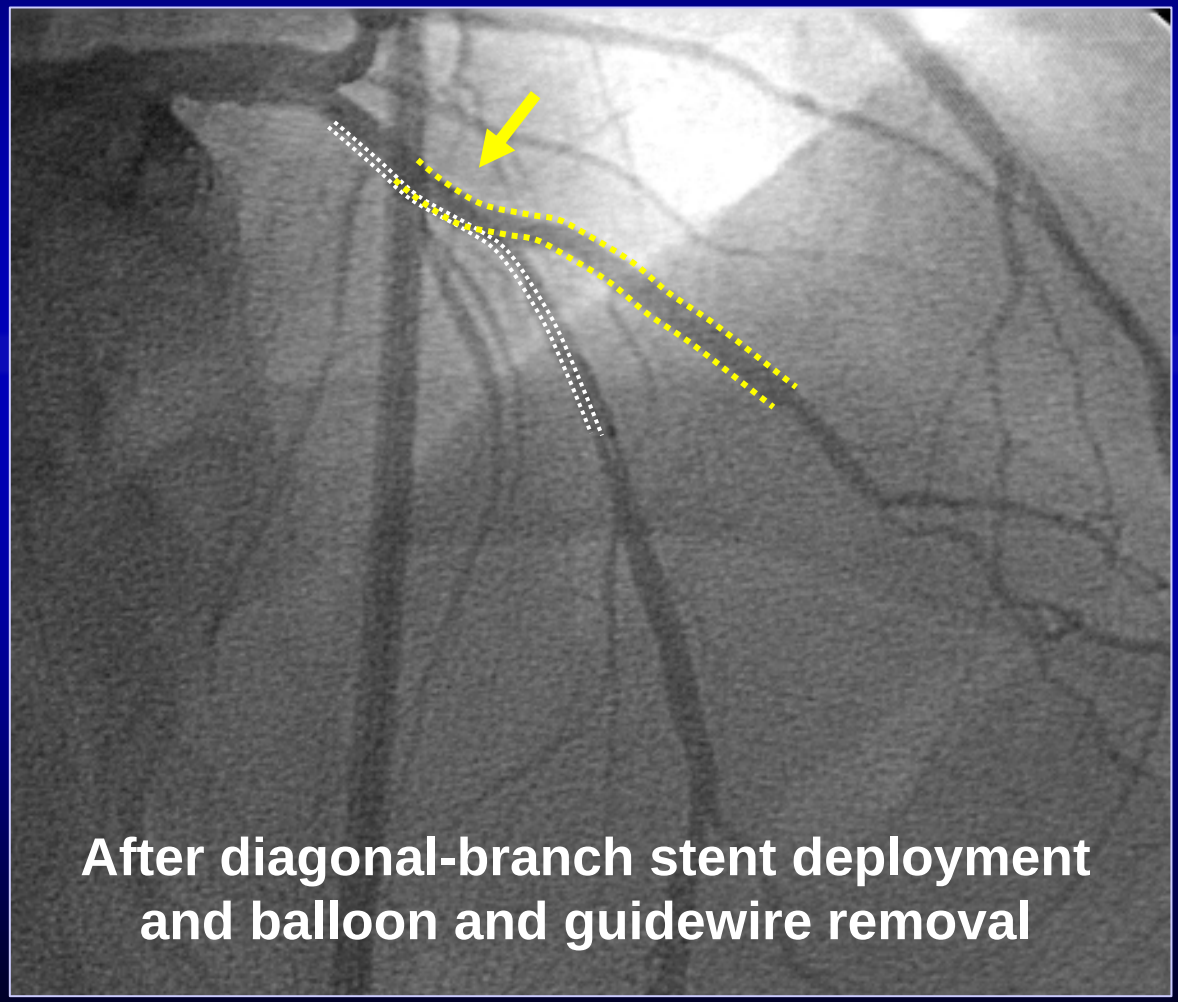
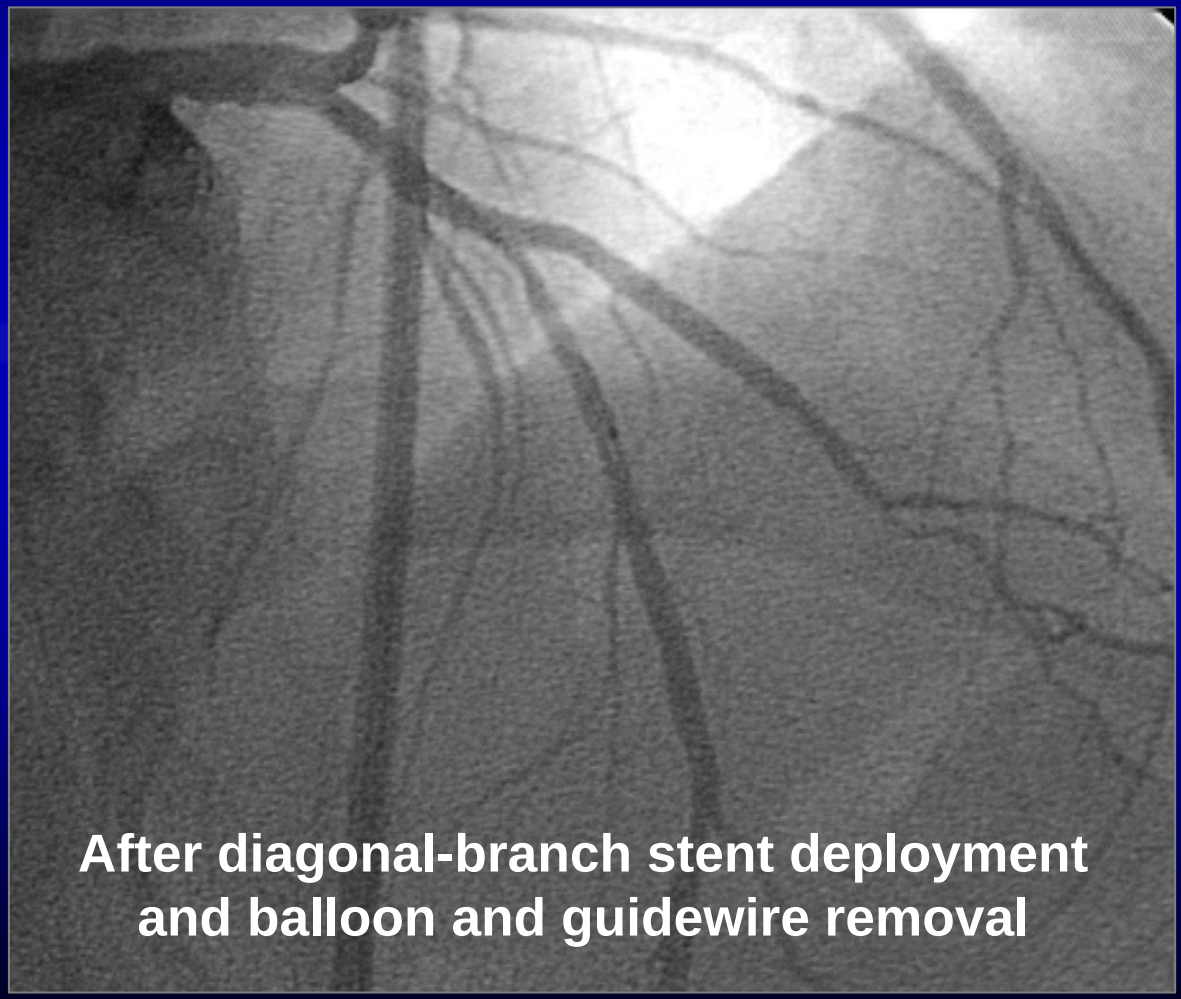


After diagonal-branch stent deployment
and balloon and guidewire removal

Classic "Crush" Technique

Excessive Protrusion of Diagonal Stent in the LAD



After diagonal-branch stent deployment
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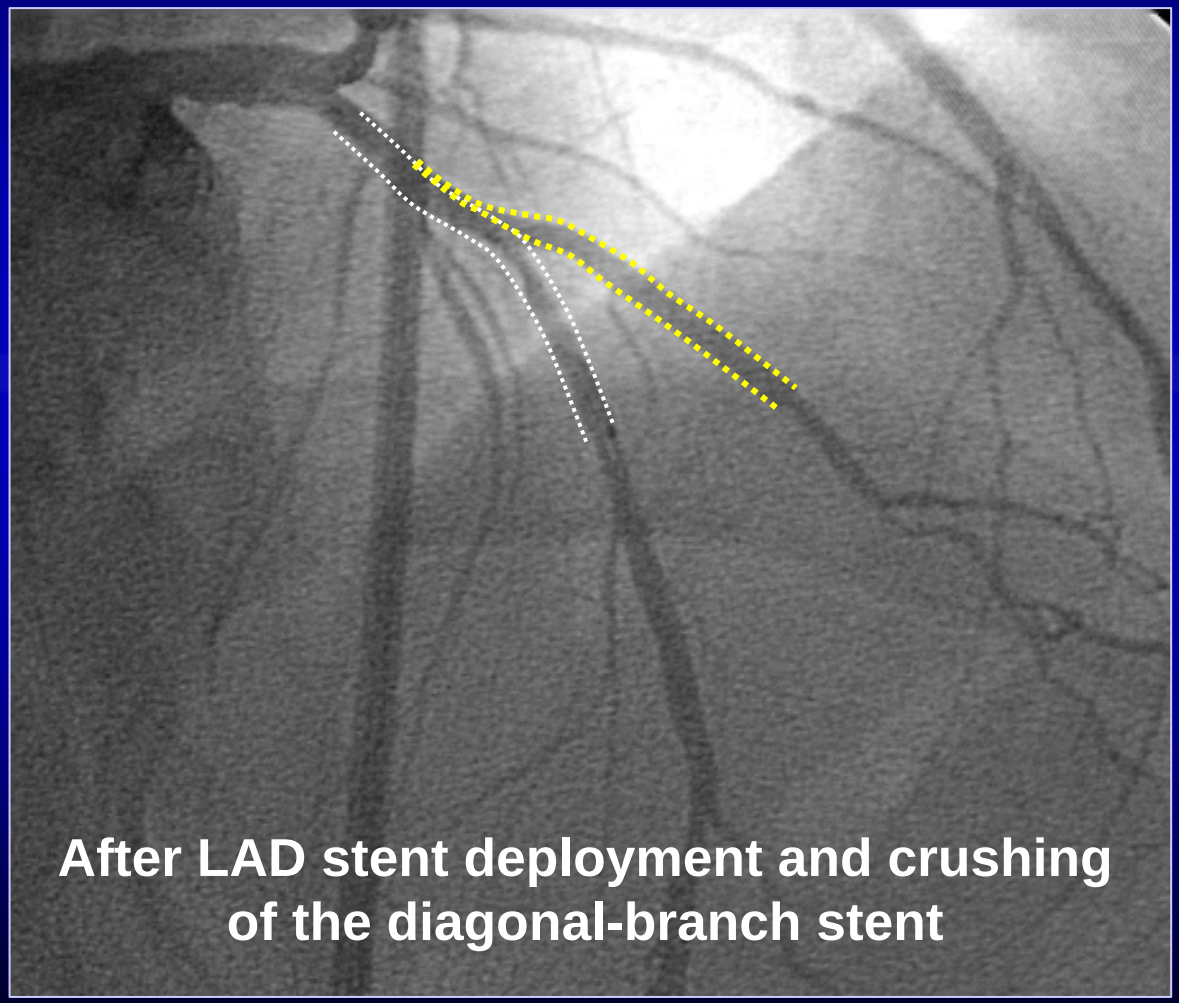
Classical "Crush" Technique

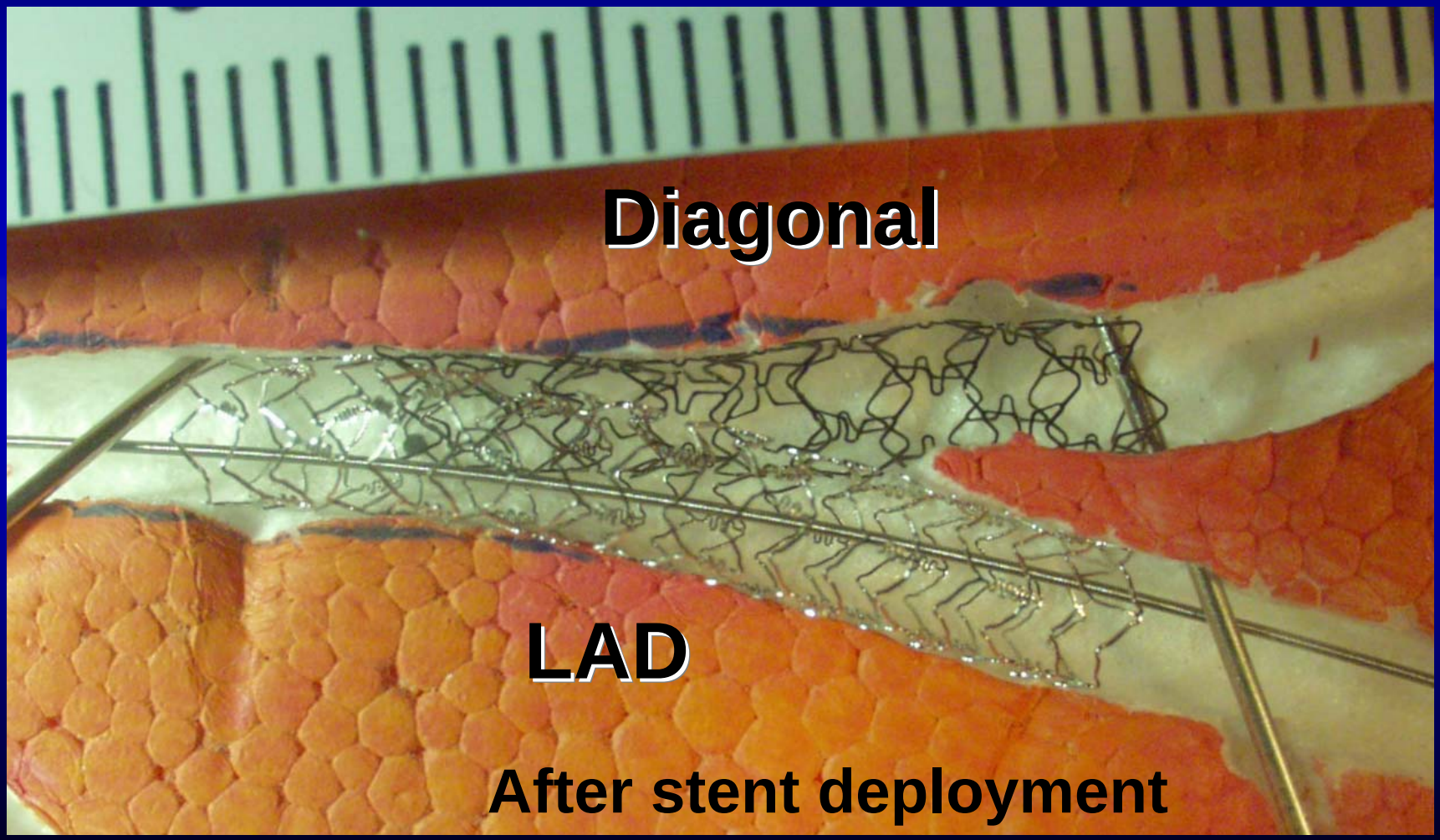
Excessive Protrusion of Diagonal Stent in the LAD



After LAD stent deployment and crushing of the diagonal-branch stent

"Crush" Technique

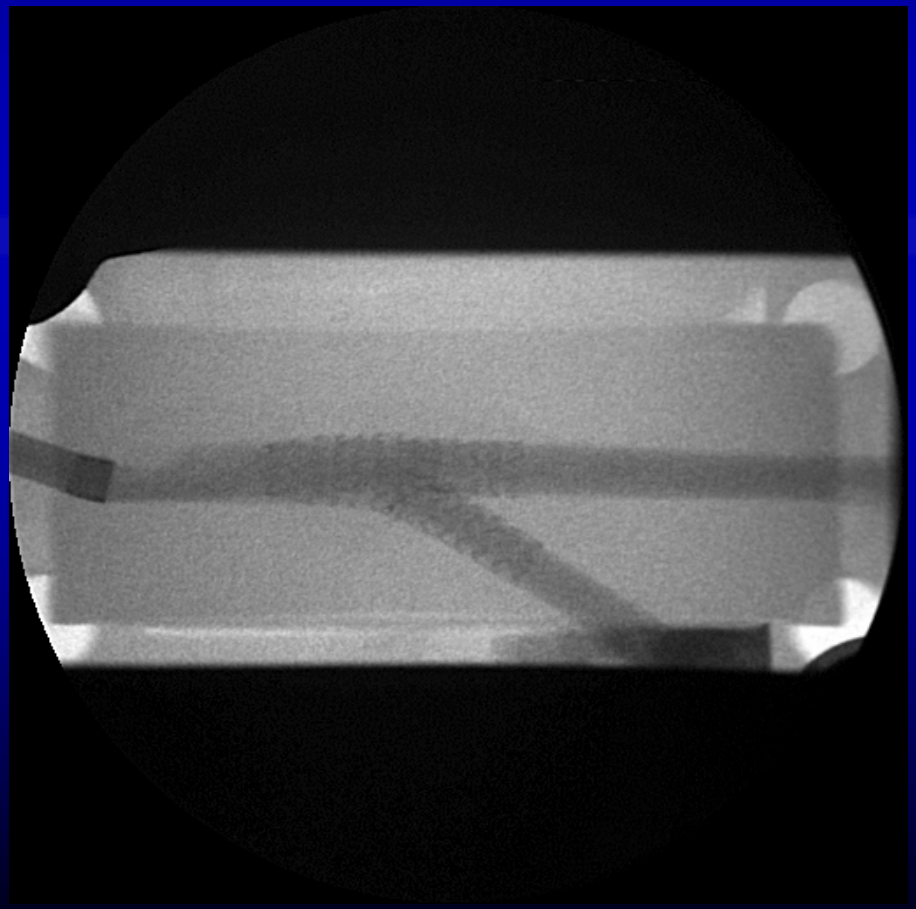
Excessive Protrusion of Diagonal Stent in the LAD may cause more blood flow stagnation between the struts



Original Studies

Catheterization and Cardiovascular Interventions 00:000–000 (2007)

Long-term Outcomes of Bifurcation Lesions After Implantation of Drug-Eluting Stents With the "Mini-Crush Technique"



Mini-Crush Technique
Bench Work
courtesy of J. Ormiston
(Mercy Angiography,
New Zealand)

Mini-Crush Technique Bench Work

Courtesy of J. Ormiston (Mercy Angiography, New Zealand)

30º Degree Model

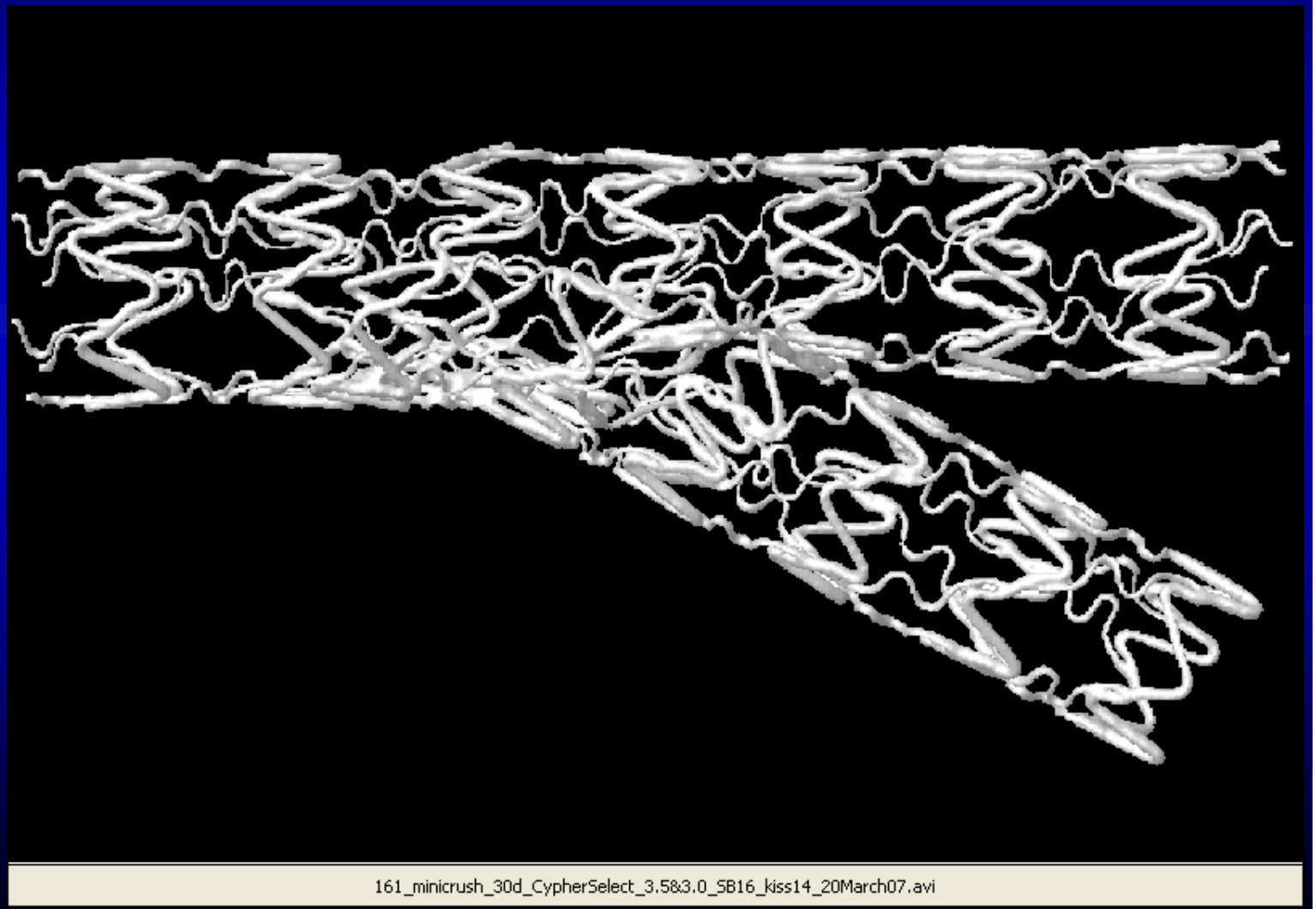
Apposition

Stagnation

Recirculation

Distortion

Fracture



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Mini-Crush Technique Bench Work

Courtesy of J. Ormiston (Mercy Angiography, New Zealand)

60º Degree Model

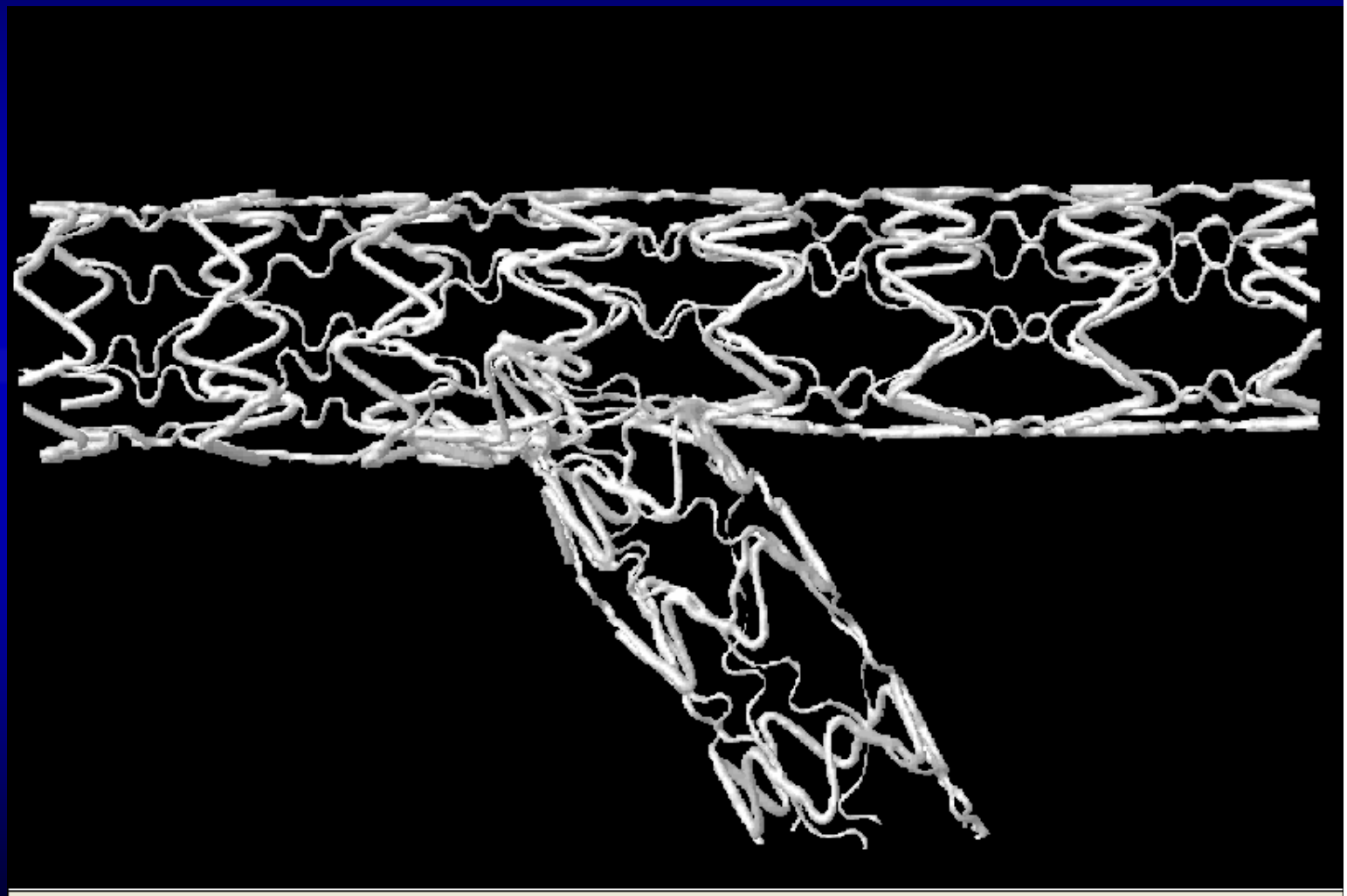
Apposition

Stagnation

Recirculation

Distortion

Fracture



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Mini-Crush Technique Bench Work

Courtesy of J. Ormiston (Mercy Angiography, New Zealand)

90º Degree Model

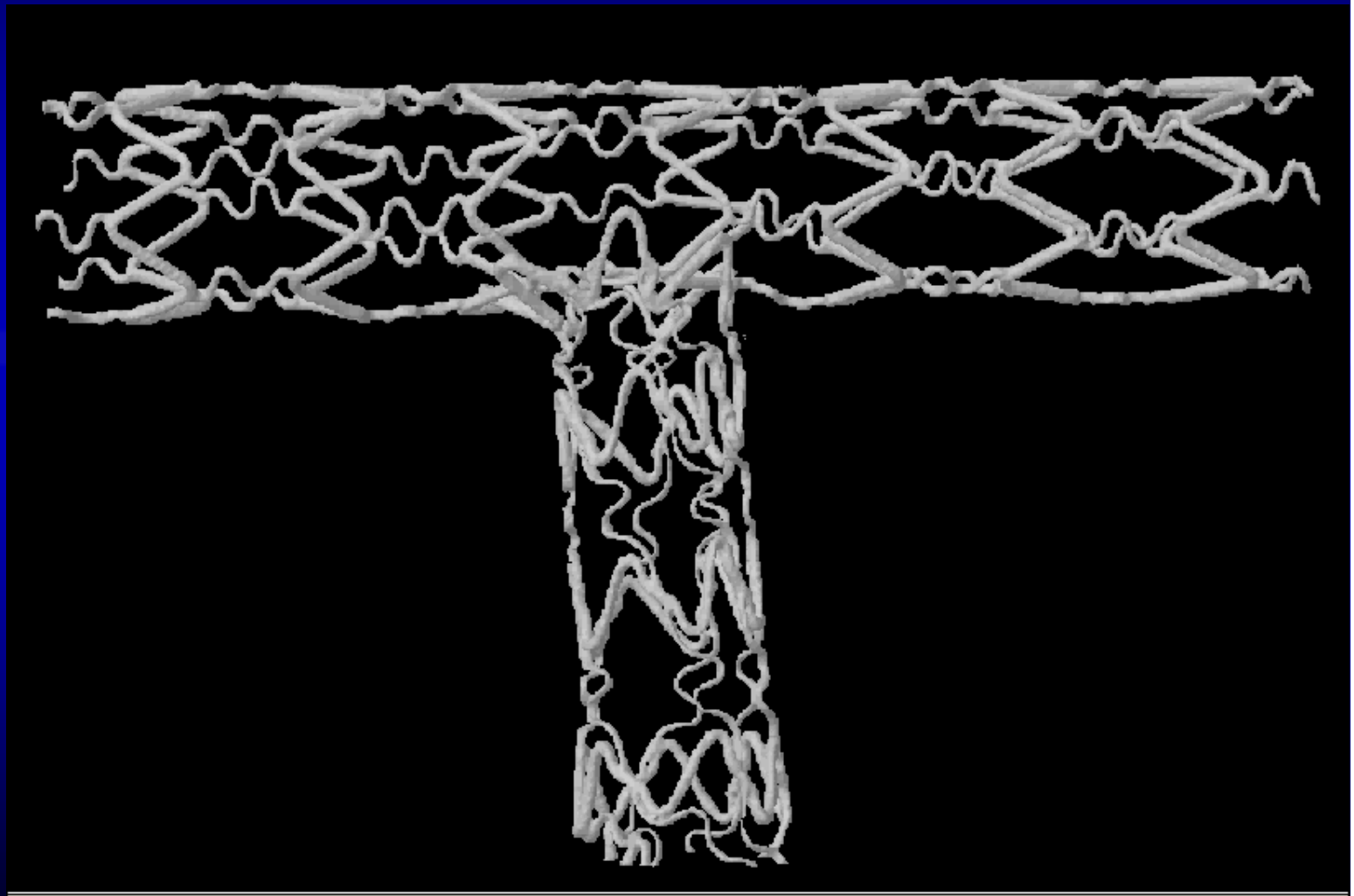
Apposition

Stagnation

Recirculation

Distortion

Fracture



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The "Mini-Crush" Technique

Galassi et al. Catheter Cardiovasc Interv in press 2007

TABLE IV. Quantitative Coronary Angiographic Analysis for Main and Side Branch (*n* = 49 Lesions)

	Main branch	Side branch	*P*
Baseline			
RVD mm (mean ± SD)	2.68 ± 0.48	2.28 ± 0.34	
MLD mm (mean ± SD)	0.90 ± 0.55	1.14 ± 0.47	
Diameter stenosis % (mean ± SD)	68.19 ± 17.72	49.71 ± 18.78	<0.000001
Mean lesion length mm (mean ± SD)	16.25 ± 9.56	7.20 ± 6.95	<0.000001
After procedure			
RVD mm (mean ± SD)	3.00 ± 0.38	2.53 ± 0.31	
MLD mm (mean ± SD)	2.56 ± 0.39	2.16 ± 0.29	
Diameter stenosis % (mean ± SD)	14.74 ± 7.51	14.61 ± 6.27	NS
Acute gain mm (mean ± SD)	1.66 ± 0.54	1.02 ± 0.49	<0.000001
Follow up			
RVD mm (mean ± SD)	2.79 ± 0.51	2.28 ± 0.40	
MLD mm (mean ± SD)	1.99 ± 0.65	1.63 ± 0.48	
Diameter stenosis % (mean ± SD)	29.75 ± 16.97	28.44 ± 16.77	NS
Late lumen loss mm (mean ± SD)	0.30 ± 0.53	0.35 ± 0.51	NS
Restenosis (%)	6 (12.2)	1 (2.0)	NS

RVD = reference vessel diameter; MLD = minimal luminal diameter.

The "Mini-Crush" Technique

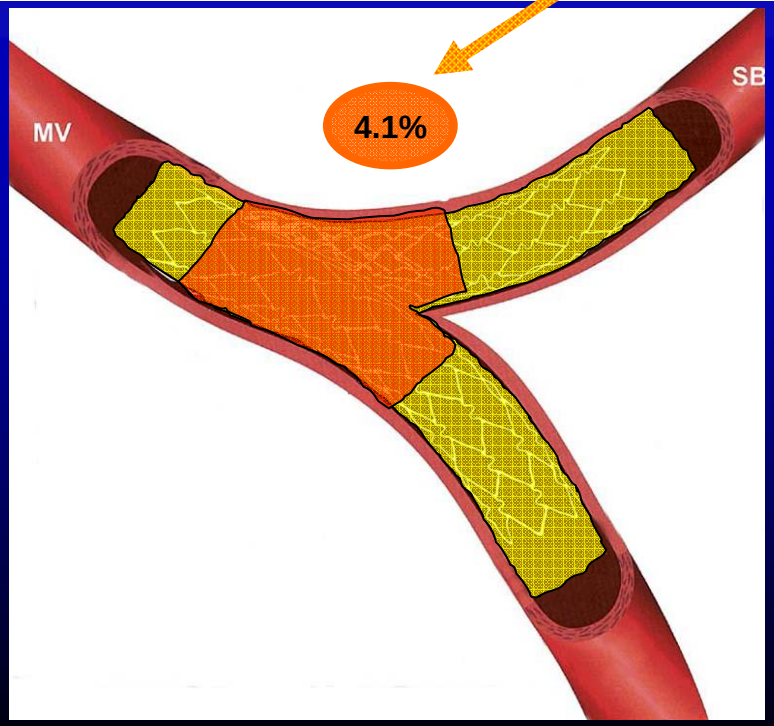
Galassi et al. Catheter Cardiovasc Interv in press 2007

	RVD			Restenosis Rate		
	Main branch	Side branch	Technique	Total (%)	Main branch (%)	Side branch (%)
Colombo et al. [6]	2.60 ± 0.40	2.10 ± 0.30	Provisional	19	4.8	14.2
			T-, V-stenting and crush	27.5	5.7	21.8
Tanabe et al. [23]	2.64 ± N/A	1.99 ± N/A	T stenting, Culotte, V stenting, crush	22.7	9.1	13.6
Ge et al. [10]	2.81 ± 0.58	2.44 ± 0.58	Crush FKB,	20	8.9	11.1
			Crush NoFKB	[illegible]	15.5	37.9
Present study	2.68 ± 0.48	2.28 ± 0.34	Mini-crush	14.2	12.2	2.0

RVD = reference vessel diameter; FKB = final kissing balloon.

Clinical Follow-Up at 8-Month

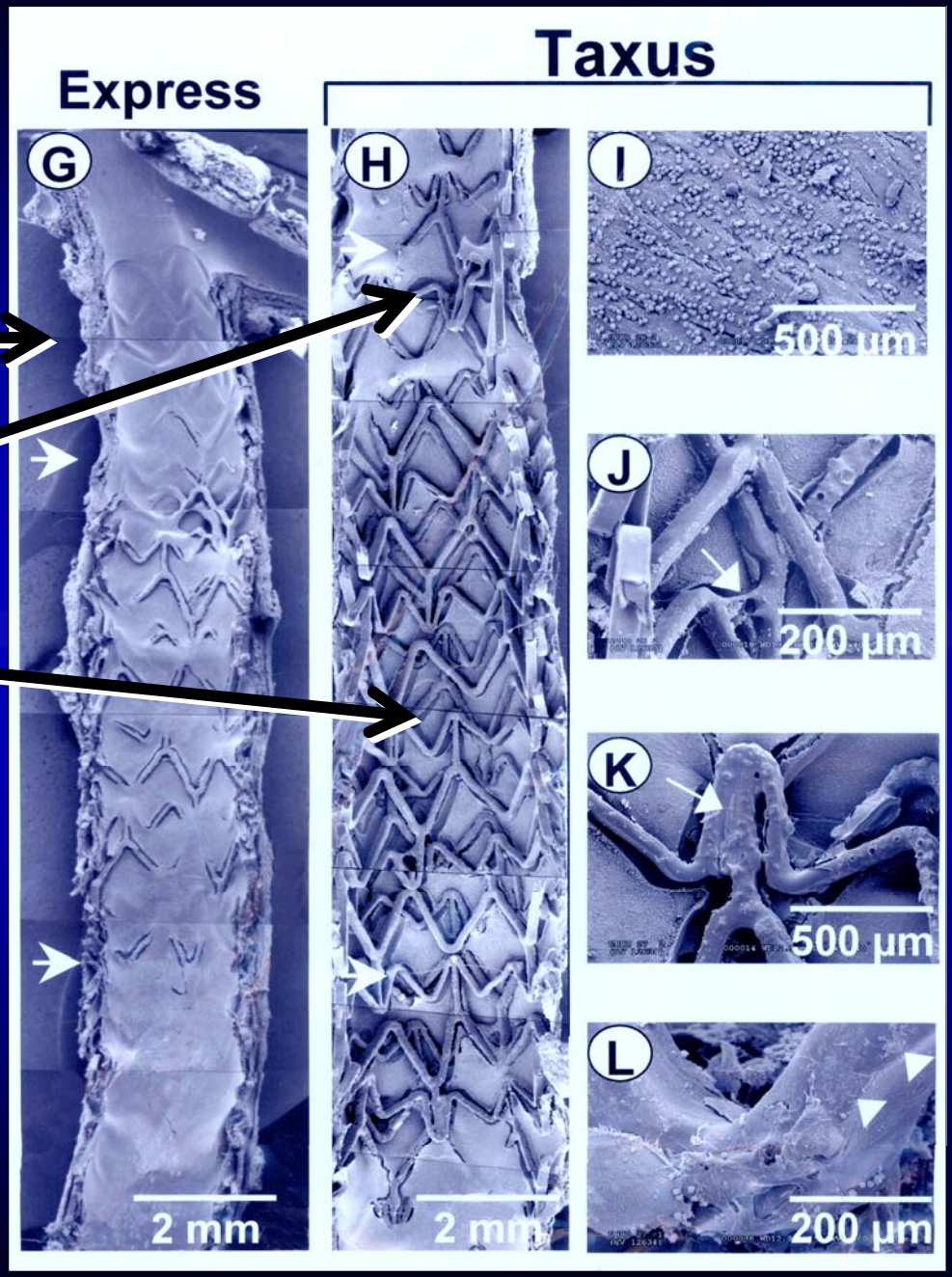
Acute thrombosis (%)	0
Late thrombosis (%)	1 (2.2)
Myocardial infarction (%)	
Non Q waves	0
Q waves	1 (2.2)
Death	0



Endothelialization was complete after single or overlapping BMS

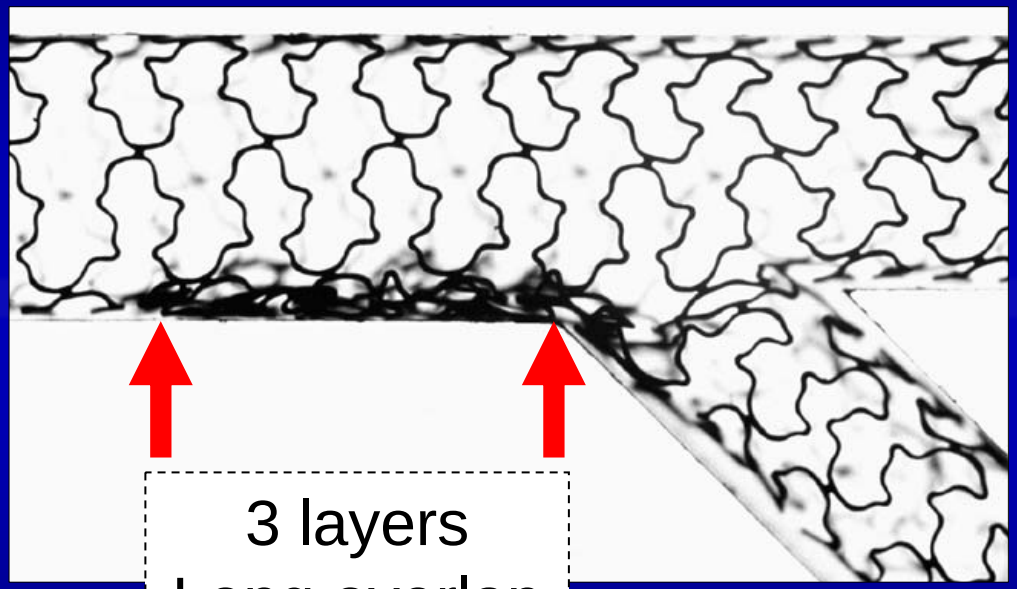
- ❑Reduced with single layer DES
- ❑Further reduced by overlapping DES

Does overlapping predispose to SAT?

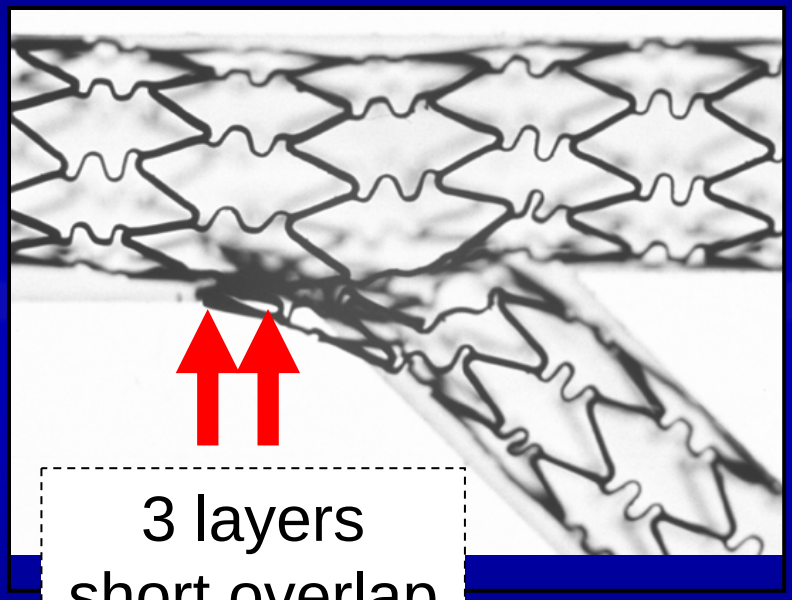


Courtesy of J. Ormiston

- The ideal bifurcation stent or strategy should not have multiple layers with current DES
- Or overlap should be limited eg with “mini-crush”



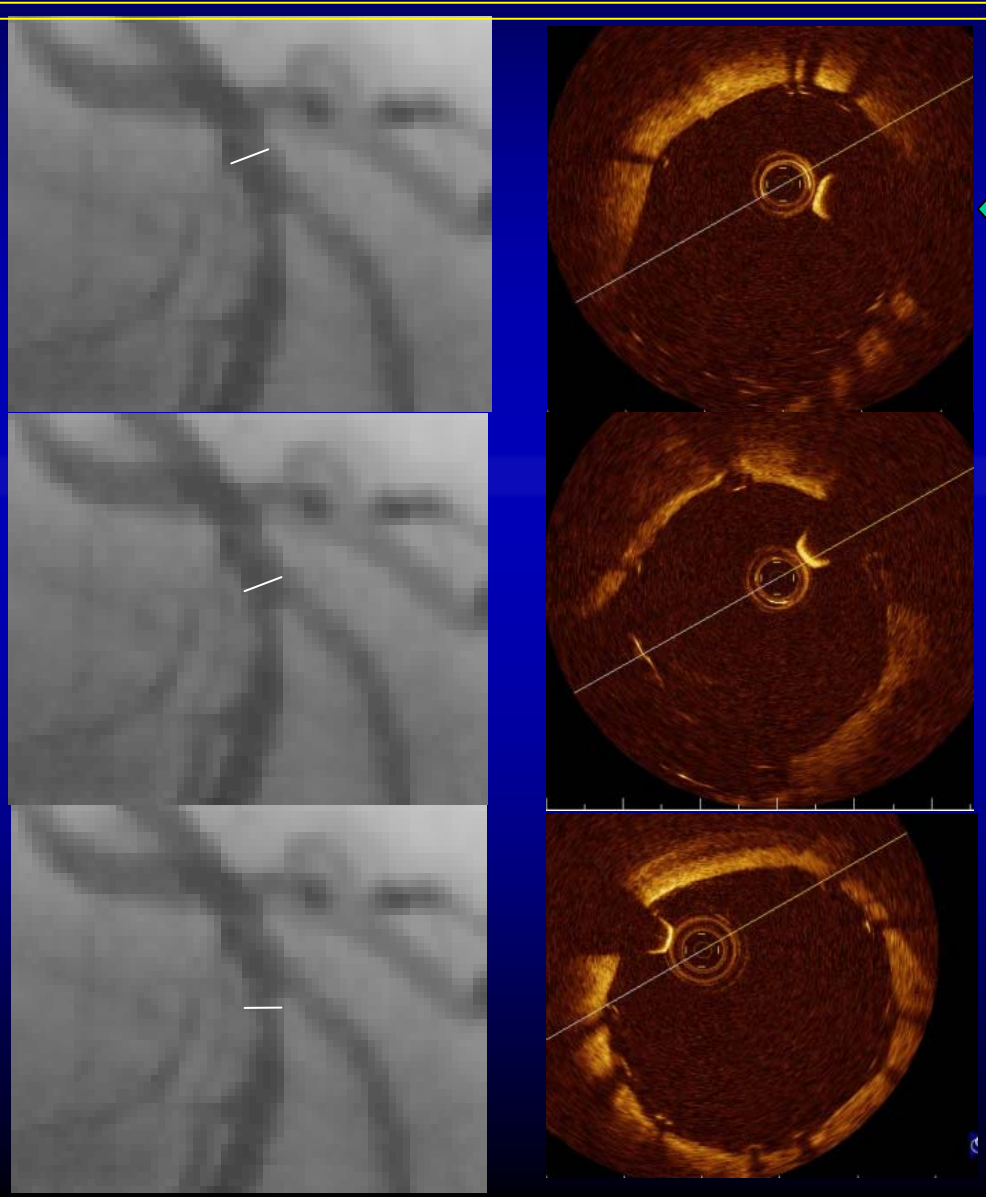
3 layers
Long overlap



3 layers
short overlap

Courtesy of J. Ormiston

Post Mini-Crush of a Bifurcation LAD-D1

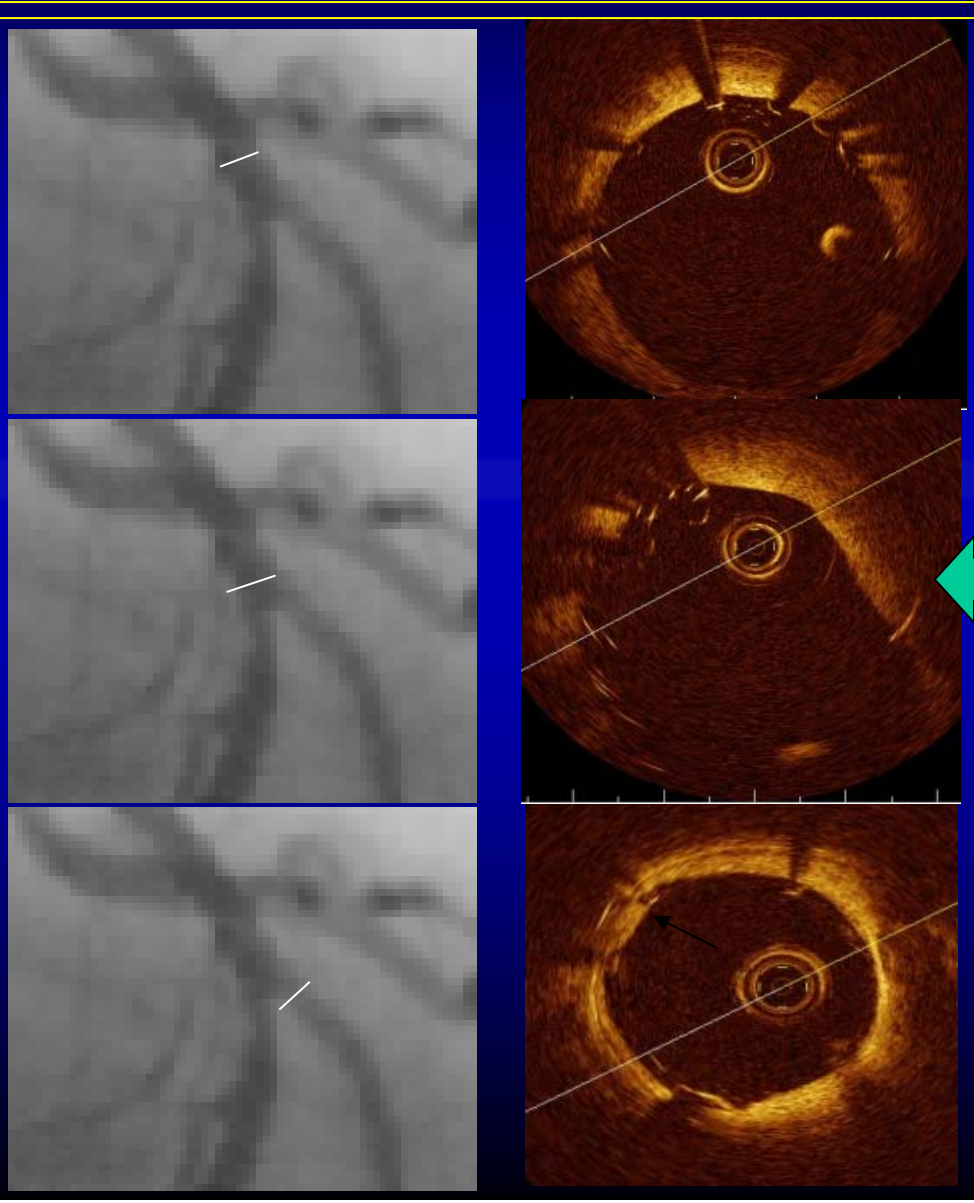


OCT on LAD

Short crushed segment in the LAD

Courtesy of F. Prati

Post Mini-Crush Bifurcation LAD-D1

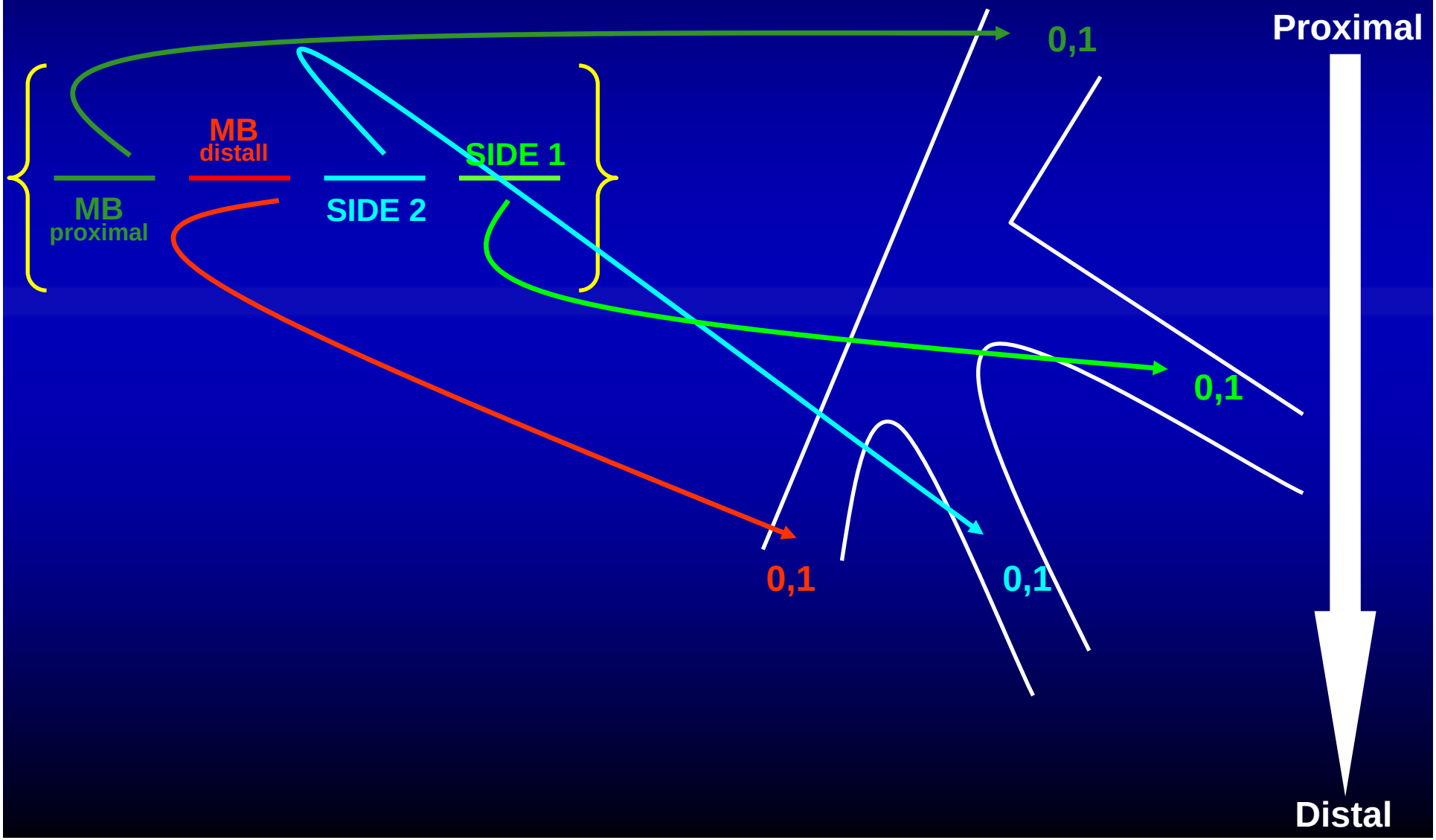


OCT on D1

Optimized stent struts opening by the mini-crush technique

Courtesy of F. Prati

Medina Classification for Coronary Trifurcation Lesion (adapted)



Long-term outcomes of trifurcation lesions after implantation of drug-eluting stents with the "mini-crush technique".

Table I. Patient Characteristics and Procedural Details

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age and gender	58 M	47 M	76 M	58 M	71 M
Risk factor	Smoker	Hypertension, Dislipidemia, Smoker, Family of CAD	Dislipidemia, Hypertension	Smoker, Family of CAD	Smoker
Prior MI	N	N	N	N	N
Prior CABG	N	N	N	N	N
Prior PCI	N	Y, on RCA with BMS	Y, on RCA with DES	N	N
Ejection Fraction (%)	45	55	61	65	55
Clinical presentation	AMI	Stable Angina	Unstable Angina	Unstable Angina	Stable Angina
LMT disease	N	N	Y	N	N
N° of vessel disease	1	2	3	2	2
Lesion location (Medina adapted)	LAD,Db1,Db2	LAD,Db1,Db2	LMT/LAD, LCX1, BI2	LAD,Db1,Db2	LAD,Db1,Db2
Calcification	N	N	Y	Y	Y
Procedure time	1,4 h	1,2 h	1,8 h	2,2 h	2,3 h
Contrast dose	350 cc	320 cc	400	700 cc	900 cc
Fluoroscopy time	56,1	40,1	36,3	42,2	68,3
IVUS	Y	Y	N	N	Y

Long-term outcomes of trifurcation lesions after implantation of drug-eluting stents with the "mini-crush technique".

Table II. Procedural Details.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Vascular access	Right femoral	Right femoral	Right femoral	Right femoral	Right femoral
Guiding catheter type and size	XB LAD 3.5 7 Fr	XB LAD 3.5 8 Fr	XB 3.5 7 Fr	XB LAD4 7 Fr	XB LAD 3.5 8 Fr
DKBI pre-procedure	Y	Y	Y	Y	Y
TKBI post-procedure	Y	Y	Y	Y	Y
Jailed wire technique on both branches	N		N		
Jailed wire technique on a single branch		N		N	N
N° of stent implanteted	3	4	3	4	4
MV stent	SES 3.5/23 mm	PES 3.5/24 mm, PES 3.0/12 mm	SES 3.5/23 mm	SES 3.5/23 mm	SES 3.5/13 mm, SES 3.0/33mm
SB1 stent	SES 2.75/18 mm	PES 2.75/12mm	SES 3.0/13 mm	SES 2.5/13 mm	SES 2.25/33 mm
SB2 stent	SES 2.25/18 mm	PES 2.5/12 mm	SES 2.25/8 mm	SES 2.25/8mm, SES 2.25/33 mm	SES 2.25/28 mm
Angiographic success	Y	Y	Y	Y	Y
Periprocedural MI*	N	N	N	N	N

DKBI= Double kissing balloon inflation; TKBI= Triple kissing balloon inflation; Y = yes; N= no; * = (Q wave or non-Q wave)

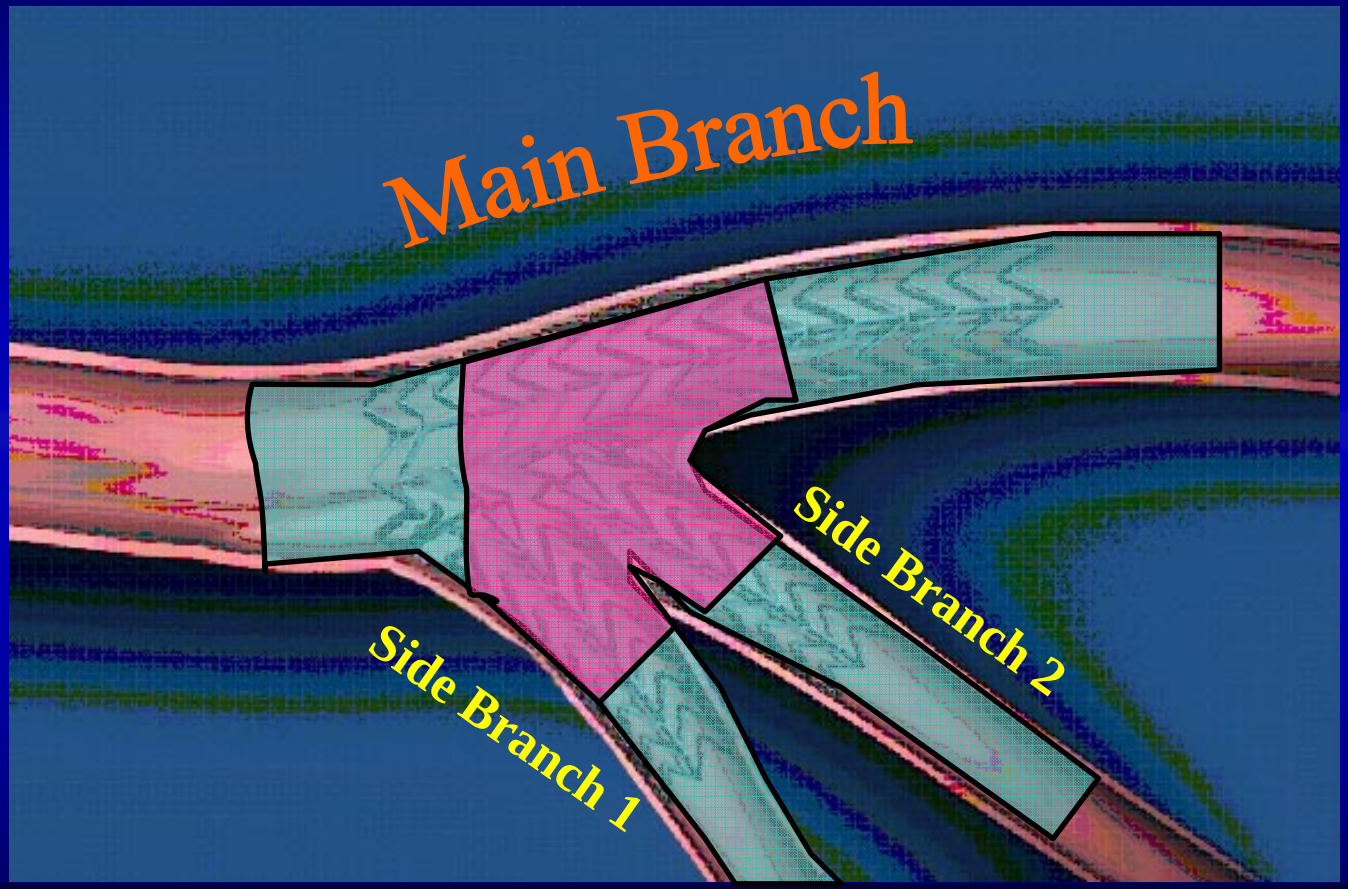
Catheterization and Cardiovascular Interventions

Long-term outcomes of trifurcation lesions after implantation of drug-eluting stents with the "mini-crush technique".

Table III. Quantitative coronary angiographic analysis

	Baseline	Post-procedure	Follow up
Side branch 2			
MLD mm	0.71 ± 0.37	2.43 ± 0.26	2.08 ± 0.22
DS %	71 ± 10.97	7 ± 7.70	29.7 ± 11.6
Lesion lenght mm	17.4 ± 13.39	.....	.....
Acute gain mm	.....	1.67 ± 0.32	.....
Late lumen loss	.....	.....	0.27 ± 0.19

Trifurcation Definition

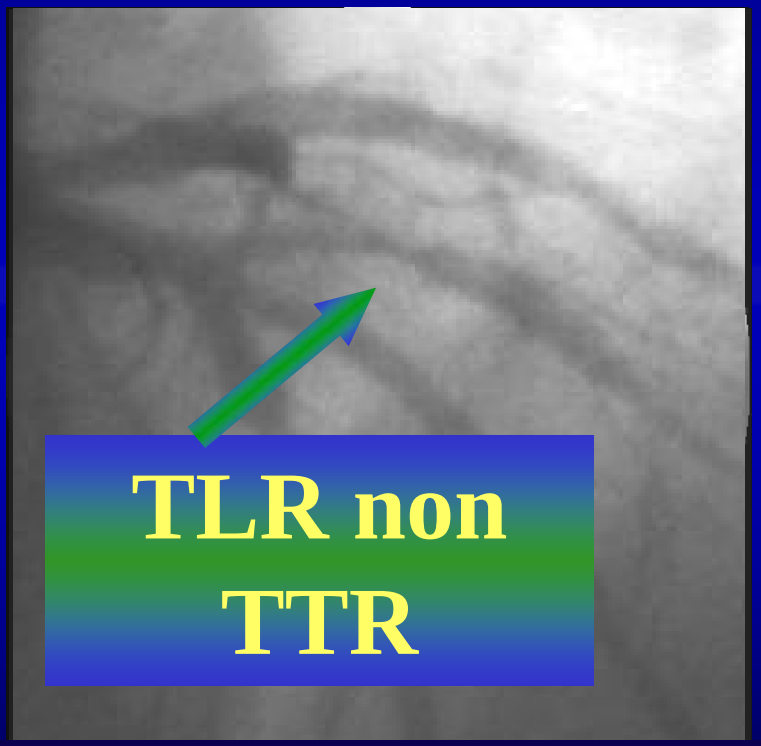


TLR = target lesion revascularization due to restenosis (≥50%) intrastent and/or 5 mm proximal and/or 5 mm distal to stent in main or side branch

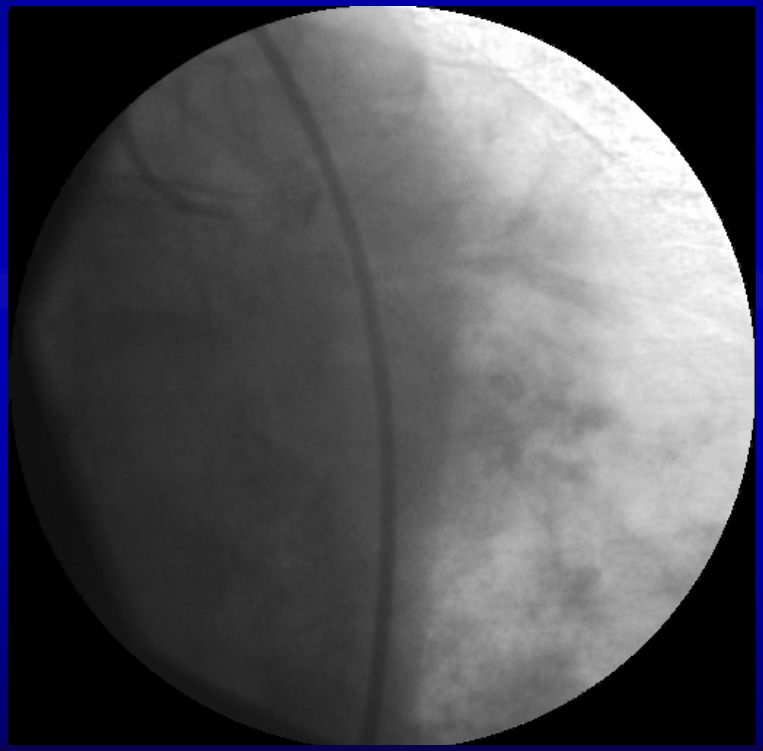
TTR = target trifurcation revascularization due to restenosis (≥50%) within 5 mm proximal or distal to the carina of bifurcation, both onto the main branch and/or side branch

Angiographic Characteristics

4/5 of lesion LAD-DB1-DB2



1/5 of lesion LMT-LAD-LCX-RI



8-month Follow-up

N° stents implanted per lesion: 3,4 ± 0,5

Catheterization and Cardiovascular Interventions

Long-term outcomes of trifurcation lesions after implantation of drug-eluting stents with the "mini-crush technique".

Table IV. In Hospital/30-day and at 8-Month Results

	In hospital/30-day	8-month
Non-Q MI (%)	0	0
Q-MI (%)	0	0
Acute thrombosis (%)	0	0
Late thrombosis (%)	0	0
CABG (%)	0	0
Re-PTCA (%)	0	1 (20)
TLR (%)	0	1 (20)
Restenosis		
Main branch (%)	0	0
Side branch 1 (%)	0	1 (20)
Side branch 2 (%)	0	0
Death (%)	0	0
Cumulative MACE (%)	0	1 (20)

Conclusions

- The “mini-crush” technique may be considered a very good refiniment of the crush technique
- Experimental bench work, as well as IVUS and OCT first clinical applications showed excellent results
- The application of this technique in the clinical setting of both bifurcation and trifurcation lesions proved to be very promising
- Now it is the time of a clinical multicenter randomized study!

Thank you

argalassi@virgilio.it

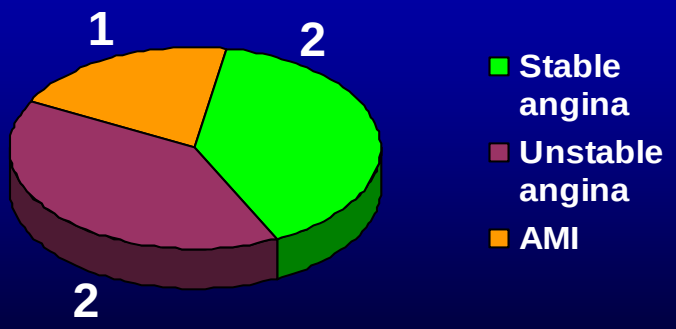
Catheterization and Cardiovascular Interventions

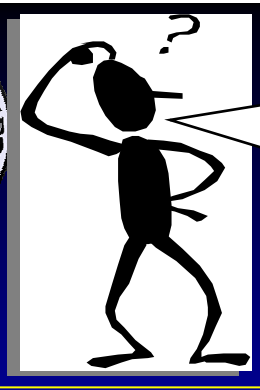
Long-term outcomes of trifurcation lesions after implantation of drug-eluting stents with the "mini-crush technique".

Clinical Characteristics	Pts=5
Male	5/5 (100%)
Age (mean±SD)	65±11,5
EF (mean±SD)	54±5,8
Hypertension	2/5 (20%)
Dislipidemia	2/5 (20%)
Diabetes	0
Smokers	4/5 (80%)
Family History of CAD	2/5 (20%)
Previous MI	0
Previous PCI	2/5 (20%)

N° of vessel disease

Clinical presentation



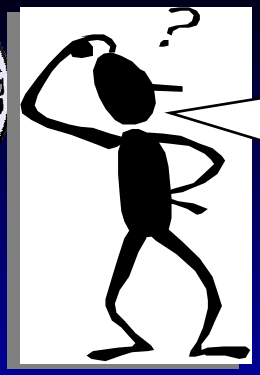


Does The Side Branch Need Protection by a Stent?

- Is the side branch a large vessel?
- Does the side branch comes out from the main with an acute angle?
- Does the ostium or the proximal segment of the side branch have a significant narrowing?
- Is the side branch very difficult to be wired?
- Is the patient a very high risk patient and the side branch appears relatively important?
- Is the main branch severely narrowed with a lot of plaque burden?

If the answer is YES, suggestion is that the operator will lean more towards two stents

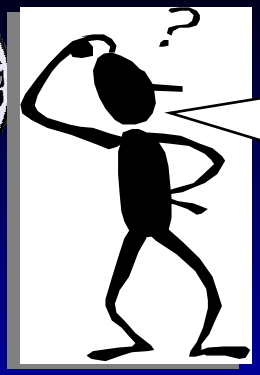
… sometimes a decision should be made only following predilatation of the main branch and of the side branch!



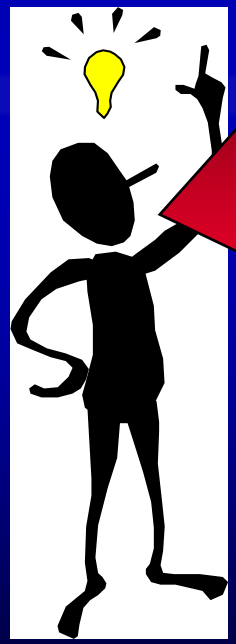
Does The Side Branch Need Wire Protection?

Which is the risk of closure while treating the main branch (severity of ostial involvement, length of the disease and angle of origin)?

What is the size of the side branch?

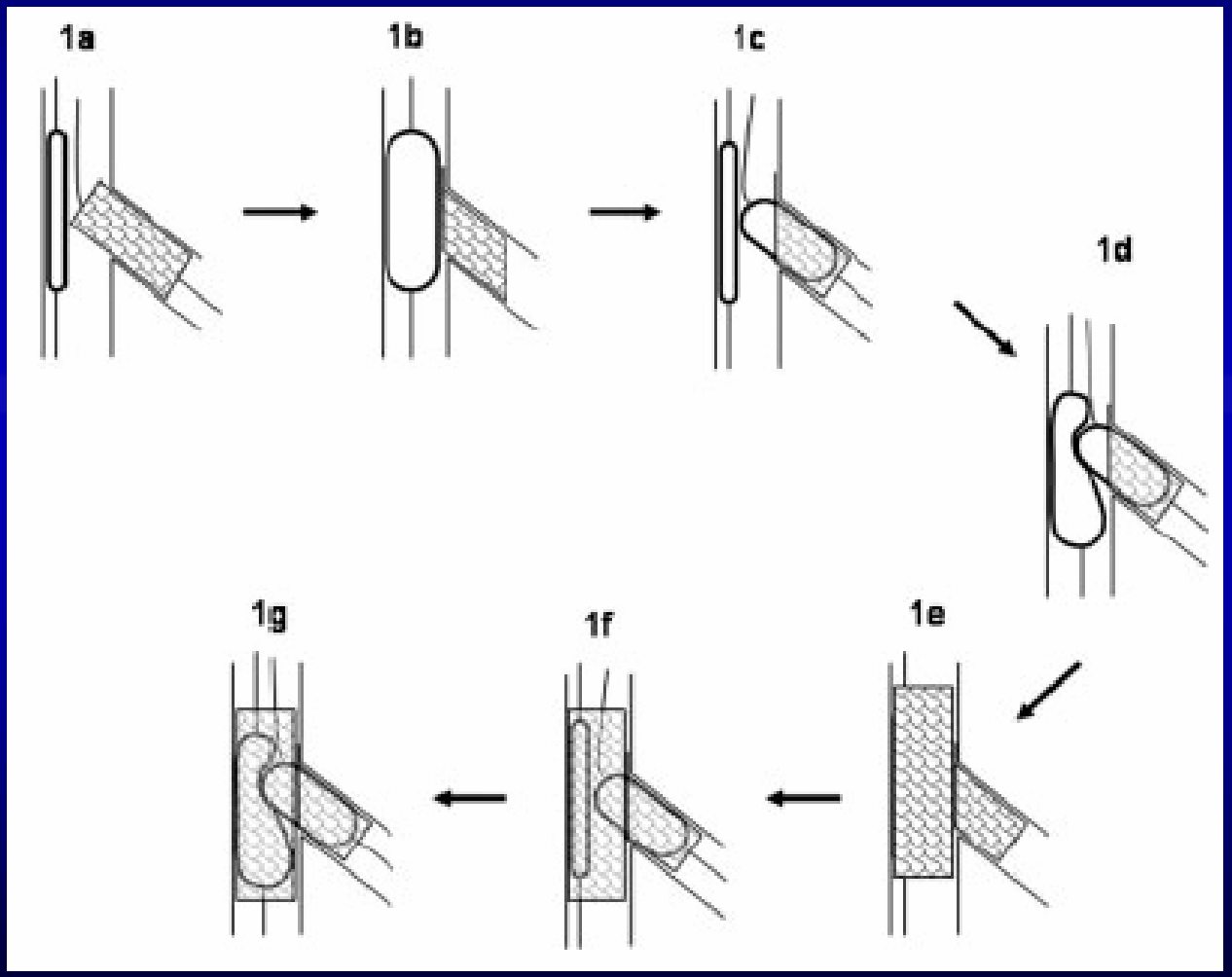


Does The Side Branch Need Balloon Dilatation?



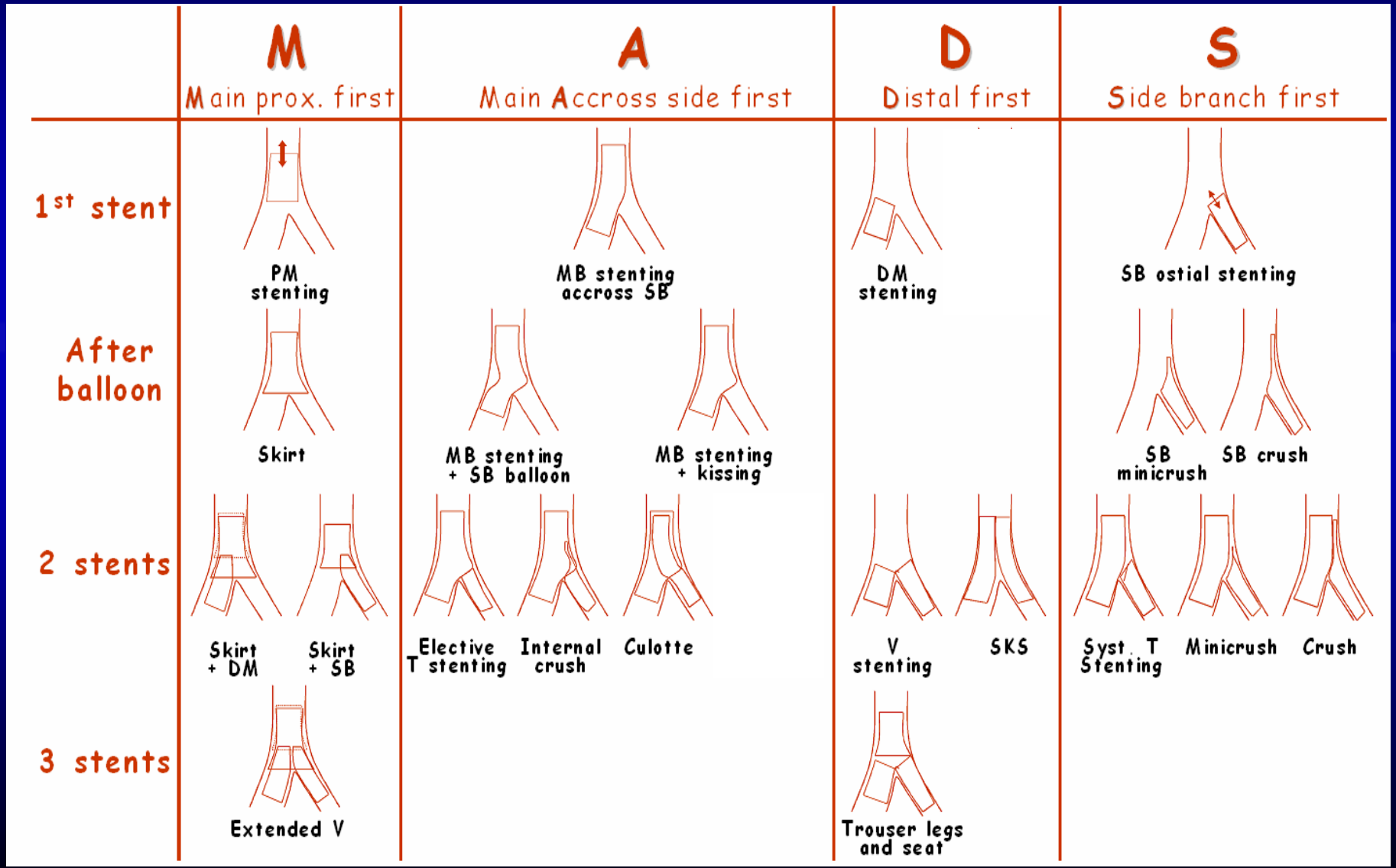
…if the side branch is ≥ 2.5 mm in diameter
with ostial disease or at risk of plaque shift elective balloon dilatation with or without kissing balloon is advised…
……. but remember no oversized balloon in the side branch to prevent dissection!!!

The Sleeve Technique

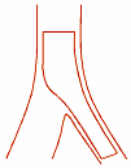
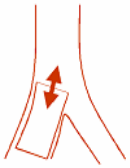
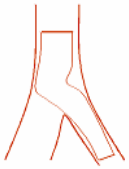
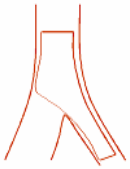
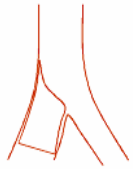
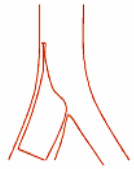
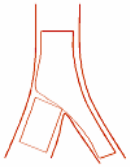
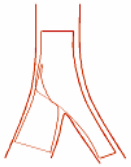
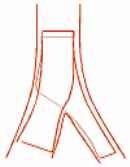
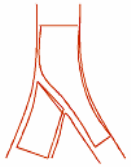


Jim et al. Catheter Cardiovasc Interv 2006

Classification of Bifurcation Lesions Treatment by the European Bifurcation Club

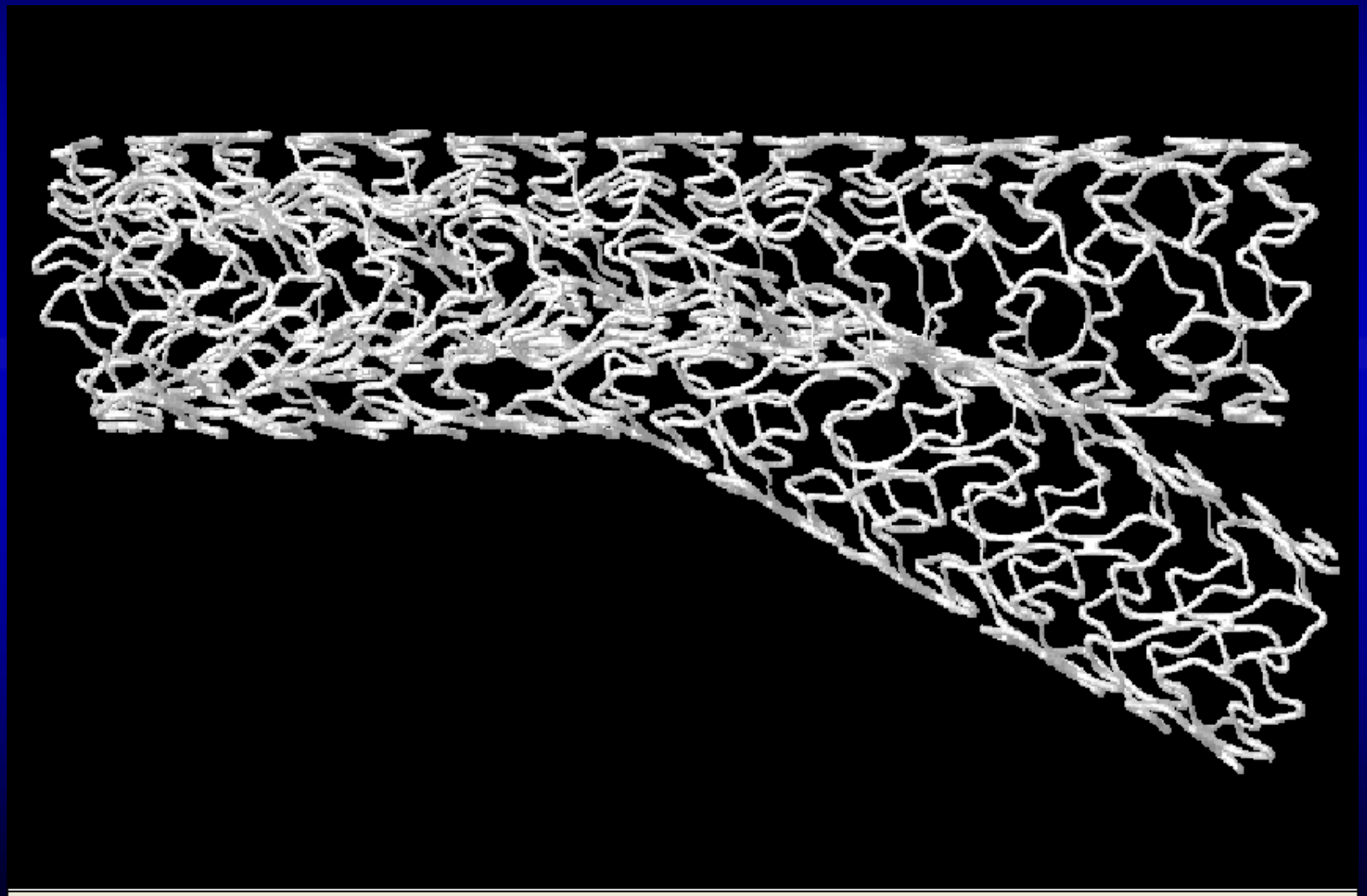


Classification of Bifurcation Lesions Treatment by the European Bifurcation Club

	M Main prox. first	A Main Accross side first	D Distal first	S Side branch first
1st stent		 Inv. MB stenting accross SB		 DM ostial stenting
After balloon		 MB to SB stenting + DM balloon  MB to SB stenting + kissing		 DM minicrush  DM crush
2 stents		 Inv. Elective T stenting  Inv. Internal crush  Inv. Culotte		 Inv. Syst. T Stenting  Inv. Minicrush  Inv. Crush
3 stents				

V Stenting Bench Work

Courtesy of J. Ormiston (Mercy Angiography, New Zealand)



029halved_Liberte_3+3.5_VStenting_30d_06April2006.avi

Original Studies

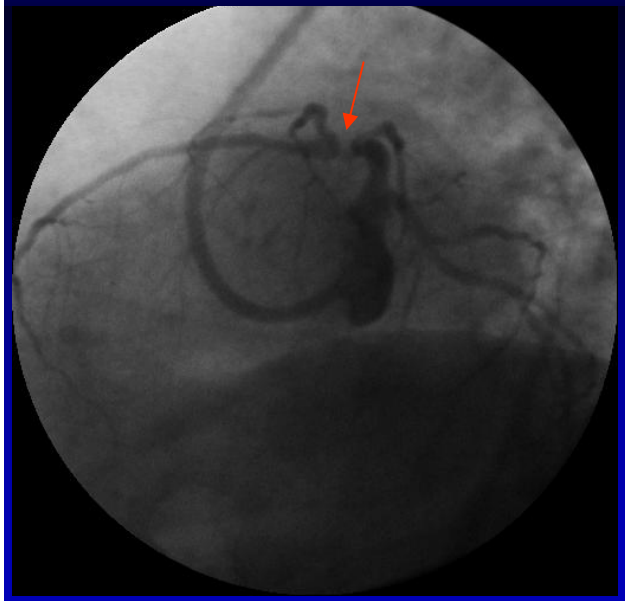
Catheterization and Cardiovascular Interventions 00:000–000 (2007)

Long-term Outcomes of Bifurcation Lesions After Implantation of Drug-Eluting Stents With the "Mini-Crush Technique"

Alfredo R. Galassi,[1*] MD, FACC, FSCAI, Antonio Colombo,[2] MD, FACC, FSCAI, FESC, Maurice Buchbinder,[3] MD, FACC, FSCAI, Carmelo Grasso,[1] MD, Salvatore D. Tomasello,[1] MD, Gian P. Ussia,[1] MD, FSCAI, and Corrado Tamburino,[1] MD, FSCAI, FESC

Mini-Crush Technique Bench Work

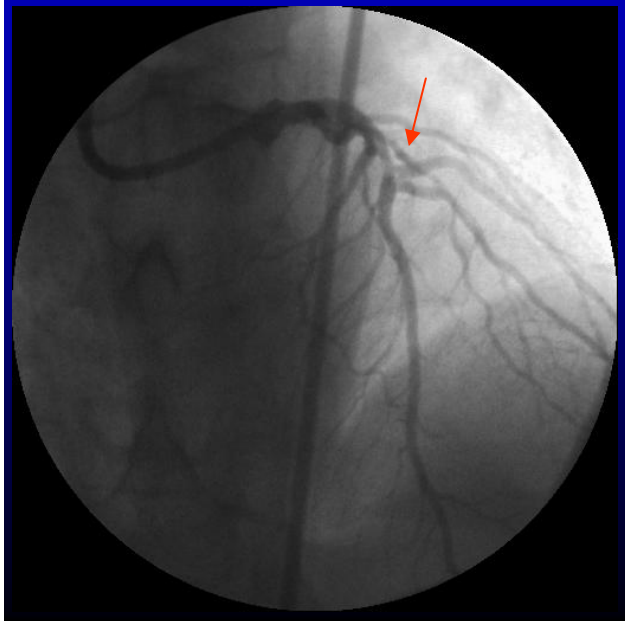
Mini-Crush in a Trifurcation Lesion

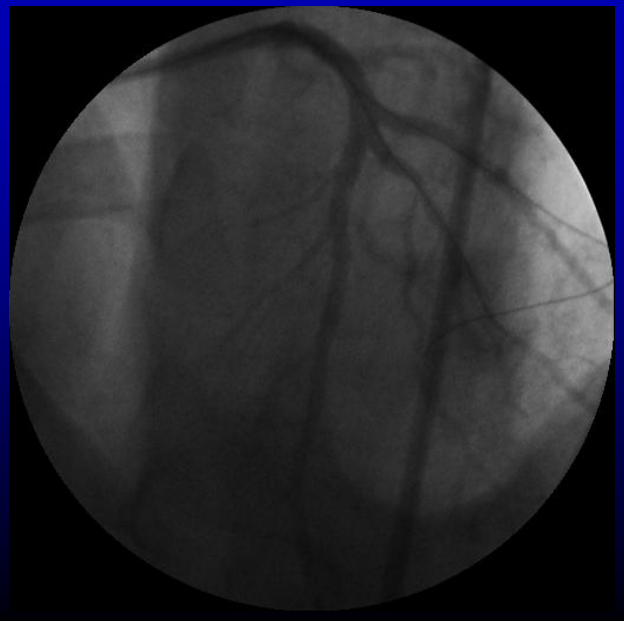


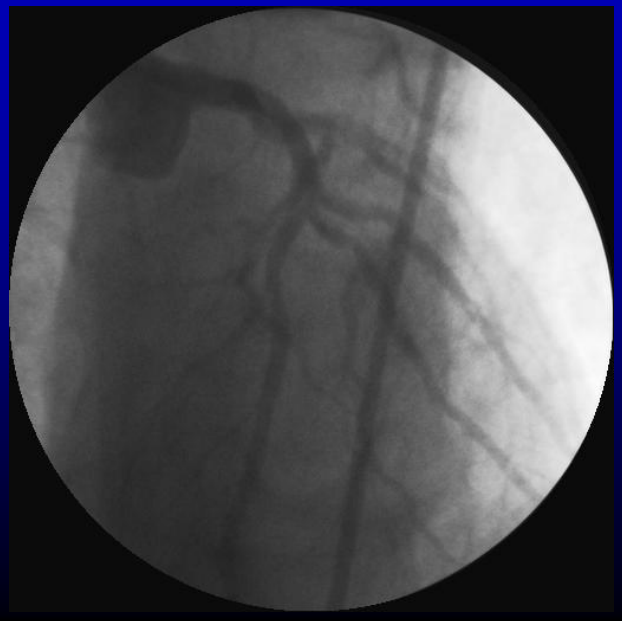
PRE

POST

7 mo ANGIO FU







…but remember that…

… whatever strategy you will use the most simple and safe technique will survive

V Stenting Bench Work

Courtesy of J. Ormiston (Mercy Angiography, New Zealand)

Stagnation area between the stents struts

Recirculation

Distortion

029halved_Liberte_3+3.5_VStenting_30d_06April2006.avi

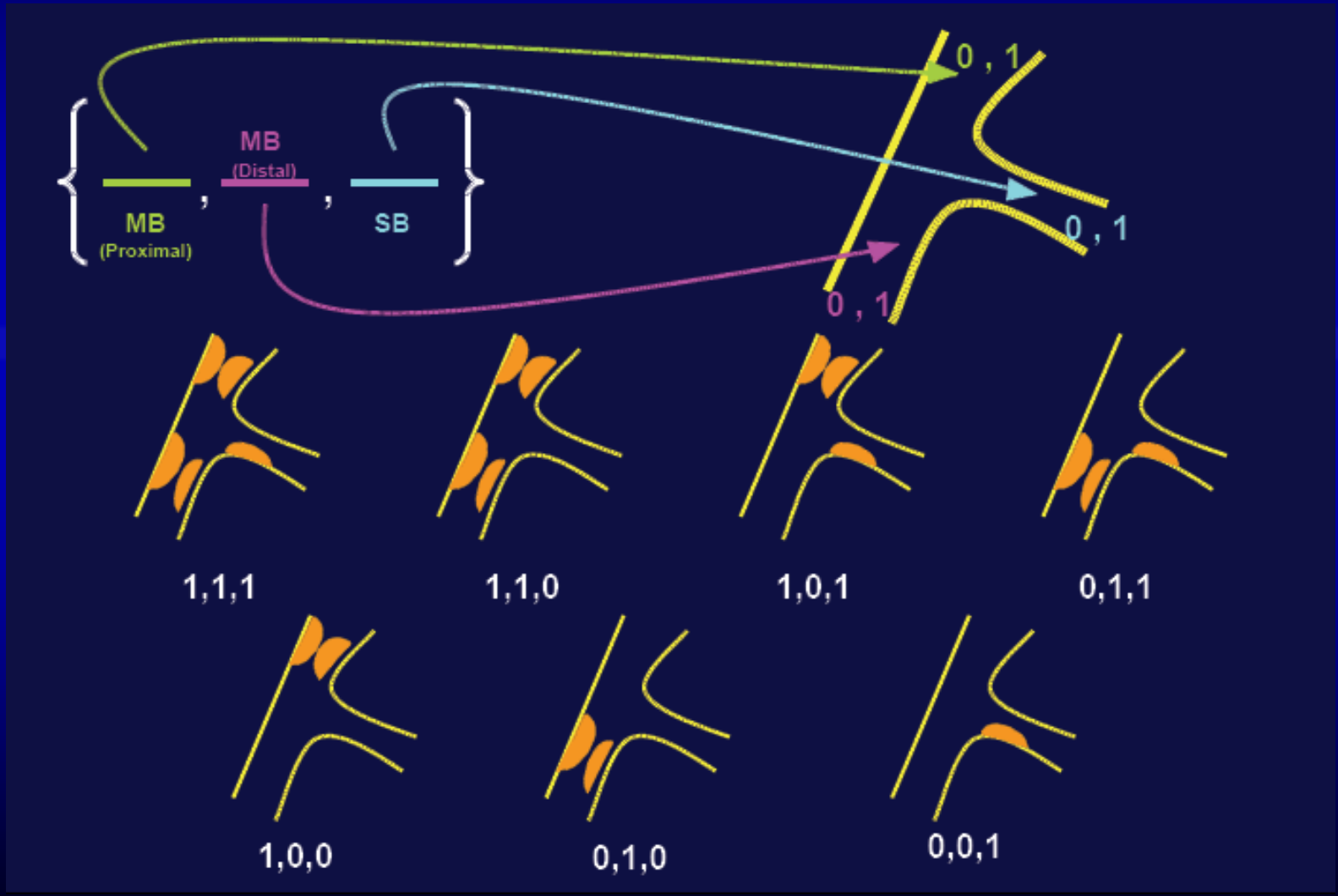
Results in the Five Patients With a Trifurcation Lesion

	Immediate and 30-Day	*7-month*
Procedural success	**5/5**	**.....**
Non-Q MI	**0**	**0**
Q-MI	**0**	**0**
Death	**0**	**0**
TLR	**0**	**1/5**
TBR	**0**	**0**
Acute thrombosis	**0**	**.....**
Subacute thrombosis	**0**	**.....**
Late thrombosis	**.....**	**0**
Main branch restenosis	**.....**	**0**
Side branch 1 restenosis	**.....**	**1/5**
Side branch 2 restenosis	**.....**	**0**
CABG	**0**	**0**
Total MACE	**0**	**1/5**

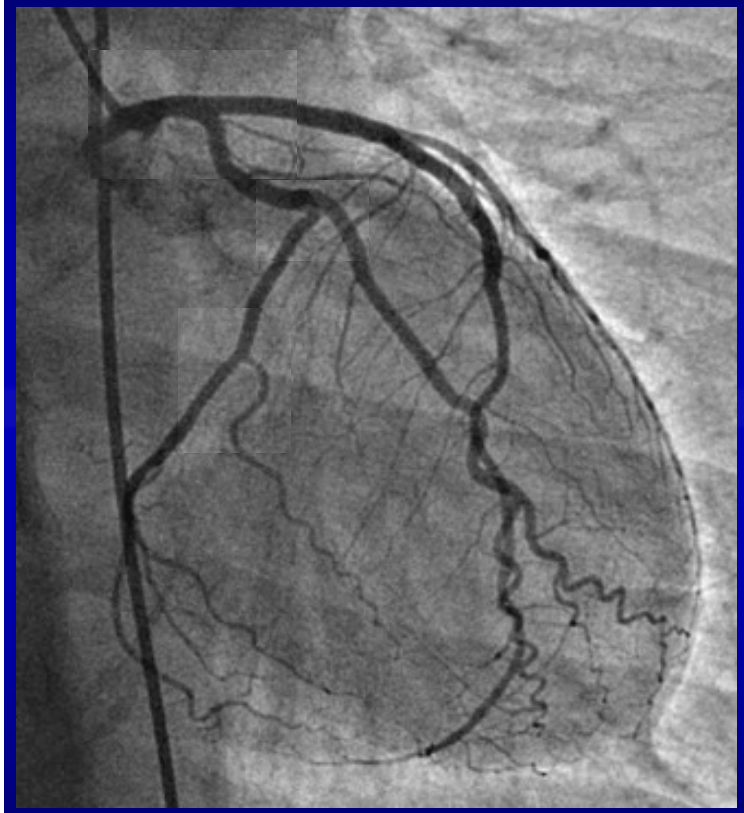
Is it so complex….?

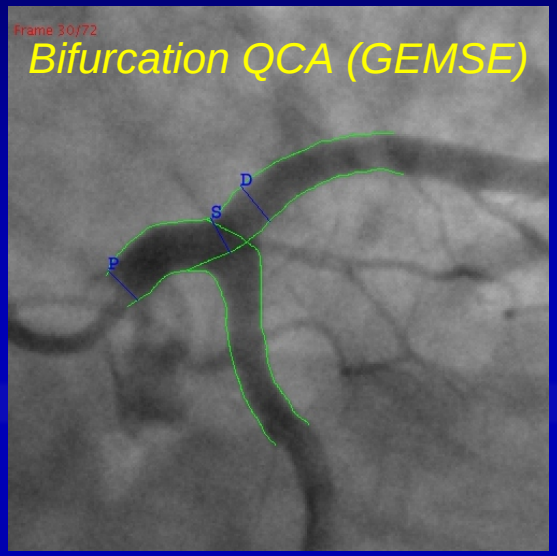
"Nurse, get on the internet, go to www.bifurcation.net scroll down and click on the 'Are you totally lost?' icon."

Medina Classification



Fractals Geometry Governed by Murray's Law and Verified in Human Coronary Artery by IVUS





214 coronary bifurcations

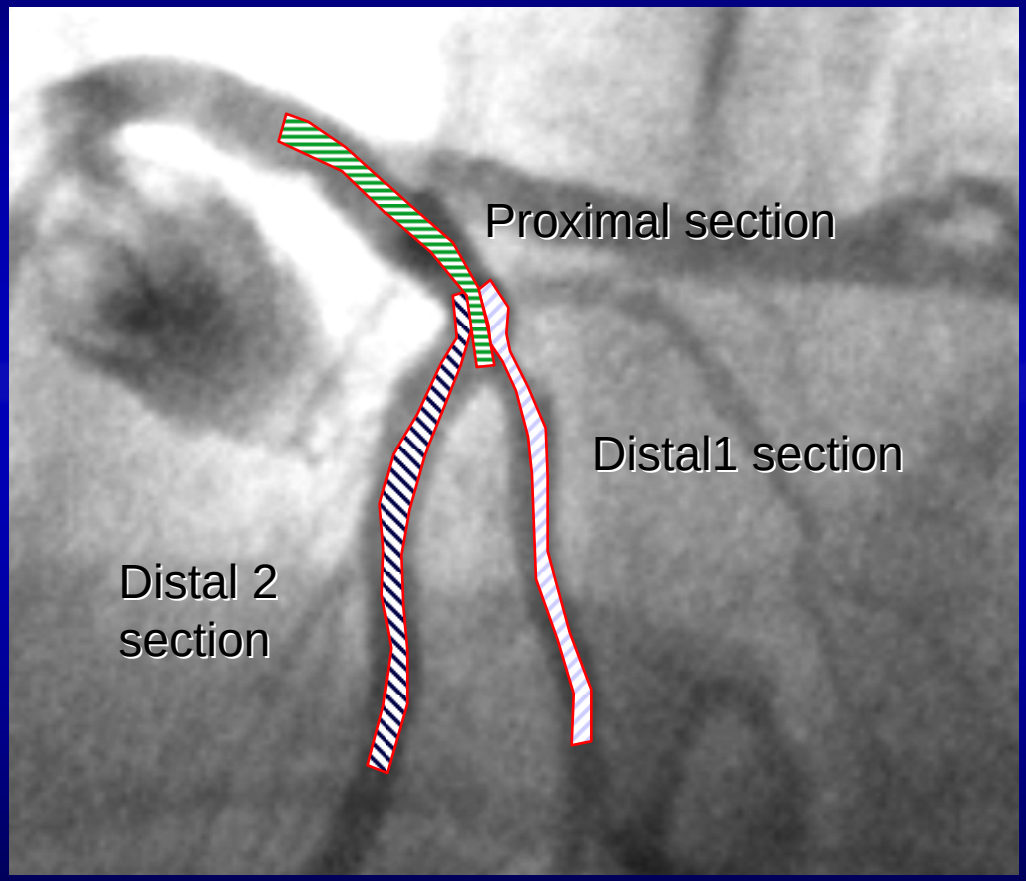
$$R = \frac{D_{mother}}{D_{daughter\ 1} + D_{daughter\ 2}}$$

Ratio = 0.670

Finet et al. www.bifurc.net

Diameter (mm)	>4.5	[4.5-4.0]	[4.0-3.5]	[3.5-3.0]	[3.0-2.5]	<2.5
Ratio	0.66	0.67	0.66	0.69	0.66	0.66

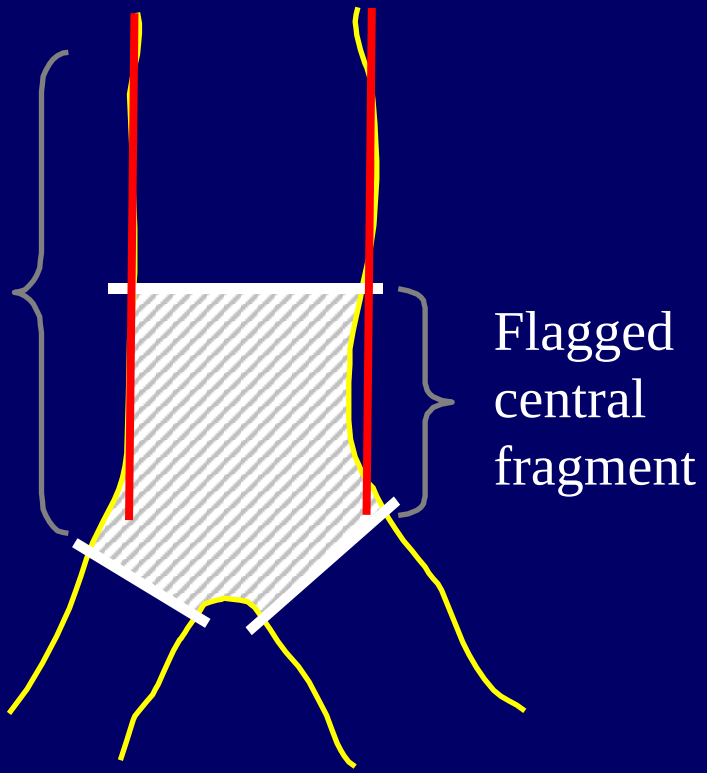
Three Segments Model for the Bifurcation Analysis



Courtesy of Drs Reiber, Koning, Tuinenburg LKEB and Medis

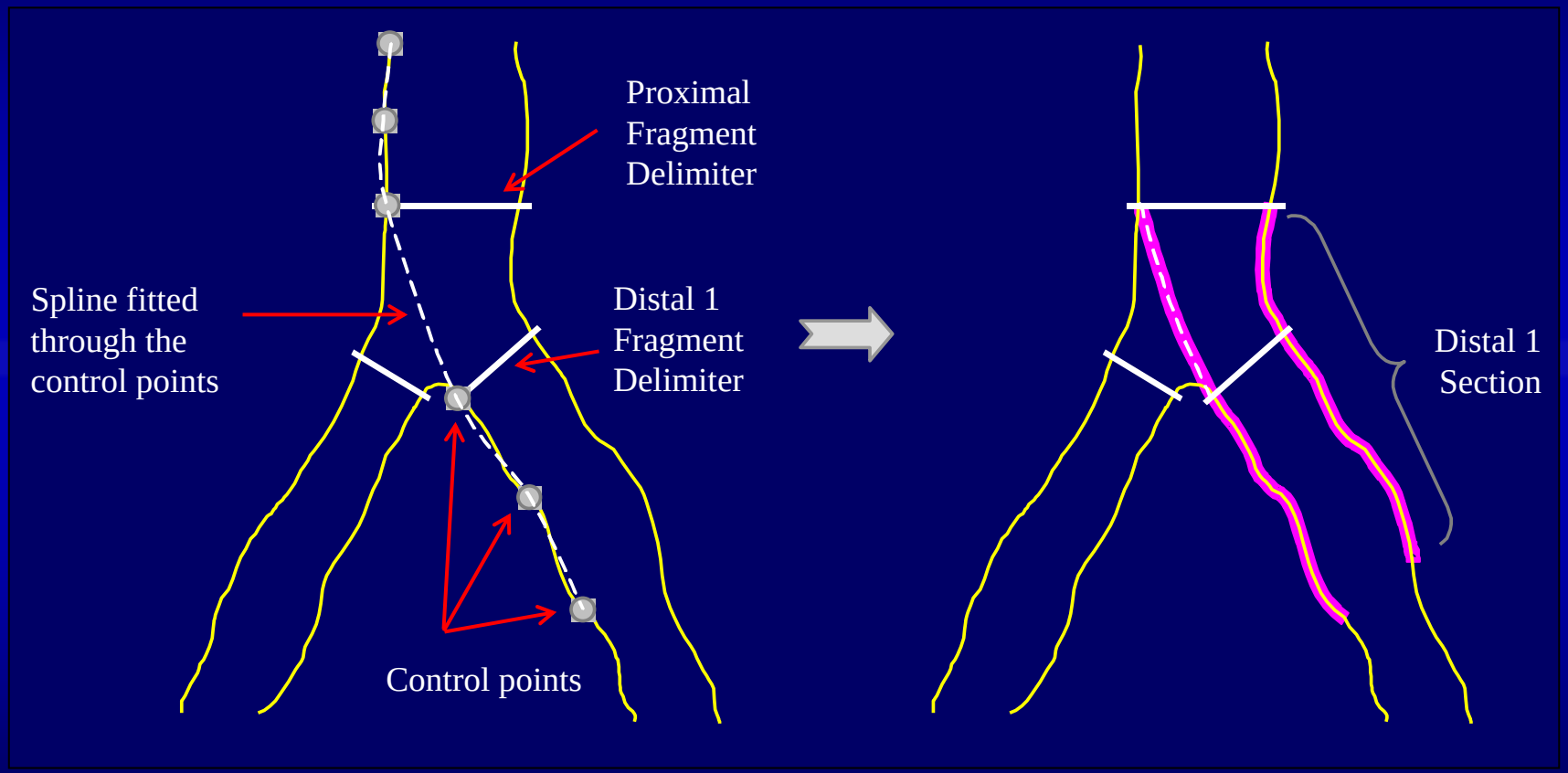
Reference Diameter Calculation

Diameters of the central fragment are automatically excluded from the calculation of the reference diameter function (flagging)



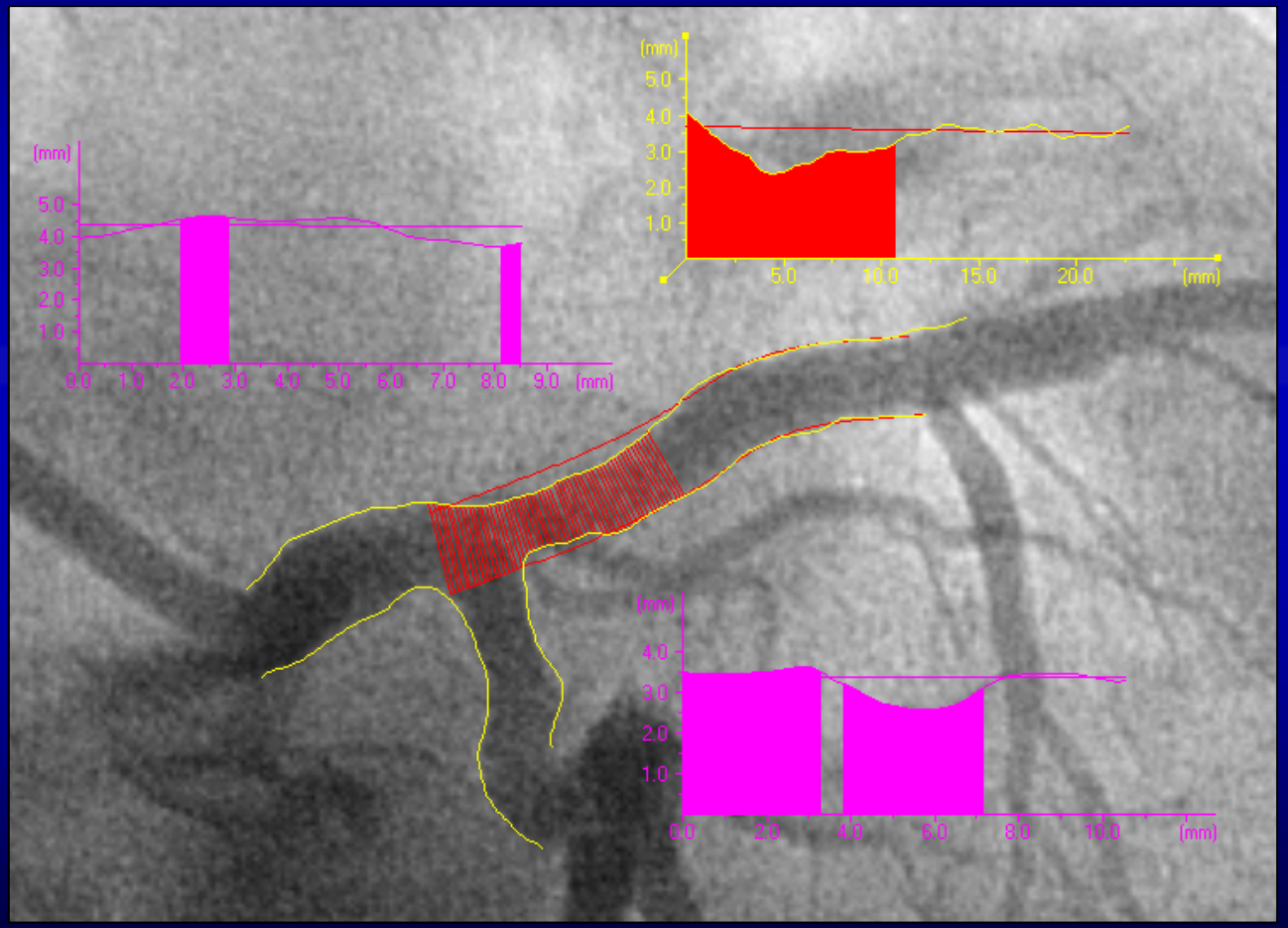
Courtesy of Drs Reiber, Koning, Tuinenburg LKEB and Medis

Side Branch Assessment



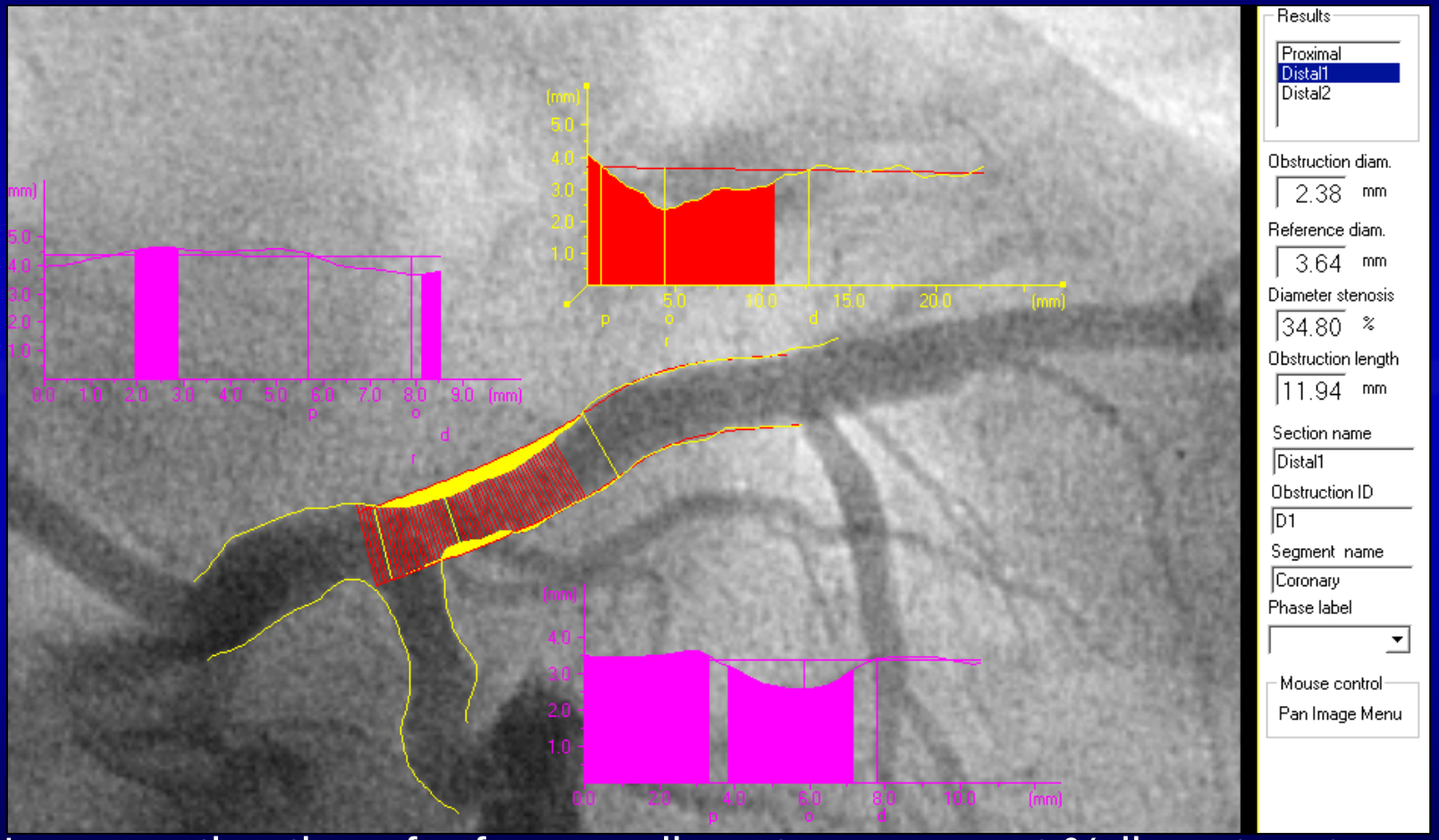
Courtesy of Drs Reiber, Koning, Tuinenburg
LKEB and Medis

Reference Diameter for the 3 Segments



Courtesy of Drs Reiber, Koning, Tuinenburg LKEB and Medis

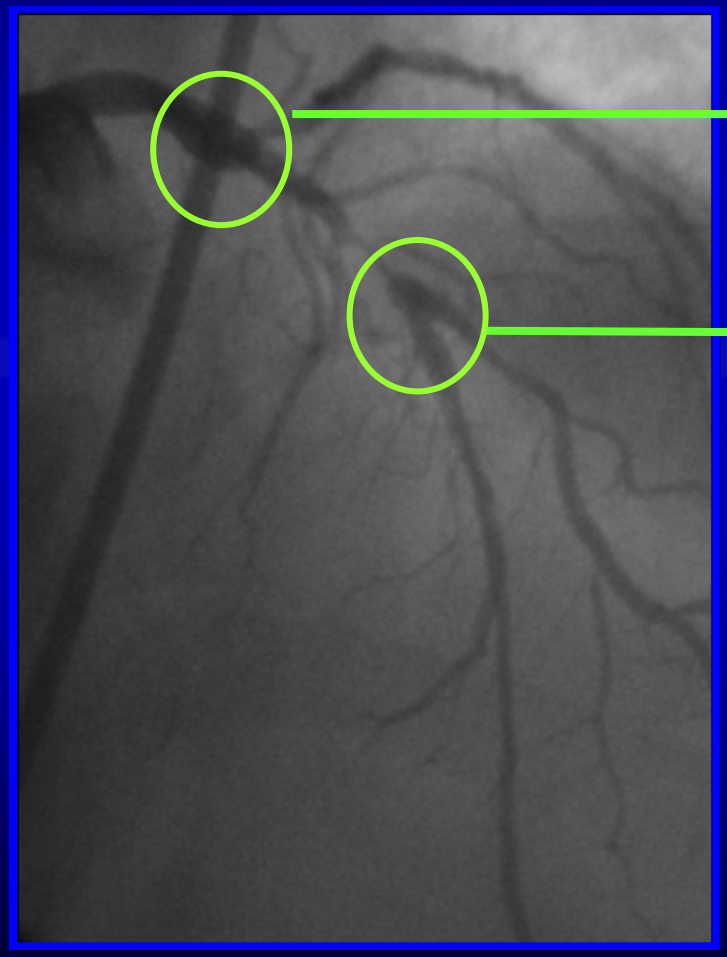
Analysis results for Side Branch



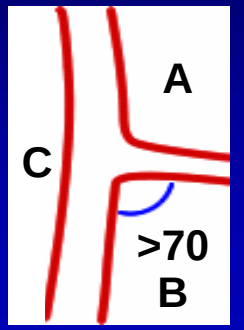
No overestimation of reference diameter → correct %diameter stenosis

Courtesy of Drs Reiber, Koning, Tuinenburg LKEB and Medis

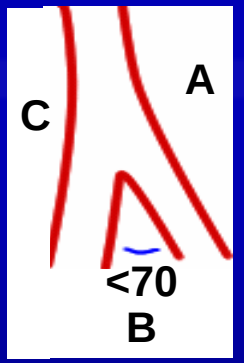
Classification by the Angle of Bifurcation Lesions between MB and SB



T shape

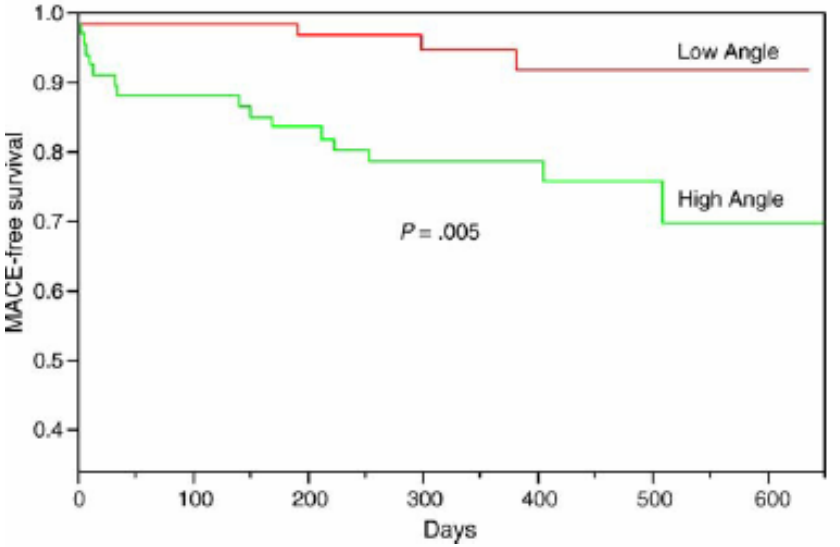


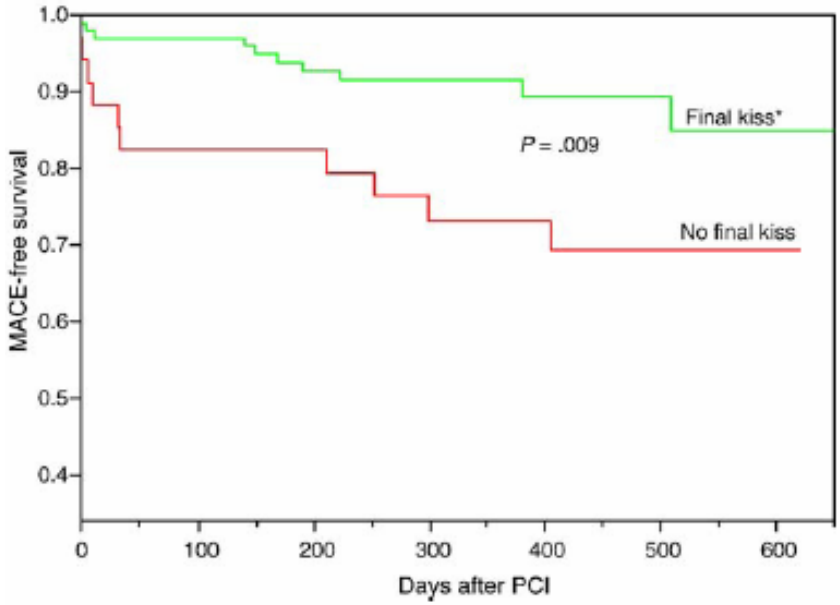
Y shape

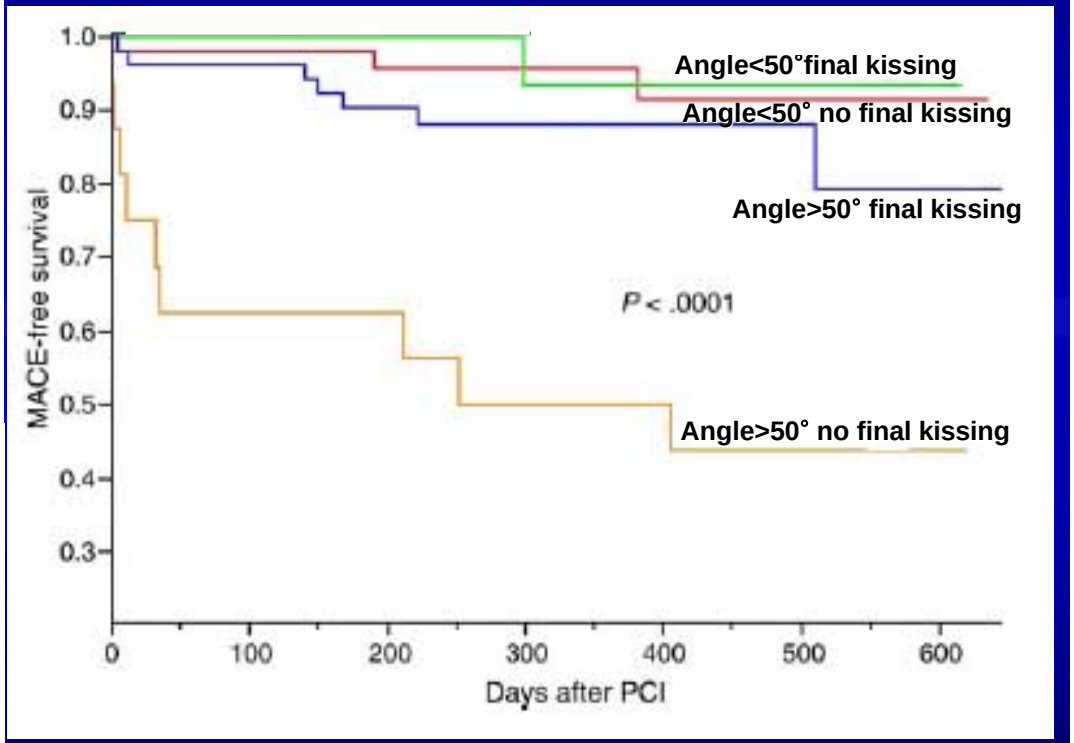


SB access:	easy	difficult
Plaque shift:	more	less

Importance of the Bifurcation Angle "B" and Final Kissing Balloon



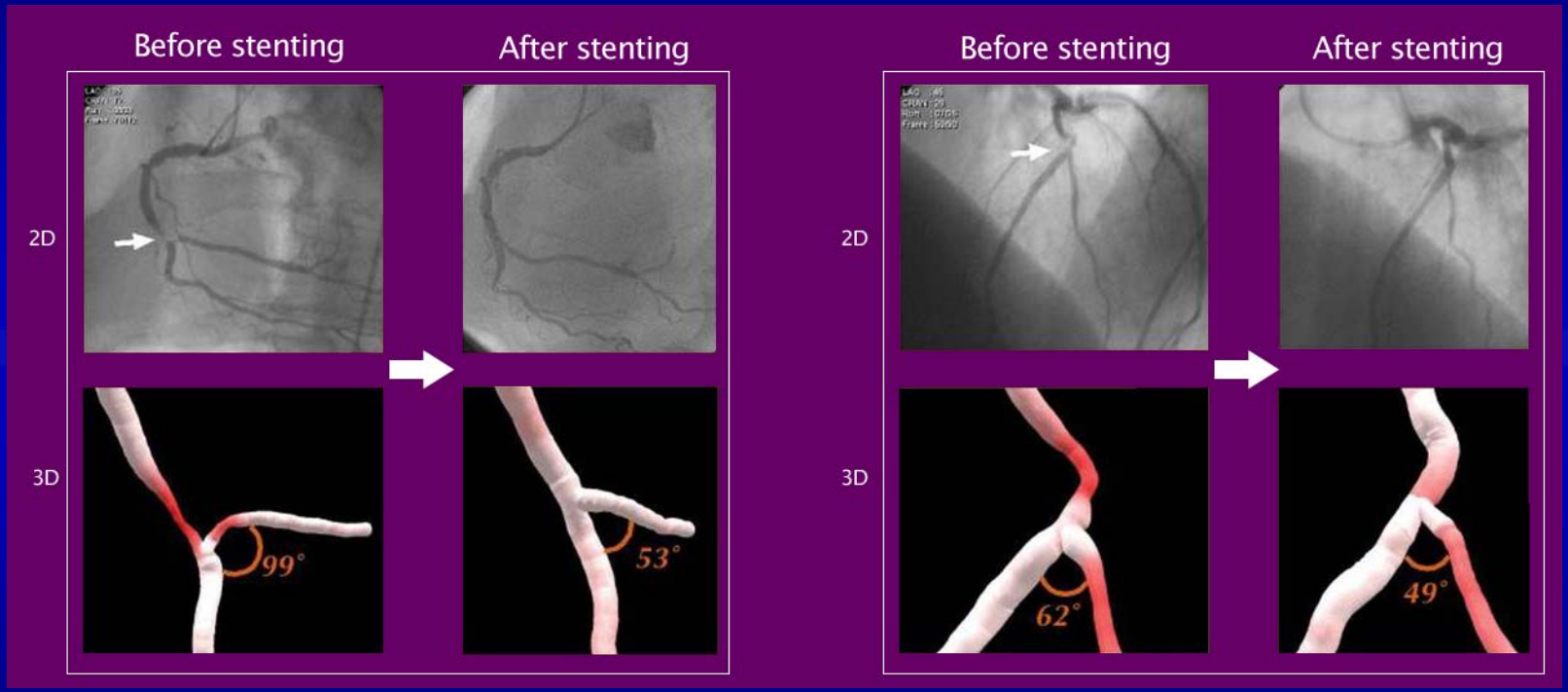




Dzavik et al, Am Heart J 2006

Geometrical Changes Noted During Bifurcation Stenting

D. Dvir et al WCC Barcelona 9/2006



- Bifurcation stenting causes significant geometrical changes in 3D
- Two vs. one stenting technique causes most changes
- 3D bifurcation reconstruction may be an important tool for planning PCI procedures and evaluating their results

Side Branch Occlusion during PCI

- Generally clinical sequelae are transient chest pain and ST-T wave changes
- A small percentage of patients develop Q-wave infarction or require emergency surgery as long as main vessel remain patent
- Non Q-wave myocardial infarction undoubtely occurs frequently (serial systematic evaluation of enzymes not available)

Risk of Acute Side Branch Occlusion

	Occlusion rate (%)
Side branch with minimal disease	< 4
Side branch with significant disease	> 27

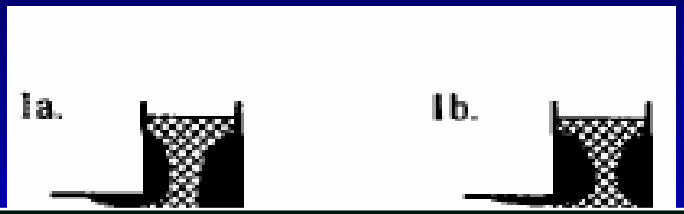
Meier B et al. Am J Cardiol 1984; 53: 10-4

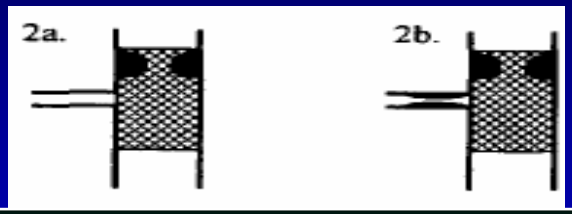
Incidence and Predictors of Side Branch Occlusion Following Stenting

	Occlusion	No occlusion	P value
Patients (n)	10	156	-
Calcifications (%)	0	16	NS
Lesion eccentricity (%)			
Concentric	0	12.9	
Excentric IPSI	80	49	0.143
Excentric Contro	20	38.1	
Angle "B" >70° (T shape)	140°± 19°	137°± 26°	NS
Angle "B" <70° (Y shape)	42°± 22°	60° ± 22°	0.033
Stenosis main banch (%)	58±10	62±12	NS
side banch (%)	46±20	38±21	NS
Jailed guide wire technique (%)	80	91	NS

Y. Louvard, T. Lefèvre et al, TCT 2004

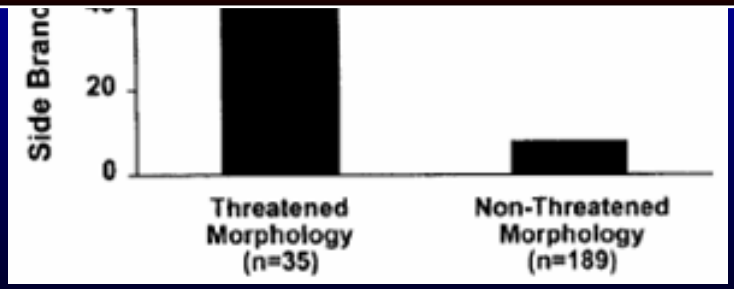
Incidence and Predictors of Side Branch Occlusion Following Stenting





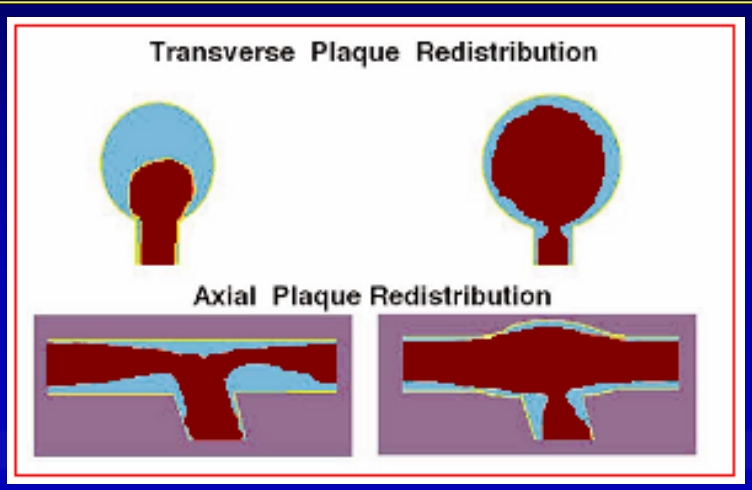
Thus, nonthreathened side branch of a small size should not be wired!!!

Side branch >2.0 mm that are at risk of closure should be protected!!!

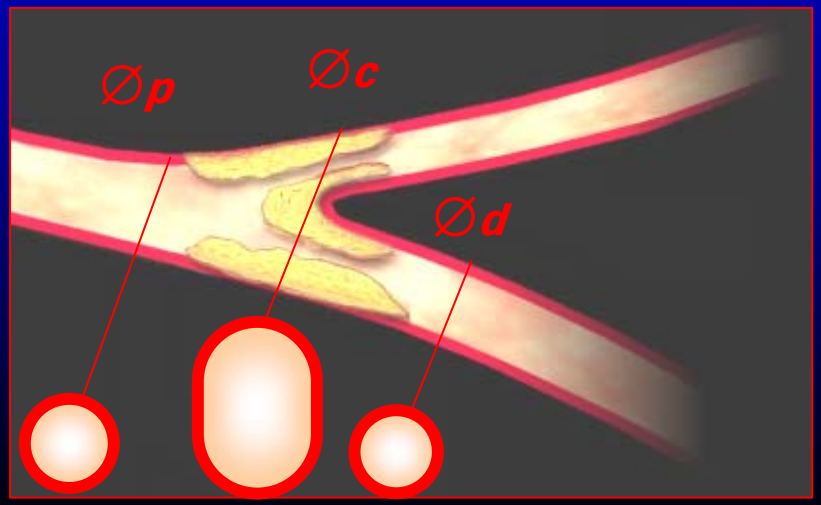


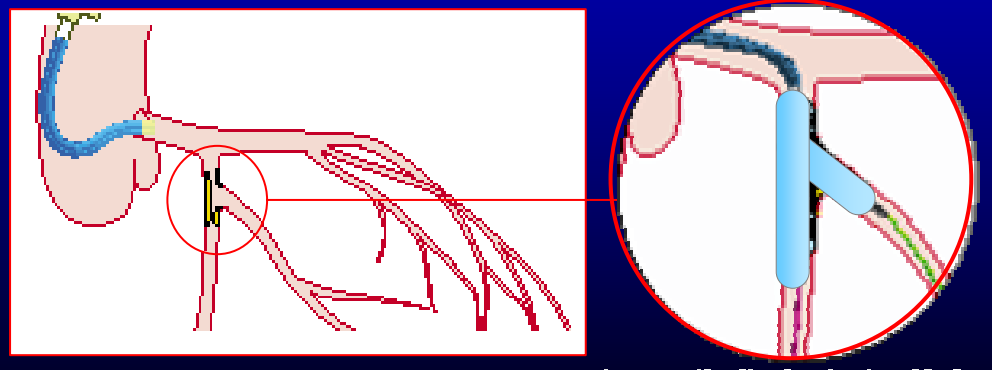
Aliabadi et al, Am J Cardiol 1997

Common Approaches to Bifurcation Lesions: the Role of Kissing Balloon



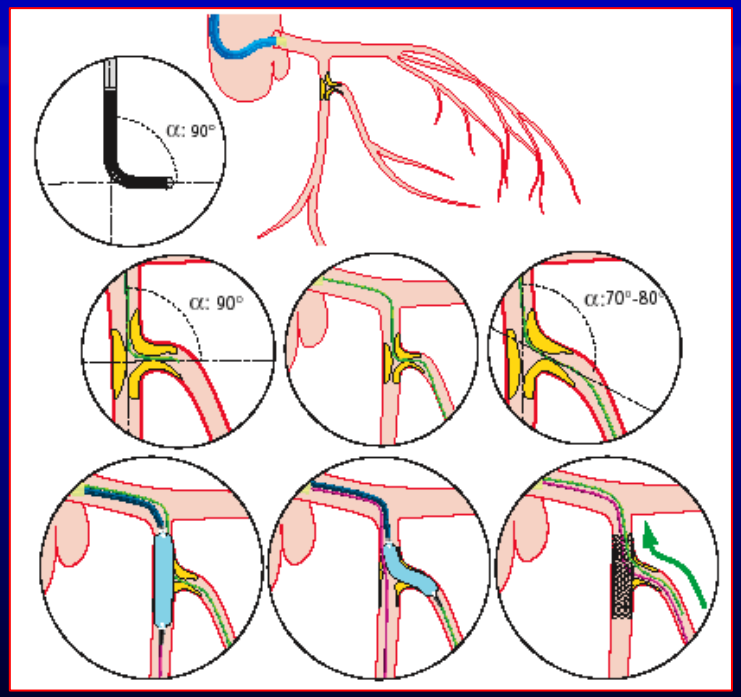
Pre-dilatation *with Kissing Balloon* it avoids closure of side branch (or main vessel) by plaque shift





Common Approaches to Bifurcation Lesions: the Role of Jailed Wire

- Guide wire is left inside the side branch during main vessel stenting
- Side branch guide wire is jailed between main vessel stent struts and main vessel wall



- Used in T shaped Bifurcations in order to favorably modify the angle between the two vessels thus facilitating side branch re-wiring
- Helps to maintain side branch patency
- In case of side branch closure assures side branch traceability by radiopaque distal wire

Jailed Wire Effect on Proximal Main Branch/Side Branch Angle

	Baseline	Wiring	° modification	p value
Angle "A" > 120° (%)	77	87	-	<0.02
Angle A (°)	149±17	160±18	+ 11	<0.001
Angle "A" ≤ 120° (%)	23	13	-	<0.02
Angle A (°)	107±11	140±19	**+ 33**	<0.001

Y. Louvard, T. Lefèvre TCT 2003

Angiographic Predictors of Side Branch Success (Lesion <50% by QCA)

Age (years)	66±11 vs 57±8	p=0.0007
Larger MB reference (mm)	3.1±0.4 vs 2.8±0.3	p=0.0085
Larger SB reference (mm)	2.5±0.5 vs 2.2±0.3	p=0.0413
Kissing balloon (%)	98.1 vs 76.5	p=0.0019
"Jailed wire technique" (%)	92.9 vs 71.4	p=0.031

T. Lefèvre, Y. Louvard, 2003