Al-Azhar International Medical Journal

Volume 3 | Issue 10 Article 28

10-1-2022

Behavior of restenosis after distal unprotected bifurcation left main coronary artery stenting

Ezz-eldein El-sawy
Cardiology Department, Faculty of Medicine, Al-Azhar University, Cairo, Egypt, ezzeldein@gmail.com

Khaled Al Merry
Kuwait Heart Center, Chest Disease Hospital, Kuwait, khaled.merry@gmail.com

Ahmed Hassanin
Kuwait Heart Center, Chest Disease Hospital, Kuwait, ahmedhassanin7788@gmail.com

Ehab Al-hefny
Cardiology Department, Faculty of Medicine, Al-Azhar University, Cairo, Egypt, ehab.hefny@gmail.com

How to Cite This Article

El-sawy, Ezz-eldein; Al Merry, Khaled; Hassanin, Ahmed; and Al-hefny, Ehab (2022) "Behavior of restenosis after distal unprotected bifurcation left main coronary artery stenting," *Al-Azhar International Medical Journal*: Vol. 3: Iss. 10, Article 28.
DOI: https://doi.org/10.21608/aimj.2022.131347.1899

OPEN AIMJ ORIGINAL ARTICLE

Behavior of Restenosis After Distal Unprotected Bifurcation Left Main Coronary Artery Stenting

Cardiology

Ezz-eldein A. El-sawy [1] MD; Khaled Al Merry [2]MD ; Ahmed H. Hassanin [2*]MSc and Ehab A. Al-hefny [1]MD

Corresponding Author:
Ahmed H. Hassanin
ahmedhassanin430@yahoo.com

Received *for publication April 18, 2022;* ***Accepted*** *October 26, 2022;* ***Published online*** *October 26,2022.*

doi: *10.21608/aimj.2022.131347.1899*

Citation: *Mohamed S. , Abdallah M. and Behavior of Restenosis After Distal Unprotected Bifurcation Left Main Coronary Artery Stenting. AIMJ. 2022; Vol.3-Issue 10 : 174-181.*

[1]Cardiology Department, Faculty of Medicine, Al-Azhar University, Cairo , Egypt.

[2]Kuwait Heart Center, Chest Disease Hospital, Kuwait.

ABSTRACT

Background: There is controversy concerning the optimal stenting strategy in distal unprotected left main coronary artery (ULMCA) stenosis.
Aim of The Work: To compare provisional stenting (PS), double kissing (DK) crush, and T and protrusion (TAP) stenting techniques in distal ULMCA stenosis.
Patients and Methods: This cohort study enrolled 150 patients scheduled for percutaneous coronary intervention (PCI) and stenting with PS, TAP, and DK crush techniques. Quantitative coronary angiography (QCA) assessment was done for distal left main (LM), left circumflex (LCX), and left anterior descending (LAD) arteries pre-PCI, post-PCI, and during follow-up.
Results: Post-PCI QCA revealed a significantly higher median percentage of in-stent residual stenosis in PS compared to TAP and DK crush groups in the distant LM (3.2% vs. 2 and 2.1%, p=0.001) and proximal LAD (2.5% vs. 1.8 and 2.4%, p=0.022, respectively), but not in LCX (p=0.185). Twelve-months later, no significant differences of in-stent restenosis percentage in distant LM and proximal LAD were observed, while the PS group had a significantly higher in-stent restenosis percentage of proximal LCX (21.5 vs. 12 and 11%, respectively, p<0.001). The time to revascularization was significantly shorter in PS than TAP and DK groups (p=0.008).
Conclusion: TAP and DK crush techniques are recommended over PS in proximal LCX. PS or two-stent techniques can be used in distal LM and proximal LAD without significant differences in restenosis. Further studies are needed to confirm the superiority of two-stent techniques over the PS in individual vessels.

Keywords: *provisional stenting; left main coronary artery; two-stenting technique; percutaneous coronary intervention; quantitative coronary angiography.*

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*
Authorship: *All authors have a substantial contribution to the article.*

INTRODUCTION

The left main coronary artery (LMCA) arises from the left coronary sinus and gives off two main branches in most individuals: the left anterior descending (LAD) and left circumflex (LCX) arteries. Unprotected LMCA (ULMCA) disease is a condition of significant LMCA stenosis without earlier coronary artery bypass surgery (CABG) or patent bypass grafts of the LAD or LCX arteries.[1]

The optimal strategy of stenting is a major issue in treating distal ULMCA stenosis. A small number of studies addressed this issue. They compared the available treatment approaches and reported controversial results.[2, 3] For most coronary bifurcation lesions, the provisional stenting (PS) technique is recommended. However, the two-stent techniques could be a better choice for lesions with diseased large side branch (SB).[4] The most used two-stent strategies are T-stenting, T and protrusion (TAP), culotte, double kissing (DK) crush, and classic crush techniques.[5] The present study aimed to compare PS, TAP, and DK crush in distal ULMCA stenting.

PATIENTS AND METHODS

The study protocol obtained approval from the Ethics Committees of both the Faculty of Medicine, Al Azhar University, Egypt and Kuwait Heart Center, Chest Disease Hospital, Kuwait. Written consents were obtained from all participants after receiving full information about the study. Patients' confidentiality was maintained by assigning specific codes to patients and keeping the records anonymous.

This cohort study included 150 patients who were enrolled from the chest hospital (Kuwait Heart Center, a tertiary care referral center for interventional cardiology) and Al –Salam International Hospital in Kuwait from the 1st of May 2018 to the 31st of October 2020.

Patients with distal LM bifurcation lesion were referred for coronary angiography due to stable or unstable angina (UA) or non-ST-segment elevation myocardial infarction (NSTEMI).

We excluded patients who had cardiogenic shock, acute STEMI, isolated ostial and midshaft LMCA stenting, or severely calcified LMCA lesions requiring atherectomy. Patients who had any condition preventing compliance to therapy or prolonged follow-up were also excluded.

The patients were divided into two main groups: one stent group done for 50 patients with PS technique and two stent groups subdivided into 50 patients with TAP technique and 50 patients with DK-crush technique. For both one- and two-stent strategies, we used the proximal optimization technique (POT) for all LMCA stents, and post-dilation of all stents with non-compliant balloons at/or more than 18 atmospheric pressure.

All patients underwent history taking and received standard PCI periprocedural care according to the guidelines.

The radial or femoral artery was accessed using the modified Seldinger technique and a 6F sheath over a guidewire. Left and right coronary angiography was carried out. Eligible patients were assigned to PS, TAP, or DK crush strategy based on the lesion characteristics and according to the standard guidelines. Using the intravascular ultrasound (IVUS) was determined based on the operator standpoint.

Based on the recent guidelines, all patients received dual antiplatelet drugs with additional medications for secondary prevention. The patients were followed-up during their visits to the outpatient clinic or at ER at 1, 6, and 12 months. For all patients, follow-up with coronary angiography was scheduled at 12-months following the index procedure. Angiograms were obtained in multiple views using visual analysis and offline quantitative coronary angiography (QCA) by an expert operator. The usage of IVUS was according to the operator decision. Angiography assessed the following: a) lesion length; b) minimal lumen diameter (MLD); c) MB reference diameter; d) SB reference diameter; and e) MB and SB TIMI flow before and after the procedure.

We used the SPSS software (v. 26). We used the Shapiro-Wilk test to assess normality of quantitative data. We presented the normally distributed data as mean and standard deviation (SD) and compared them with one-way analysis of variance test, then with the post-hoc Tukey's test if found significant. Data that were not normally distributed were presented as median and interquartile range (IQR) and were compared with the Kruskal-Wallis test, then by Dunn-Bonferroni test if found significant. Qualitative data were presented as frequencies, and group comparison was tested with the Pearson's Chi-square or Fisher-Freeman-Halton Exact tests. Kaplan-Meier analysis was used to assess the effect of stent technique on time to revascularization. Significance was adopted at p-value < 0.05.

RESULTS

The three groups were comparable regarding patients' age, sex, and body mass index (all p>0.05). Hypertension and smoking were significantly less prevalent in the TAP group compared to the PS and DK crush groups (p=0.004 and 0.009, respectively). Diabetes mellitus (DM) and chronic obstructive pulmonary disease (COPD) were significantly more prevalent in the DK crush group compared to PS and TAP groups (p=0.010 and 0.009, respectively). The ejection fraction (EF) was not significantly different among the studied groups (p=0.976). The most frequent clinical presentation was UA (p=0.127). A significantly greater percentage of patients in the DK crush group had an SYNTEX I score >32 (60% vs. 20% and 40% in PS and TAP groups, respectively, p<0.001).

The radial approach was used in most patients (p=0.109). Ticagrelor was the most prescribed antiplatelet medication (p=0.123). No complications were reported in any group. The percentages of stent covered ostial LM and the use of IVUS did not show significant differences across the groups (p=0.353; Figure 1).

The procedure showed significantly lower success in the PS group when compared to either the TAP or the DK crush groups as regards the distant LM (97 vs. 97.9 and 98, respectively, p=0.001), and was lower than the TAP regarding proximal LAD (96.9 vs. 98, p=0.003). We observed no significant difference in procedure success among the three groups in proximal LCX (p=0.215, Figure 2).

The mean length of MB and SB was significantly shorter in the PS group (p=0.016 and p<0.001, respectively). The bifurcation angle before PCI was significantly narrower in the DK crush group compared to PS and TAP groups (p<0.001). The mean pre-PCI MLD and stenosis percentage of distal LM was not significantly different among the three groups (all p>0.05). Post-procedure, the PS group showed a non-significantly lower mean acute gain but a significantly greater percentage of in-stent residual stenosis compared to the TAP and DK crush groups (p=0.002 and p=0.001, respectively; Table 2). Follow-up QCA was not significantly different among the three groups regarding the net gain or in-stent restenosis (p>0.05).

The mean pre-PCI MLD and stenosis percentage of LAD did not significantly differ across the groups (p>0.05). Post-procedure, the PS group had a significantly lower mean acute gain (p=0.034) and a higher percentage of in-stent residual stenosis (p=0.022) than the TAP group. On follow-up, the three groups were comparable regarding net gain and in-stent restenosis percentage (p>0.05; Table 3).

Before PCI, the PS group showed a significantly higher mean MLD and lower stenosis percentage (p<0.001). Post-procedure, the mean acute gain was significantly lowest in the PS group, followed by the DK crush, then the TAP group (p<0.001). We did not observe any significant difference in post-dilatation residual stenosis (p=0.185). Follow-up revealed that the PS group had a significantly less net gain (p<0.001) as well as a significantly higher median in-stent restenosis percentage (p<0.001; Table 4) than the two-stent groups which both were comparable.

Most patients did not experience cardiovascular complaints. However, a slightly higher percentage in the PS group presented with NSTEMI and UA compared to the other two groups (p=0.233). The use of IVUS was significantly greater in the PS group (24% vs 8% and 10%, respectively, p=0.043). Target lesion failure (TLF) showed a significantly greater incidence in the PS group (28% vs. 12 and 8%, respectively, p=0.016). The revascularization time was shorter in the PS group compared to the TAP and DK groups (p=0.008; table 5). A finding that was demonstrated also by the Kaplan-Meier time-to-revascularization curves (Figure 3).

		Provisional (n = 50)	TAP (n = 50)	DK crush (n = 50)	Test statistic	p
Age (years)	Mean ± SD (Min-Max)	62.5 ± 7.5 (44.0 - 78.0)	61.5 ± 6.5 (45.0 - 72.0)	60.5 ± 8.4 (42.0 - 78.0)	F = 0.908	0.405
Gender	Female	8 16.0%	5 10.0%	5 10.0%	X^2 =1.136	0.567
	Male	42 84.0%	45 90.0%	45 90.0%		
BMI (Kg/m^2)	Mean ± SD (Min-Max)	28.4 ± 2.6 (23.7 - 34.3)	29.1 ± 3.0 (23.6 - 35.6)	28.0 ± 2.2 (22.7 - 33.0)	F = 2.275	0.106
Medical history	Dyslipedemic	37 74.0%	26 52.0%	28 56.0%	X^2 = 5.755	0.056
	Hypertension	44 88.0%	30 60.0%$	39 78.0%	X^2 = 10.835	0.004*
	DM	13 26.0%	14 28.0%	26 52.0%$	X^2 = 9.162	0.010*
	Smoker	26 52.0%	16 32.0%$	31 62.0%	X^2 = 9.340	0.009*
	PVD	6 12.0%	8 16.0%	8 16.0%	X^2 = 0.426	0.808
	Prior stroke	3 6.0%	6 12.0%	4 8.0%	X^2 = 1.150	0.672
	Prior MI	12 24.0%	11 22.0%	9 18.0%	X^2 = 0.556	0.757
	Prior PCI	12 24.0%	14 28.0%	9 18.0%	X^2 = 1.416	0.493
	Prior CABG	0 0.0%	0 0.0%	0 0.0%	NA	NA
	CKD	6 12.0%	6 12.0%	9 18.0%	X^2 = 0.997	0.608
	COPD/BA	2 4.0%	5 10.0%	12 24.0%$	X^2 = 9.522	0.009*
EF (%)	Mean ± SD (Min-Max)	61.0 ± 9.5 (25.0 - 72.0)	61.0 ± 15.0 (25.0 - 78.0)	60.6 ± 11.0 (29.0 - 72.0)	F = 0.025	0.976
Clinical presentation	NSTEMI	9 18.0%	14 28.0%	17 34.0%	X^2 = 7.181	0.127
	SA	15 30.0%	14 28.0%	6 12.0%		
	UA	26 52.0%	22 44.0%	27 54.0%		
SYNTEX I	<32	40 80.0% $	30 60.0%	20 40.0% $	X^2 = 16.667	<0.001*
	>32	10 20.0% $	20 40.0%	30 60.0% $		

Table 1: Baseline characteristics of the studied groups (total n = 150)

a: significant difference from provisional group; b: significant difference from TAP group; c: significant difference from DK crush group; CABG: coronary artery bypass graft; CKD: chronic kidney disease; COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; EF: ejection fraction; F: One-way ANOVA; IQR: Interquartile range; Max: maximum; MI: myocardial infarction; Min: minimum; n: number; PCI: percutaneous coronary intervention; PVD: peripheral vascular disease; SD: standard deviation; X2: Pearson's Chi-square test/ Fisher-Freeman-Halton exact test; Z: Kruskal-Wallis test; * significant at p<0.05; $: significant difference from the other groups.

	Provisional (n = 50)	TAP (n = 50)	DK crush (n = 50)	Test statistic	p
Pre-PCI Main vessel length Mean ± SD (Min – Max)	14.6 ± 5.1 b (8.0 - 33.0)	17.7 ± 5.3 a (8.0 - 34.0)	16.1 ± 5.4 (7.0 - 27.0)	F = 4.278	0.016*
Pre-PCI SB lesion length Mean ± SD (Min – Max)	8.0 ± 4.0 b,c (4.0 - 16.0)	14.7 ± 3.9 a (8.0 - 23.0)	13.4 ± 4.2 a (7.0 - 26.0)	F = 37.935	<0.001*
Main Vessel stent length Mean ± SD (Min – Max)	21.1 ± 5.8 (12.0 - 38.0)	21.7 ± 5.2 (15.0 - 38.0)	19.9 ± 5.8 (12.0 - 32.0)	F = 1.424	0.244
Main Vessel. stent diameter Mean ± SD (Min – Max)	3.3 ± 0.2 (3.0 - 3.5)	3.4 ± 0.2 (3.0 - 3.5)	3.3 ± 0.2 (3.0 - 3.5)	F = 2.112	0.125
SB stent length Mean ± SD (Min – Max)	.	15.6 ± 4.2 (8.0 - 23.0)	16.1 ± 4.3 (12.0 - 28.0)	F = 0.404	0.527
SB stent diameter Mean ± SD (Min – Max)	.	2.9 ± 0.2 (2.5 - 3.3)	2.8 ± 0.2 (2.5 - 3.3)	F = 3.047	0.084
Bifurcation angle (degrees)					
Pre-procedure **Median [IQR] (Min – Max)**	82.0 c [77.0 - 90.0] (66.0 - 105.0)	79.0 c [75.0 - 82.0] (72.0 - 90.0)	59.5 a,b [55.0 - 66.0] (49.0 - 69.0)	Z = 100.276	<0.001*
Post-procedure **Median [IQR] (Min – Max)**	79.0 c [74.0 - 87.0] (64.0 - 103.0)	76.0 c [72.0 - 80.0] (67.0 - 88.0)	57.0 a,b [53.0 - 64.0] (47.0 - 68.0)	Z = 98.624	<0.001*
DISTAL LM					
RD Mean ± SD (Min – Max)	3.8 ± 0.2 b,c (3.3 - 4.2)	3.9 ± 0.2 a (3.4 - 4.3)	3.9 ± 0.2 a (3.5 - 4.3)	F = 3.457	0.034*
MLD (mm)					
Pre-PCI	0.8 ± 0.4	0.9 ± 0.3	0.9 ± 0.3	F = 1.658	0.196

Mean ± SD (Min – Max)	(0.4 - 1.6)	(0.4 - 1.5)	(0.4 - 1.5)		
Post-PCI	3.7 ± 0.2 b,c	3.8 ± 0.2 a	3.8 ± 0.2 a	F = 6.620	0.002*
Mean ± SD (Min – Max)	(3.2 - 4.0)	(3.3 - 4.3)	(3.4 - 4.3)		
Acute gain	2.8 ± 0.3	2.8 ± 0.3	2.8 ± 0.3	F = 0.190	0.827
Mean ± SD (Min – Max)	(2.0 - 3.4)	(2.4 - 3.6)	(2.4 - 3.4)		
Follow-up	3.1 ± 0.6	3.2 ± 0.6	3.2 ± 0.5	F = 0.467	0.628
Mean ± SD (Min – Max)	(1.0 - 3.8)	(0.8 - 3.9)	(1.1 - 4.0)		
Late loss	0.4 [0.3 - 0.6]	0.5 [0.3 - 0.7]	0.4 [0.3 - 0.6]	Z = 2.833	0.243
Median [IQR] (Min – Max)	(0.1 - 2.4)	(0.2 - 2.8)	(0.2 - 2.4)		
Net gain	2.3 ± 0.6	2.2 ± 0.6	2.3 ± 0.5	F = 0.187	0.830
Mean ± SD (Min – Max)	(0.3 - 3.0)	(0.1 - 3.4)	(0.2 - 3.0)		
Stenosis (%)					
Pre-PCI	77.8 ± 9.0	75.4 ± 6.4	75.6 ± 6.2	F = 1.308	0.275
Mean ± SD (Min – Max)	(60.0 - 89.0)	(65.0 - 90.0)	(65.0 - 90.0)		
Post-PCI	3.2 b,c [1.7 - 4.1]	2.0 a [1.1 - 3.1]	2.1 a [1.2 - 2.6]	Z = 13.105	0.001*
Median [IQR] (Min – Max)	(0.5 - 7.8)	(0.5 - 5.2)	(0.5 - 3.9)		
Follow-up (in-stent restenosis)	13.0 [9.0 - 20.0]	14.0 [11.0 - 20.0]	13.0 [11.0 - 19.0]	Z = 0.583	0.747
Median [IQR] (Min – Max)	(5.0 - 70.0)	(7.0 - 77.0)	(5.0 - 70.0)		

Table 2: QCA assessment of lesion length (main branch and side branch), bifurcation angle and distal LM (total n = 150)

a: significant difference from provisional group; b: significant difference from TAP group; c: significant difference from DK crush group; F: One-way ANOVA; IQR: Interquartile range; LAD: left anterior descending; LCX: left circumflex; LM: left main; Max: maximum; Min: minimum; MLD: minimal lumen diameter; n: number; RD: reference diameter; SB: side branch; SD: standard deviation; Z: Kruskal-Wallis test; * significant at p<0.05.

	Provisional (n = 50)	**TAP (n = 50)**	**DK crush (n = 50)**	**Test statistic**	**p**
Proximal LAD					
RD	3.3 ± 0.2	3.4 ± 0.2	3.3 ± 0.2	F = 2.804	0.064
Mean ± SD (Min – Max)	(2.8 - 3.7)	(3.0 - 3.7)	(3.0 - 3.6)		
MLD (mm)					
Pre-PCI	0.7 ± 0.2	0.7 ± 0.3	0.6 ± 0.2	F = 1.997	0.141
Mean ± SD (Min – Max)	(0.3 - 1.1)	(0.2 - 1.1)	(0.3 - 1.1)		
Post-PCI	3.2 ± 0.2 b	3.3 ± 0.2 a	3.2 ± 0.3	F = 4.176	0.017*
Mean ± SD (Min – Max)	(2.7 - 3.6)	(2.9 - 3.6)	(2.8 - 3.6)		
Acute gain	2.5 ± 0.2 b	2.6 ± 0.3 a	2.6 ± 0.3	F = 3.474	0.034*
Mean ± SD (Min – Max)	(2.1 - 3.0)	(2.0 - 3.2)	(1.9 - 3.1)		
Follow-up	2.7 ± 0.6	2.8 ± 0.5	2.7 ± 0.5	F = 0.256	0.775
Mean ± SD (Min – Max)	(0.8 - 3.3)	(0.7 - 3.2)	(1.1 - 3.3)		
Late loss	0.4 [0.2 - 0.6]	0.4 [0.3 - 0.6]	0.4 [0.3 - 0.6]	Z = 3.135	0.209
Median [IQR] (Min – Max)	(0.1 - 2.5)	(0.2 - 2.6)	(0.1 - 1.8)		
Net gain	2.0 ± 0.5	2.0 ± 0.5	2.1 ± 0.5	F = 0.620	0.540
Mean ± SD (Min – Max)	(0.2 - 2.5)	(0.0 - 2.9)	(0.3 - 2.8)		
Stenosis (%)	78.3 ± 6.2	78.9 ± 7.2	80.4 ± 5.4	F = 1.378	0.255
	(67.0 - 90.0)	(68.0 - 95.0)	(67.0 - 90.0)		
Pre-PCI	78.3 ± 6.2	78.9 ± 7.2	80.4 ± 5.4	F = 1.378	0.255
Mean ± SD (Min – Max)	(67.0 - 90.0)	(68.0 - 95.0)	(67.0 - 90.0)		
Post-PCI	2.5 b [1.6 - 4.3]	1.8 a [1.1 - 2.8]	2.4 [1.2 - 4.0]	Z = 7.598	0.022*
Median [IQR] (Min – Max)	(0.3 - 10.3)	(0.3 - 4.6)	(0.3 - 7.0)		
Follow-up (in-stent restenosis)	14.0 [10.0 - 20.0]	14.0 [12.0 - 20.0]	15.0 [12.0 - 20.0]	Z = 1.133	0.568
Median [IQR] (Min – Max)	(6.0 - 77.0)	(8.0 - 80.0)	(5.0 - 65.0)		

Table (3): QCA assessment of proximal LAD (total n = 150)

a: significant difference from provisional group; b: significant difference from TAP group; c: significant difference from DK crush group; F: One-way ANOVA; IQR: Interquartile range; LAD: left anterior descending; LCX: left circumflex; LM: left main; Max: maximum; Min: minimum; MLD: minimal lumen diameter; n: number; SD: standard deviation; Z: Kruskal-Wallis test; * significant at p<0.05.

	Provisional (n = 50)	**TAP (n = 50)**	**DK crush (n = 50)**	**Test statistic**	**p**
Proximal LCX					
RD	2.8 ± 0.2 b	2.9 ± 0.2 a,c	2.8 ± 0.2 b	F = 6.989	0.001*
Mean ± SD (Min – Max)	(2.5 - 3.2)	(2.5 - 3.3)	(2.5 - 3.3)		
MLD (mm)					
Pre-PCI	1.4 ± 0.5 b,c	0.7 ± 0.2 a	0.7 ± 0.2 a	F = 49.170	<0.001*
Mean ± SD (Min – Max)	(0.3 - 2.0)	(0.3 - 1.1)	(0.3 - 1.1)		
Post-PCI	2.7 ± 0.2 b	2.8 ± 0.2 a,c	2.7 ± 0.2 b	F = 8.402	<0.001*
Mean ± SD (Min – Max)	(2.4 - 3.1)	(2.5 - 3.2)	(2.4 - 3.2)		
Acute gain	1.4 ± 0.5 b,c	2.2 ± 0.2 a,c	2.1 ± 0.3 a,b	F = 66.103	<0.001*
Mean ± SD (Min – Max)	(0.6 - 2.3)	(1.6 - 2.8)	(1.7 - 2.7)		
Follow-up	1.8 ± 0.8 b,c	2.3 ± 0.6 a	2.4 ± 0.4 a	F = 11.238	<0.001*

Mean ± SD (Min – Max)	(0.0 - 2.8)	(0.6 - 3.0)	(0.8 - 3.1)		
Late loss	0.5 b,c [0.3 - 2.0]	0.3 a [0.2 - 0.6]	0.3 a [0.1 - 0.4]	Z = 24.204	<0.001*
Median [IQR] (Min – Max)	(0.1 - 2.5)	(0.0 - 2.4)	(0.0 - 1.9)		
Net gain	0.6 b,c [-0.1 - 1.1]	1.8 a [1.5 - 2.0]	1.7 a [1.5 - 2.0]	Z = 71.926	<0.001*
Mean ± SD (Min – Max)	(-1.4 - 1.6)	(-0.3 - 2.4)	(-0.1 - 2.6)		
Stenosis (%)					
Pre-PCI	51.3 ± 16.3 b,c	77.3 ± 6.7 a	75.4 ± 7.8 a	F = 54.464	<0.001*
Mean ± SD (Min – Max)	(27.0 - 90.0)	(65.0 - 91.0)	(65.0 - 90.0)		
Post-PCI	2.0 [1.5 - 2.9]	1.5 [1.1 - 2.9]	2.4 [1.1 - 3.9]	Z = 3.379	0.185
Median [IQR] (Min – Max)	(0.7 - 7.0)	(0.6 - 5.7)	(0.4 - 7.0)		
Follow-up (in-stent restenosis)	21.5 b,c [12.0 - 75.0]	12.0 a [9.0 - 21.0]	11.0 a [8.0 - 17.0]	Z = 26.178	<0.001*
Median [IQR] (Min – Max)	(6.0 - 100.0)	(4.0 - 80.0)	(4.0 - 70.0)		

Table 4: QCA assessment of proximal LCX (total n = 150)

a: significant difference from provisional group; b: significant difference from TAP group; c: significant difference from DK crush group; F: One-way ANOVA; IQR: Interquartile range; LAD: left anterior descending; LCX: left circumflex; LM: left main; Max: maximum; Min: minimum; MLD: minimal lumen diameter; n: number; RD: reference diameter; SB: side branch; SD: standard deviation; Z: Kruskal-Wallis test; * significant at p<0.05.

		Provisional (n = 50)		TAP (n = 50)		DK crush (n = 50)		Test statistic	p
Clinical presentation	Follow-up	33	66.0%	42	84.0%	43	86.0%	X^2 = 9.592	0.233
	NSTEMI	5	10.0%	1	2.0%	1	2.0%		
	SA	6	12.0%	4	8.0%	4	8.0%		
	STEMI	1	2.0%	0	0.0%	1	2.0%		
	UA	5	10.0%	3	6.0%	1	2.0%		
Method of lesion assessment	QCA	50	100.0%	50	100.0%	50	100.0%		
IVUS use during follow-up		12	24.0%$	4	8.0%	5	10.0%	X^2 = 6.312	0.043*
Target lesion failure		14	28.0%$	6	12.0%	4	8.0%	X^2 = 8.333	0.016*
Non-related lesion	No	48	96.0%	48	96.0%	47	94.0%	X^2 = 0.429	1.000
	Yes	2	4.0%	2	4.0%	3	6.0%		
Revascularization time (months)	Median [IQR] (Min-Max)		12.0 b,c [9.0 - 12.0] (3.0 - 12.0)		12.0 a [12.0 - 12.0] (6.0 - 12.0)		12.0 a [12.0 - 12.0] (6.0 - 12.0)	Z = 9.622	0.008*

Table 5: Clinical presentation and assessment on follow-up

a: significant difference from provisional group; b: significant difference from TAP group; c: significant difference from DK crush group; IQR: Interquartile range; IVUS: intravascular ultrasound; n: number; X2: Pearson's Chi-square test/Fisher/Freeman-Halton exact test; Z: Kruskal-Wallis test; * significant at p <0.05; $: significant difference from other groups.

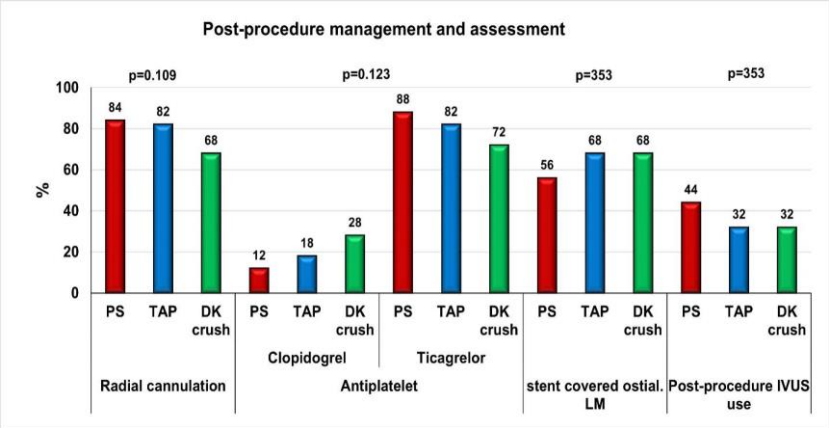

Fig. 1: Post-procedure management and assessment (total n = 150). IVUS: intravascular ultrasound.

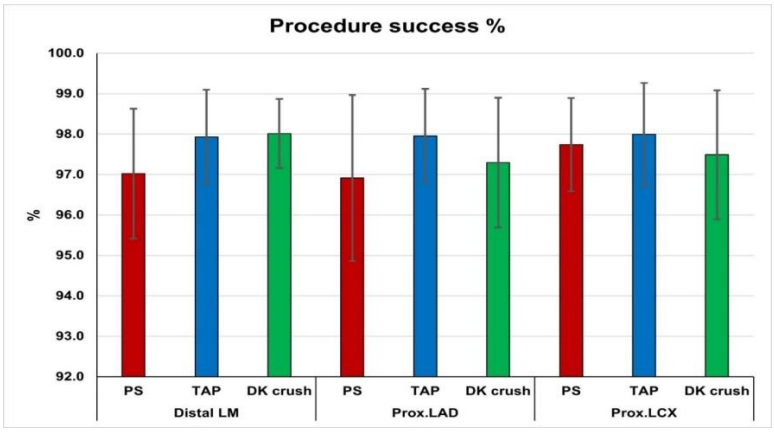

Fig. 2: Success rate of the procedure in the studied groups (total n = 150).

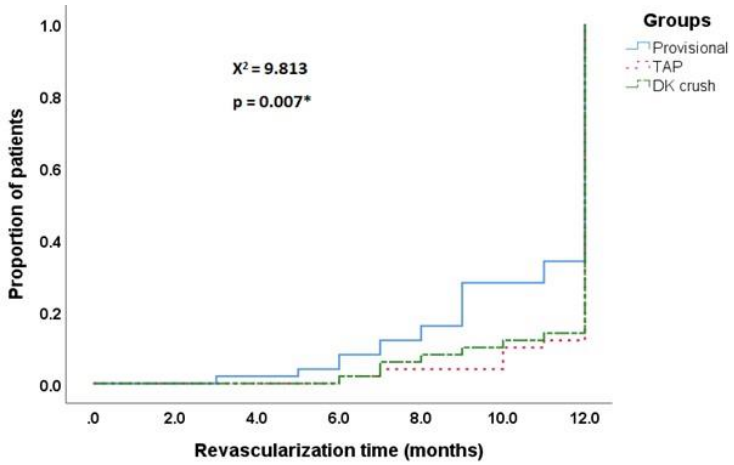

Fig. 3: Kaplan-Meier curve for time-to-revascularization (X2: Log-rank test).

DISCUSSION

Clinical trials comparing QCA of PCI techniques reported mixed results.[2, 3] Currently, PS is recommended for most cases of bifurcation lesions.[6] The DK-crush technique was superior to a PS strategy in LM bifurcation lesions,[7] and it was therefore included in the European myocardial revascularization guidelines for LM bifurcation lesions.[8]

We found no significant differences regarding most of the baseline characteristics. This agrees with findings reported by previous studies.[9-12] However, hypertension and smoking – which are conventional risk factors of ULMCA[13] – were significantly less prevalent among the TAP group compared to the PS and DK crush groups. Furthermore, DM was more prevalent in the DK crush group compared to PS and TAP groups.

We found a higher percentage of patients in the DK crush group with an SYNTEX I score>32. This finding agrees with Chen et al.[7] who found that patients with a score>32 were treated with the DK crush technique and showed better clinical outcomes. SYNTAX score>32 represents the complexity of ULMCA lesions. Hence, DK crush could be superior to PS stenting for complex as well as high-risk bifurcation lesions. Meanwhile, recommendations from recent guidelines recognize PS for patients with LMCA stenosis and low (<22) SYNTAX scores.[8] The planned two-stent technique was found to be better than the PS technique in patients with distal LM bifurcation complex lesions, but in the presence of small SBs and for simple lesions with the plaque involving predominantly the MB, the PS approach may be desirable.[7]

In this study, the bifurcation angle in the DK crush group was lower than that in the PS and TAP groups. The TAP technique is suited for 90˚ bifurcation angles. Our result coincides with Chen et al.[7] who concluded that PS and TAP techniques are preferable for wide bifurcation angles while DK crush is suitable for narrow angles.

In this study, the vessel length before the procedure was shorter in the PS group compared to the TAP group. The mean length of SB lesion was significantly longer in TAP and DK groups than in the PS group. However, no significant difference was observed post-procedure in the mean MB stent length and diameter nor the SB stent length and diameter.

No complications were reported in any of the three groups. Likewise, the percentage of stent-covered ostial LM was not significantly different. The most common site for in-stent restenosis during ULMCA stenting is the circumflex ostium. The DK crush technique provides better stent expansion and ensures coverage of the SB ostium.[14] Meanwhile, during the TAP technique the SB stent is implanted with a slight protrusion into the main vessel. Added to its technical simplicity, the TAP technique combines optimal SB coverage with little anatomical distortion throughout the entire bifurcation.[15]

After PCI in the present study, QCA showed that the MLD of distal LM, proximal LAD, and proximal LCX improved than the pre-procedure values in the three groups. The PS group had a less acute gain at distal LM (though not statistically significant) as well as proximal LAD and LCX (which was statistically significant). The TAP technique showed a significantly higher acute gain at proximal LCX than the DK group. The median percentages of residual stenosis for distal LM and proximal LAD in the TAP group were better than both DK and PS groups, while no difference was detected in proximal LCX. These findings coincide with Ruiz-Salmerón et al.[15] who found that T-stenting lacked clinical and angiographic advantages compared to the simple strategy.

In the present study, the procedure success was significantly lower in the PS group compared to TAP and DK crush groups as regards the distant LM and was lower compared to TAP regarding proximal LAD. Meanwhile, procedure success did not significantly vary in proximal LCX across the three groups. This finding partially agrees with Yamashita et al.[16] who found that the stenting both vessels had no advantage over stenting only the parent vessel regarding the procedural success and late outcome. Meanwhile, Chen et al.[7] showed no difference regarding the procedure success between PS and DK techniques. Success is influenced by several factors including not only the operator experience but also the availability of dedicated equipment.[17]

Our result showed a greater incidence of TLF in the PS group compared with both the TAP stenting strategy and DK crush. These results correspond to findings of a randomized clinical trial on non-LM coronary bifurcation lesions where the planned DK crush two-stent strategy was associated with lesser rates of TLR compared with the PS procedure.[18] This also agrees with Aldujeli et al.[19] who found that at two-years follow-up, the planned TAP stenting technique was associated with a lower rate of TLF compared with the DK crush strategy. Chen et al.[7] found that TLF may bear a relation to the distal LM segment anatomy. Compared with non-LM bifurcation lesions, the true distal LM bifurcation lesions usually affect larger blood vessels and have a wider bifurcation angle. In addition, they commonly involve 3 vessel segments.[20, 21] Meanwhile, the PS technique may entail crossover to a second stent in a large percentage of cases, besides a reported failure of second stent delivery in about 9% of patients. Furthermore, during treatment of complex coronary bifurcations, the PS technique was reported to have greater rates of clinical recurrence compared to the two-stent strategy.[7]

In the current study, QCA at 12 months showed similar rates of in-stent restenosis among the three stenting techniques in distal LM and proximal LAD. However, the rate of restenosis of proximal LCX was higher in PS compared to TAP and DK crush groups. On the other hand, a multicenter study reported that PCI of true distal lesions of the LM bifurcation performed with a planned DK technique had a lower TLF rate at one year compared to a PS strategy.[22] The DKCRUSH-II study that was conducted on unselected patients with coronary bifurcation lesions indicated that the DK crush technique was associated with reduced MB and SB restenosis and lowered TLR.[7] Ye et al.[23] reported a significant TLR reduction with the DK-Crush technique compared to the PS strategy. The DK-Crush is associated with higher rates of FKB inflation, which allow for a greater acute gain and lowered late loss of SB fractional flow reserve.

Previous studies showed that the different two-stent strategies (T-stenting, V-stenting, and crush stenting) provided comparable outcomes, without significant differences in terms of mortality, cardiac mortality, MI, TLR, and restenosis. Therefore, there seems to be no basis to prefer one two-stenting technique rather than another.[24] This accords with our findings where TAP and DK crush strategies were comparable regarding restenosis of distal LM and proximal LAD, as well as TLR.

Deciding to use a particular technique for management of distal ULMCA stenosis is a challenge. Several factors should be considered including the bifurcation angle, the degree of the lesion, and the disease extension in the LM carina. Also, the involvement and the diameter of the LCX as well as the relation between the diameter of the LM and the diameter of the stemming arteries need to be taken into account in this decision making.[24]

CONCLUSION

The use of TAP or DK techniques is recommended over the PS in the case of proximal LCX, as both techniques showed comparable results. However, in cases of distal LM and proximal LAD, PS or two-stent techniques can be used without significant differences in terms of restenosis. The interpretation requires caution because this is not a randomized trial. Therefore, the outcomes may have been impacted by complexity of the lesion. However, the importance of this study emerges from revealing that the strategy of stenting should be carefully considered when deciding the policy of revascularization or assessing the outcome differences between various PCI stenting techniques. Future randomized clinical trials need to be conducted to verify the superiority of two-stent techniques relative to PS in individual vessels.

Conflict of interest : none

REFERENCES

1. Kuchulakanti PK. Left Main PCI—Current Evidence, Techniques, and Triumph. *Indian J Clin Cardiol.* 2020;1:86-93.
2. Lin QF, Luo YK, Lin CG, Peng YF, Zhen XC, *et al.* Choice of stenting strategy in true coronary artery bifurcation lesions. *Coron Artery Dis*. 2010;21:345-51.
3. Hildick-Smith D, de Belder AJ, Cooter N, Curzen NP, Clayton TC, *et al.* Randomized trial of simple versus complex drug-eluting stenting for bifurcation lesions: the British Bifurcation Coronary Study: old, new, and evolving strategies. *Circulation*. 2010;121:1235-43.
4. Burzotta F, Trani C. Technical Aspects of Provisional Stenting in Percutaneous Treatment of Complex Bifurcation Lesions. *Interv Cardiol.* 2013;8:96-9.
5. Raphael CE, O'Kane PD. Contemporary approaches to bifurcation stenting. *JRSM Cardiovasc Dis*. 2021;10:2048004021992190-90.
6. Banning AP, Lassen JF, Burzotta F, Lefèvre T, Darremont O, *et al.* Percutaneous coronary intervention for obstructive bifurcation lesions: the 14th consensus document from the European Bifurcation Club. *EuroIntervention*. 2019;15:90-8.
7. Chen X, Li X, Zhang JJ, Han Y, Kan J, *et al.* 3-Year Outcomes of the DKCRUSH-V Trial Comparing DK Crush With Provisional Stenting for Left Main Bifurcation Lesions. *JACC Cardiovasc Interv*. 2019;12:1927-37.
8. Neumann F-J, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, *et al.* 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J.* 2018;40:87-165.
9. Kumsars I, Niels Ramsing H, Niemelä M, Erglis A, Kervinen K, *et al.* Randomised comparison of provisional side branch stenting versus a two-stent strategy for treatment of true coronary bifurcation lesions involving a large side branch: the Nordic-Baltic Bifurcation Study IV. *Open Heart*. 2020;7.
10. Crimi G, Mandurino-Mirizzi A, Gritti V, Scotti V, Strozzi C, *et al.* Percutaneous Coronary Intervention Techniques for Bifurcation Disease: Network Meta-analysis Reveals Superiority of Double-Kissing Crush. *Can J Cardiol*. 2020;36:906-14.
11. Gheisari F, Emami M, Raeisi Shahraki H, Samipour S, Nematollahi P. The Role of Gender in the Importance of Risk Factors for Coronary Artery Disease. *Cardiol Res Pract*. 2020;2020:6527820.
12. Askari B, Mahoori A, Heidari M, Farzanehnourinejad. Left Main Coronary Artery Disease: traditional risk factors in a study from northwest of Iran. *Urmia Med J*. 2019;29:719-25.
13. Beig JR, Shah TR, Hafeez I, Dar MI, Rather HA, *et al.* Clinico-angiographic profile and procedural outcomes in patients undergoing percutaneous coronary interventions: The Srinagar registry. *Indian Heart J*. 2017;69:589-96.
14. Brilakis ES, Burke MN, Banerjee S. DK-Crush Should Become Preferred Strategy for Treating Unprotected LM Bifurcation Lesions: No Pain, No Gain∗. *J Am Coll Cardiol*. 2017;70:2618-20.
15. Ruiz-Salmerón RJ, Valenzuela LF, Pérez I, Fuentes M, Rodríguez-Leiras S, *et al.* Approach to coronary bifurcation lesions using the everolimus-eluting stent: comparison between a simple strategy and a complex strategy with T-stenting. R*evista espanola de cardiologia (English ed)*. 2013;66:636-43.
16. Yamashita T, Nishida T, Adamian MG, Briguori C, Vaghetti M, *et al.* Bifurcation lesions: two stents versus one stent--immediate and follow-up results. *J Am Coll Cardiol.* 2000;35:1145-51.
17. Maeremans J, Walsh S, Knaapen P, Spratt JC, Avran A, *et al.* The Hybrid Algorithm for Treating Chronic Total Occlusions in Europe: The RECHARGE Registry. *J Am Coll Cardiol.* 2016;68:1958-70.
18. Chen SL, Sheiban I, Xu B, Jepson N, Paiboon C, *et al.* Impact of the complexity of bifurcation lesions treated with drug-eluting stents: the DEFINITION study (Definitions and impact of complEx biFurcation lesIons on clinical outcomes after percutaNeous coronary IntervenTIOn using drug-eluting steNts). *JACC Cardiovasc Interv*. 2014;7:1266-76.
19. Aldujeli A, Briedis K, Al dujeili M, Braukyliene R, Unikas R, *et al.* CRT-100.68 Double Kissing (DK) Crush Versus T Stent and Small Protrusion (TAP) Stenting for Treatment of De Novo Coronary Bifurcation Lesions With the Need for Side-Branch Stenting. *JACC Cardiovasc Interv.* 2020;13:S17-S17.
20. Morice M-C, Serruys PW, Kappetein AP, Feldman TE, Ståhle E, *et al.* Five-Year Outcomes in Patients With Left Main Disease Treated With Either Percutaneous Coronary Intervention or Coronary Artery Bypass Grafting in the Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery Trial. *Circulation*. 2014;129:2388-94.
21. Stone GW, Sabik JF, Serruys PW, Simonton CA, Généreux P, *et al.* Everolimus-Eluting Stents or Bypass Surgery for Left Main Coronary Artery Disease. *N Engl J Med*. 2016;375:2223-35.
22. Michael Jansen S, Shao-Liang C. Intravascular ultrasound-guided percutaneous coronary intervention in left main coronary bifurcation lesions: a review. *Res Rep Clin Cardiol.* 2017;8:49-59.
23. Ye F, Zhang JJ, Tian NL, Lin S, Liu ZZ, *et al.* The acute changes of fractional flow reserve in DK (double kissing), crush, and 1-stent technique for true bifurcation lesions. *J Interv Cardiol.* 2010;23:341-5.

Palmerini T, Marzocchi A, Tamburino C, Sheiban I, Margheri M, *et al.* Impact of bifurcation technique on 2-year clinical outcomes in 773 patients with distal unprotected left main coronary artery stenosis treated with drug-eluting stents. *Circ Cardiovasc Interv*. 2008;1:185-92.