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Original Research

Double-Kissing Crush Versus Provisional Stenting for Coronary Bifurcations: A 1-Year Follow-up Study in Vietnam

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ABSTRACT

Background: Coronary bifurcation lesions (CBLs) present significant challenges in interventional cardiology, especially in low and middle-income countries like Vietnam. While the double-kissing (DK) crush technique is gaining attention for its potential benefits, its efficacy and safety compared with provisional stenting (PS) in the Vietnamese population remain underexplored. This study aimed to assess the effectiveness of the DK crush technique in reducing major adverse cardiovascular events (MACE) compared with those of PS, providing essential data to inform clinical decision-making in settings with limited resources.

Methods: This prospective cohort study included 58 patients with CBL, 33 patients undergoing the DK crush technique and 25 receiving PS. Clinical follow-up at 1, 3, 9, and 12 months assessed MACE, including cardiovascular disease–related death, acute myocardial infarction, hospitalization for heart failure, and stroke.

Results: Post-percutaneous coronary intervention side branch diameter stenosis in the DK crush group was 5.64% ± 5.80%, significantly lower than the PS group (48.2% ± 28.5%; $P < .001$). One-year follow-up data revealed greater MACE reduction in the DK crush group (91% MACE-free vs 72% in the PS group; $P = .03$; hazard ratio [HR], 3.689; 95% CI, 1.034-13.160). However, the DK crush technique had longer procedural times (91.1 vs 54.6 minutes) and required higher contrast and radiation doses ($P < .01$).

Conclusions: Although DK crush requires longer procedure times and greater radiation exposure, it results in greater MACE reduction than does PS in patients with CBL. Clinicians should weigh the benefits and limitations of both techniques, particularly in resource-limited settings.

Coronary bifurcation lesions (CBLs), defined as coronary artery narrowing occurring near or involving the origin of a significant side branch (SB), account for approximately 15% to 25% of all percutaneous coronary interventions (PCIs).[1–3] The complex nature of these lesions contributes to inferior procedural, early, and late outcomes.[4] Consequently, this subset of complex lesions has garnered considerable attention within the interventional cardiology community, leading to the development of various stenting methodologies.[5] Among these, the provisional stenting (PS) technique typically serves as the default strategy.[3] However, a major complication of this technique is SB occlusion, which can lead to periprocedural myocardial infarction or even death. Despite numerous studies addressing this issue, definitive guidelines for treating these lesions are lacking.[6,7] Consequently, conflicting data remain regarding the optimal approach to CBL.[8–11]

The 2-stent strategy is regarded as the optimal technique for treating CBL, especially in patients with significant and diffuse SB stenosis.[12,13] Double-kissing (DK) crush is the most extensively studied 2-stent CBL stenting strategy.[14] Although published data support its use, DK crush can be challenging to perform. Notably, the DK crush technique has been shown to outperform PS and other complex strategies in randomized trials.[6]

In Vietnam, a lower-middle-income country, there is increasing emphasis on interventions for CBL. However, these efforts are constrained by limited resources, including both human and material assets. The DK crush intervention technique is being adopted, yet its efficacy within the

Abbreviations: CBL, coronary bifurcation lesion; DK, double-kissing; MACE, major adverse cardiovascular events; PCI, percutaneous coronary intervention; PS, provisional stenting; RVD, reference vessel diameter; SB, side branch; SYNTAX, Synergy between PCI with Taxus and Cardiac Surgery.

Keywords: coronary bifurcation; double-kissing crush technique; major adverse cardiovascular events; percutaneous coronary intervention; provisional stenting.

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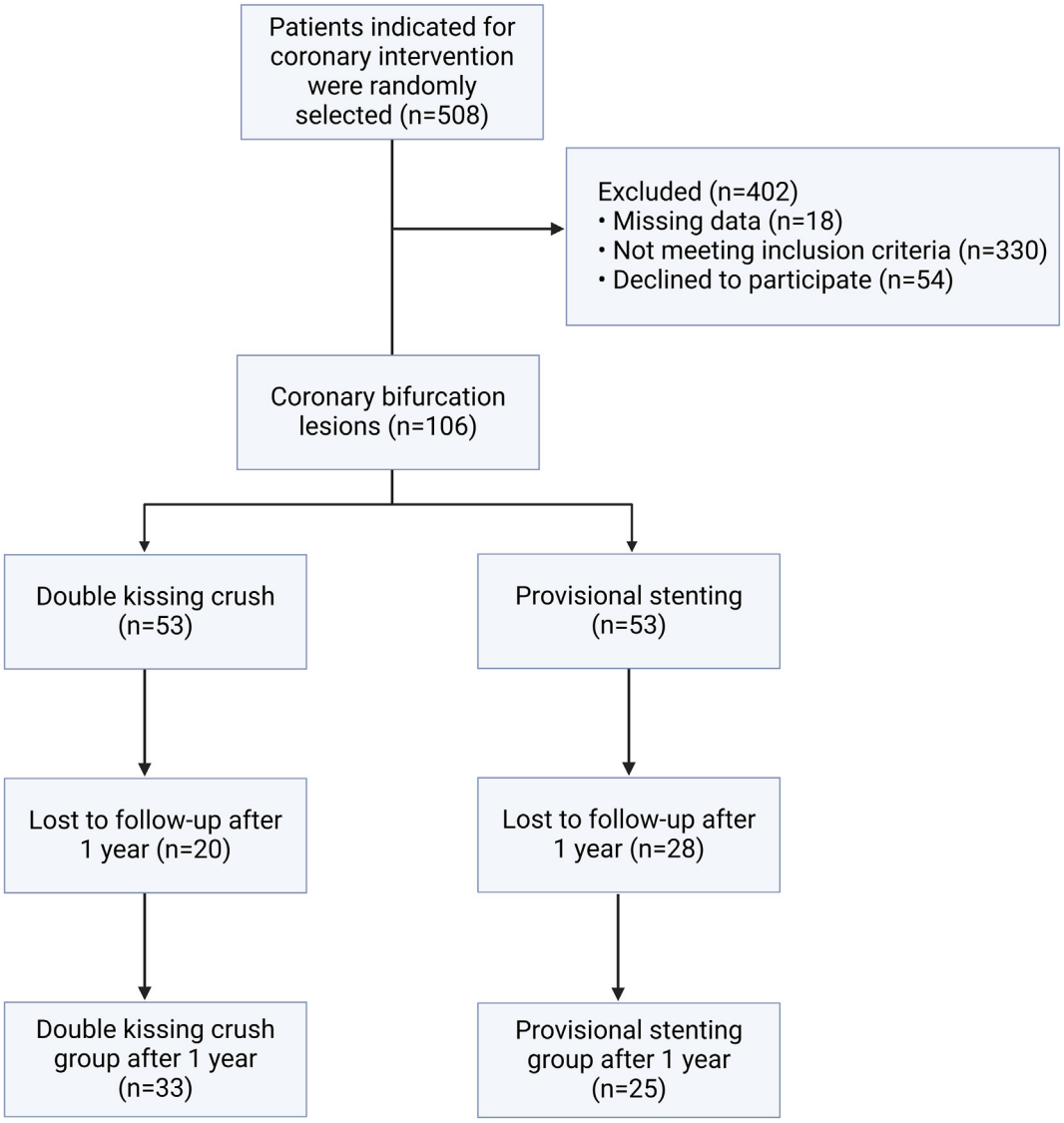


Figure 1.
Flowchart illustrating the sample collection and subgroup allocation of the study.

Vietnamese population, specifically regarding the preservation of SB in CBL, and its effectiveness in assessing 1-year outcomes evaluated by major adverse cardiovascular events (MACE) of DK crush have not been validated by any studies. Therefore, our study was conducted to evaluate the effectiveness of DK crush in reducing the rate of SB narrowing after PCI and to simultaneously assess the 1-year MACE outcomes compared with those of PS among the Vietnamese population. By analyzing the differences between the 2 techniques, this study aimed to gain valuable insights into the benefits and drawbacks of each technique. The findings aim to offer evidence-based guidance for clinicians in selecting appropriate treatment strategies within resource-limited settings, contributing to efforts to alleviate the treatment burden and reduce disease impact worldwide, particularly in developing countries.

Materials and methods

Study population

This single-center study, with a 1-year follow-up, was conducted at Khanh Hoa General Hospital from April 2022 to February 2024. The study initially involved the random selection of 508 patients indicated for coronary intervention. After applying exclusion criteria, 106 patients with CBL were divided into 2 groups: 53 patients in the DK crush intervention group and 53 patients in the PS intervention group. After 1 year of follow-up, 20 patients in the DK crush group and 28 patients in the PS group were lost to follow-up. Ultimately, 33 patients from the DK crush group and 25 patients from the PS group were included in the final data analysis. The detailed sampling process is shown in Figure 1.

All patients who underwent coronary angiography with CBL and who were eligible for intervention met the following criteria: lesion severity (typically $\geq$50% diameter stenosis of the reference vessel diameter [RVD] with optical coherence tomography) at or within 3.0 to 5.0 mm proximal or distal to the ostium of the significant SB. An SB was considered significant if the RVD (assessed by quantitative coronary angiography) was $\geq$2.0 mm. All lesions were classified as Medina 1.1.1, 1.0.1, or 0.1.1. The exclusion criteria for patients were as follows: main vessel diameter at the bifurcation site with an SB diameter of $<$2 mm, previous intervention at the bifurcation site, acute coronary syndrome with cardiogenic shock, recent cerebrovascular accident within 3 months, severe concurrent medical conditions (eg, end-stage cancer and severe liver or kidney failure), or contraindications to dual antiplatelet therapy.

Table 1. Clinical characteristics of the study population.

	DK crush (n = 33)	PS (n = 25)	*P*
Baseline demographic and clinical features			
Age, y	64 ± 10	69 ± 10	.122
Body mass index, kg/m^2	23.1 ± 2.1	21.8 ± 2.8	.049
Female sex	7 (21.2)	5 (20.0)	>.99
Current smoking	8 (24.2)	3 (12.0)	.320
Hypertension	21 (63.6)	17 (68.0)	.786
Diabetes	11 (33.3)	8 (32.0)	>.99
Stroke	1 (3.0)	2 (8.0)	.572
ACS	29 (87.9)	18 (72.0)	.738
LVEF, %	48.3 ± 13.3	48.5 ± 13.1	.958
Laboratory parameters			
Cholesterol, mg/dL	4.7 ± 1.2	5.2 ± 1.6	.220
Triglyceride, mg/dL	2.0 (1.2-2.9)	1.6 (1.0-2)	.097
HDL-C, mg/dL	1.1 (0.9-1.3)	1.0 (1.0-1.4)	.702
Non–HDL-C, mg/dL	3.6 ± 1.1	4.0 ± 1.4	.244
LDL-C, mg/dL	3.1 ± 1.0	3.5 ± 1.3	.107
Urea, mmol/L	5.20 (4.50-6.75)	5.80 (4.65-8.00)	.285
Creatinine, μmol/L	87 (74-103)	84 (78-99)	.931
CK-MB, UI/L	28 (17-58)	34 (12-55)	.826
hs-cTnT, pg/mL	313 (70-805)	280 (33-885)	.969

Values are mean ± SD, median (IQR), or n (%), as appropriate.
ACS, acute coronary syndrome; CK-MB, creatine kinase MB; HDL-C, high-density lipoprotein cholesterol; hs-cTnT, high-sensitivity cardiac troponin T; LDL-C, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction.

Table 2. Angiographic and lesion characteristics.

	DK crush (n = 33)	PS (n = 25)	*P*
IVUS-guided PCI	12 (36.4)	2 (8.0)	.015
Lesion characteristics			
SYNTAX score	27.3 ± 8.5	21.3 ± 8.9	.011
Complex	20 (60.6)	11 (44.0)	.018
Thrombus	10 (30.3)	12 (48.0)	.186
Severe calcification	20 (60.6)	10 (40.0)	.185
Tortuous	18 (54.5)	11 (44.0)	.596
Chronic occlusion	2 (6.1)	0 (0.0)	.501
Lesion location, %			
LAD-diagonal	33 (100)	24 (96.0)	.431
Distal LM	15 (45.5)	9 (36.0)	.592
LCX-marginal	30 (90.9)	19 (76.0)	.154
Distal RCA	20 (60.6)	13 (52.0)	.597
Maximum pressure, atm			
Main vessel	20.0 (16.0-20.0)	20.0 (14.0-20.5)	.488
Side branch	17.0 (14.0-20.0)	13.0 (12.0-14.5)	.009
Lesion length, mm			
Main vessel	39.3 ± 18.2	25.5 ± 10.9	.001
Side branch	20.4 ± 13.4	12.3 ± 10.1	.014
Stent length, mm			
Main vessel	36 (27-48)	28 (23-38)	.014
Side branch	23 (18-33)		
Stent diameter, mm			
Main vessel	3.0 (3.0-3.5)	3.0 (2.8-3.0)	.066
Side branch	2.5 (2.5-2.8)		
Medina 1.1.1	18 (54.5)	15 (60.0)	.279
Medina 1.0.1	1 (3.0)	3 (12.0)	.274
Medina 0.1.1	14 (42.4)	7 (28.0)	.137
Angle, °	79.60 ± 27.90	54.96 ± 25.80	.001
Contrast volume, mL	193.3 ± 62.6	152.0 ± 45.8	.007
Fluoroscopy time, min	24.2 ± 9.1	13.9 ± 5.7	<.001
Radiation dose, mGy	6906 ± 3860	3708 ± 1962	.001
Procedure time, min	91.1 ± 27.1	54.6 ± 16.4	<.001

Values are mean ± SD, median (IQR), or n (%), as appropriate. IVUS, intravascular ultrasound; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main artery; PCI, percutaneous coronary intervention; RCA, right coronary artery; SYNTAX, Synergy between PCI with Taxus and Cardiac Surgery.

Coronary angiography, intervention procedure, and medications

Patients who underwent coronary angiography in the catheterization laboratory and those with CBL according to the selection criteria were eligible for participation in the study. The decision to choose the DK crush or PS technique depended on the patient's clinical condition and economic status. After discussion and selection of the appropriate method, patients were treated by PCI experts. These experts were blinded to the other study information.

The PS technique and DK crush technique were performed according to the guidelines outlined by the European Bifurcation Club.[15,16] Angiographic success was defined as residual stenosis of <30% with thrombolysis in myocardial infarction flow grade 3 in both branches. Procedural success was defined as angiographic success in the absence of any in-hospital MACE.[17]

We used identical drug-eluting coronary stents for all patients included in the study. The recommended stents were Xience Sierra (Abbott Vascular). The main stenting techniques were performed as described previously. Some studies have demonstrated the influence of final kissing balloon inflation on patient outcomes.[18–21] Therefore, we conducted final kissing balloon inflation at the end of the procedure for all lesions to eliminate its potential impact on the study results.

Before the intervention, a loading dose of dual antiplatelet therapy was administered following the guidelines of the European Society of Cardiology. After the intervention, they continued to use dual antiplatelet therapy for at least 1 year.[22]

Bifurcation classifications

A bifurcation was characterized as a ≥50% diameter stenosis adjacent (within 3 mm) to a significant division of a major epicardial coronary artery as outlined in the anatomical Synergy between PCI with Taxus and Cardiac Surgery (SYNTAX) score definition.[23,24] The Medina classification describes a bifurcation lesion with 3 numbers that aim to define the pattern of atherosclerotic disease based on angiographic appearance. Each number is designated either 1 or 0 to indicate the presence or absence of significant (>50%) stenosis, respectively. The first number refers to the proximal main branch (MB), the second refers to the distal MB, and the third refers to the SB ostium. Lesions that involve both the MB and SB are often defined as true bifurcation lesions.[25]

The DEFINITION criteria were applied to classify lesions as complex or simple bifurcation lesions. This classification system includes 2 major and 6 minor angiographic criteria. The major criteria specify that for distal left main bifurcations, the SB lesion length must be of ≥10.0 mm with a diameter stenosis of ≥70%; for non-left main bifurcations, the SB lesion length must be of ≥10.0 mm with a diameter stenosis of ≥90%. The 6 minor criteria are (1) moderate-to-severe calcification, (2) multiple lesions, (3) bifurcation angle of <45° or >70°, (4) main vessel RVD of <2.5 mm, (5) thrombus-containing lesions, and (6) main vessel lesion length of ≥25 mm. A bifurcation lesion is classified as complex if it meets 1 major criterion plus any 2 minor criteria.[26]

Follow-up protocol and definition of study end points

Clinical follow-up was performed with office visits or telephone contact at 1, 3, 9, and 12 months. The primary outcome of MACE was defined, according to a previously published cohort study. The end point was the 1-year rate of MACE, including myocardial infarction, hospitalization because of heart failure, or increase in New York Heart Association functional class by ≥1 class, stroke, revascularization (PCI or coronary artery bypass grafting), all-cause death, or cardiovascular disease–related death.[27] Deaths were considered attributable to cardiac causes unless a noncardiac cause could be confirmed. The experts monitored MACE independently with respect to the data of the study participants.

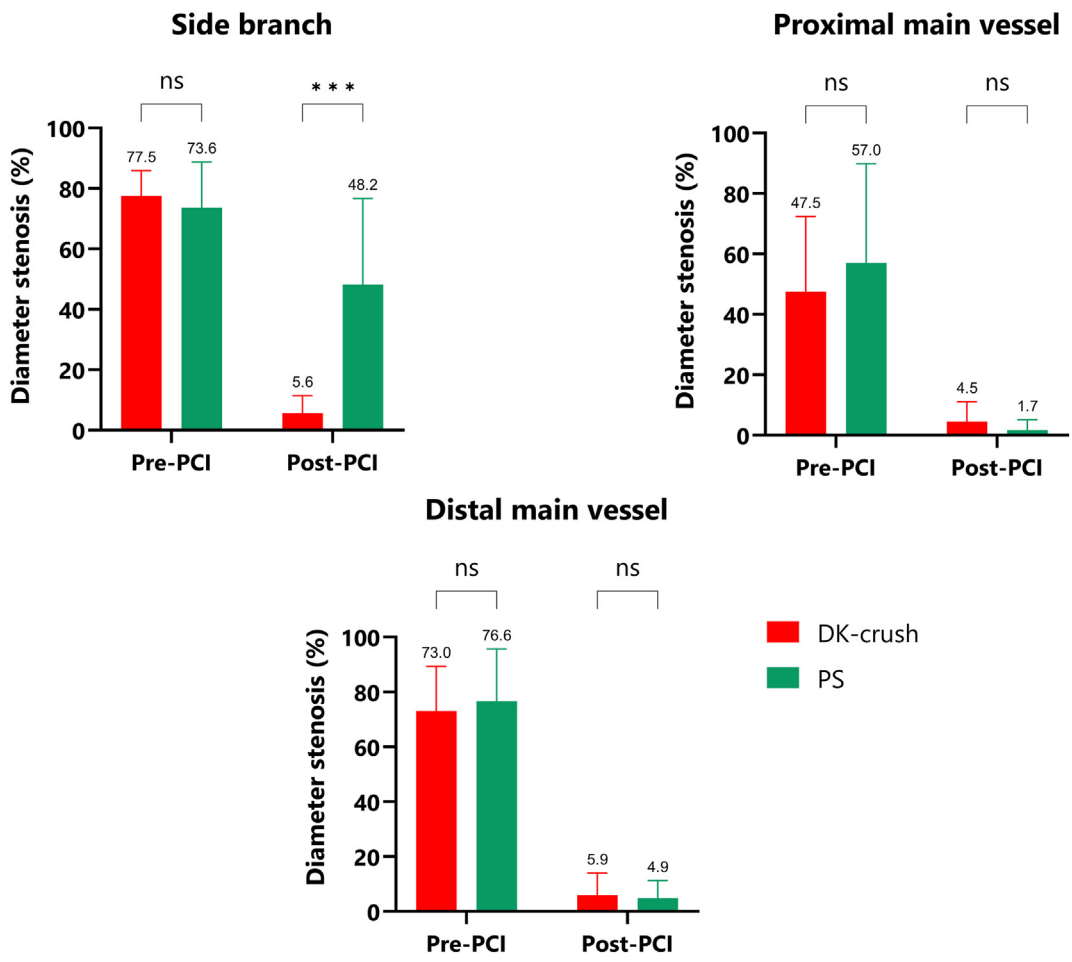


Figure 2.
Comparison of the estimated glomerular filtration rate before and after the intervention, procedure time, radiation dose, and contrast agent dose between the DK crush and PS groups. DK, double-kissing; ns, not significant ($P > .05$); PCI, percutaneous coronary intervention; PS, provisional stenting; ***$P < .001$.

Statistical analysis

All statistical analyses were performed using SPSS version 26 (IBM Corp) and GraphPad Prism Version 10 (GraphPad Software). Data normality was assessed using the Kolmogorov-Smirnov tests. Categorical variables are presented as frequencies and percentages. Continuous variables are presented as the mean ± SD (normal distribution); otherwise, they are presented as the median (Q1-Q3) if the distribution is non-normal. Proportions were compared by the χ^2 test or Fisher exact test when appropriate. *T* tests (for normally distributed data) or Mann-Whitney tests (for non-normally distributed data) were performed to compare differences between 2 groups of quantitative variables. Cox proportional hazards analysis was conducted to identify independent factors associated with 1-year MACE, including variables that differed between the DK and PS groups and could potentially impact the outcomes of each technique. MACE-free survival rates were generated by Kaplan-Meier analysis and compared using the log-rank test. All statistical tests were 2-tailed and used a level of significance of 0.05. We followed SAMPL guidelines to prevent avoidable errors in reporting statistical data.[28]

Results

Baseline clinical characteristics

This study included 58 patients with CBL who underwent PCI at a hospital in the central region of Vietnam. The patients were divided into 2 groups: one group underwent PCI using the PS technique, and the other

Table 3. Procedural characteristics.

	DK crush (n = 33)	PS (n = 25)	*P*
Proximal main vessel			
Baseline			
RVD, mm	2.20 ± 0.70	1.88 ± 0.67	.090
DS, %	47.5 ± 24.9	57.0 ± 32.9	.214
Post-PCI			
RVD, mm	3.74 ± 0.51	3.37 ± 0.39	.010
DS, %	4.5 ± 6.6	1.7 ± 3.4	.099
Distal main vessel			
Baseline			
RVD, mm	1.50 ± 1.29	1.29 ± 0.64	.171
DS, %	73.0 ± 16.3	76.6 ± 19.0	.445
Post-PCI			
RVD, mm	3.30 ± 0.34	2.90 ± 0.36	<.001
DS, %	5.94 ± 8.02	4.88 ± 6.33	.589
Side branch			
Baseline			
RVD, mm	1.18 ± 0.47	1.16 ± 0.54	.872
DS, %	77.5 ± 8.4	73.6 ± 15.2	.217
Post-PCI			
RVD, mm	2.80 ± 0.30	1.58 ± 0.53	<.001
DS, %	5.64 ± 5.80	48.20 ± 28.50	<.001
Angiographic success	33 (100.0)	23 (92.0)	.180
Complete revascularization	33 (100.0)	22 (88.0)	.075

Values are mean ± SD, median (IQR), or n (%), as appropriate.
DK, double-kissing; DS, diameter stenosis; PCI, percutaneous coronary intervention; PS, provisional stenting; RVD, reference vessel diameter.

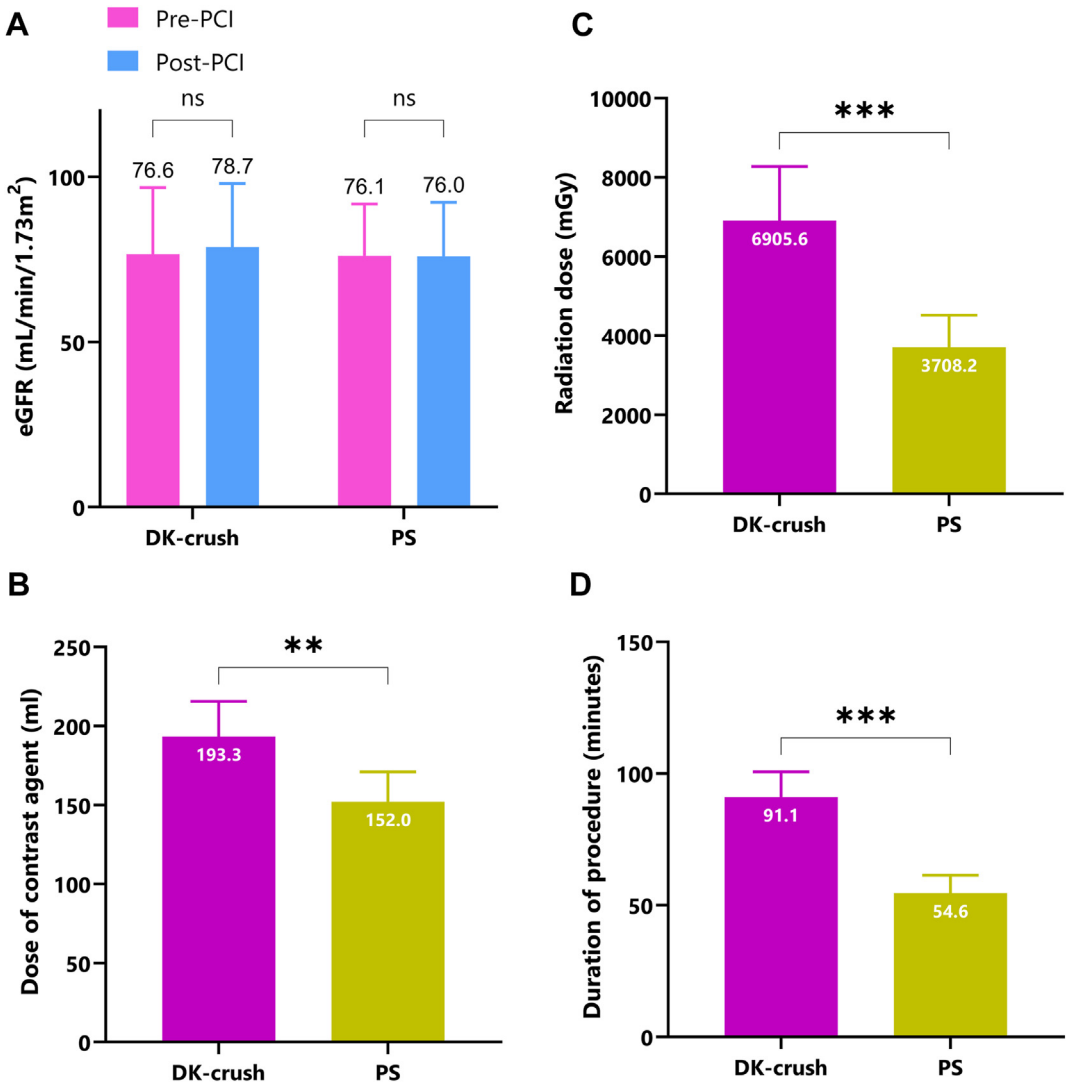


Figure 3.

Comparison of the degree of diameter stenosis before and after PCI in the 2 groups. DK, double-kissing; ns, not significant ($P > .05$); PCI, percutaneous coronary intervention; PS, provisional stenting; $^{**}P < .05$; $^{***}P < .001$.

group underwent PCI using the DK crush technique. The results of this study revealed that the demographic and clinical characteristics were quite similar between the 2 groups. Detailed information is provided in Table 1.

Baseline lesion and procedural characteristics

The results revealed that the DK crush group had significantly greater SYNTAX scores and a greater proportion of complex coronary lesions than did the PS group ($P < .001$). Conversely, patients who underwent the DK crush technique experienced significantly longer procedural times and fluoroscopy times and higher contrast agent volumes and radiation doses than those who underwent the PS technique. Notably, the estimated glomerular filtration rate remained unchanged before and after stent placement in both groups. The detailed parameters are clearly presented in Table 2 and Figure 2.

Quantitative angiographic analysis of coronary branches in the bifurcation lesions before and after intervention

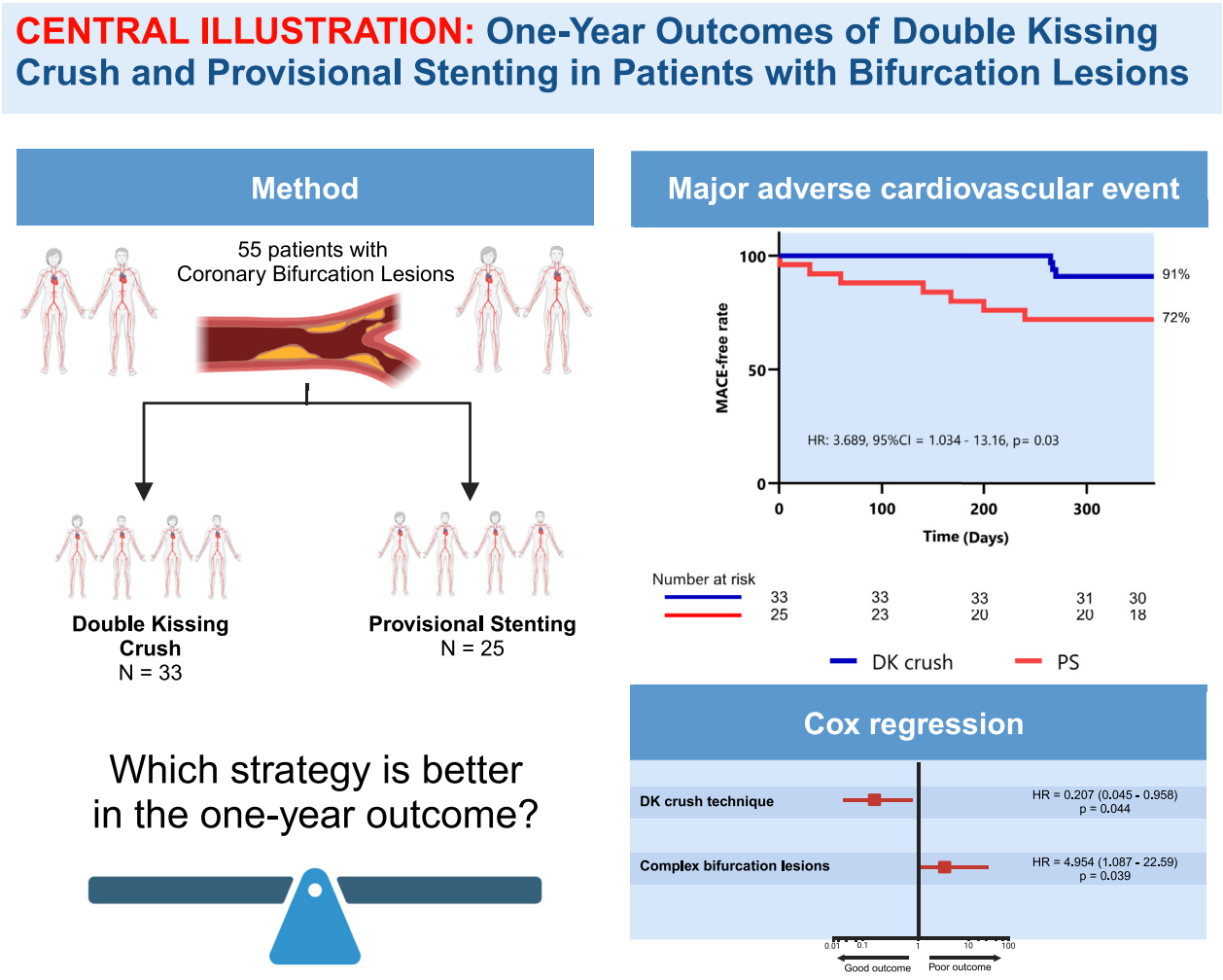
The study results indicated a statistically significant difference in the rate of SB stenosis post-intervention between the DK crush and PS groups. However, there was no difference in the rate of stenosis of the main vessel post-intervention between the DK crush and PS groups. Detailed information is provided in Table 3 and Figure 3.

Clinical outcomes after 1-year DK crush and PS

Our study indicated that patients who underwent the DK crush technique had a lower MACE occurrence rate than those in the PS group (a probability of MACE-free survival of 91% for the DK crush group and 72% for the PS group outcomes after 1-year PCI), with a hazard ratio (HR) of 3.689 (95% CI, 1.034-13.160; $P = .03$). The rates of MACE-free survival are depicted in Central Illustration and Figure 4. Additionally, each component of MACE that occurred in the DK and PS groups is detailed in Supplemental Table S1.

Risk factors associated with 1-year MACE

Table 4 and Central Illustration present the Cox regression analysis results identifying factors associated with the 1-year MACE outcome. The analysis indicated that the use of the DK crush technique significantly reduced the risk of 1-year MACE, with an HR



Central Illustration.
Comparative 1-year outcomes of DK crush and PS in CBL. DK, double-kissing; HR, hazard ratio; PS, provisional stenting.

of 0.207 (95% CI, 0.045-0.958) and a *P* value of .044. In contrast, complex bifurcation lesions were associated with a significantly higher risk, showing an HR of 4.954 (95% CI, 1.087-22.590) and a *P* value of .039. Both factors demonstrated *P* values <.05, suggesting they are independent risk factors for 1-year MACE. However, other variables did not reach statistical significance, including intravascular ultrasound–guided PCI (HR, 0.532; *P* = .573) and the SYNTAX score (HR, 0.967; *P* = .409). This lack of significance suggests that these

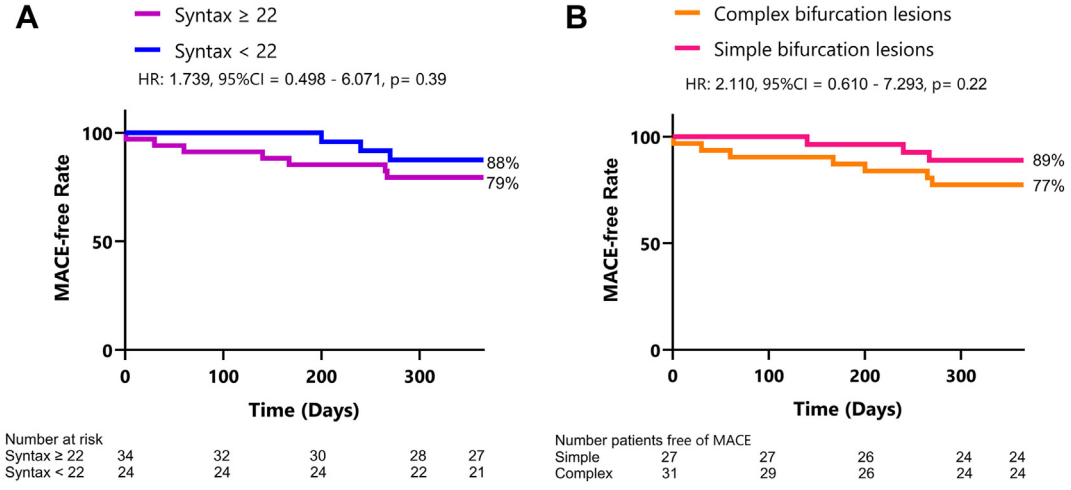


Figure 4.
Clinical 1-year outcomes after DK crush and PS. DK, double-kissing; HR, hazard ratio; MACE, major adverse cardiovascular events; PS, provisional stenting.

Table 4. Cox regression analysis of risk factors associated with 1-y MACE.

Factors	Hazard ratio	95% CI	*P*
DK crush technique	0.207	0.045-0.958	.044
Complex bifurcation lesions	4.954	1.087-22.590	.039
IVUS-guided PCI	0.532	0.059-4.777	.573
SYNTAX score	0.967	0.892-1.047	.409

IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; PCI, percutaneous coronary intervention; SYNTAX, Synergy between PCI with Taxus and Cardiac Surgery.

variables may not substantially impact the 1-year MACE outcome within this model.

Discussion

Our study demonstrated several benefits of the DK crush technique compared with those of PS. Specifically, the results showed a statistically significant reduction in SB stenosis following the intervention in the DK crush group compared with that in the PS group. Additionally, patients who underwent the DK crush technique exhibited lower rates of MACE than those who underwent PS. The DKCRUSH-II study suggested that lower rates of restenosis in the SB, along with a greater rate of carina shifting, plaque shifting, and SB recoiling in the PS group, may explain the improved acute gain and late loss of the SB fractional flow reserve associated with the DK crush technique compared with those of the PS technique.[9] Furthermore, compared with the PS technique, the DK crush technique is associated with a decreased MACE rate.[9,29,30]

However, the DK crush technique also has some limitations compared with the PS technique. Based on our study results, the DK crush technique requires a longer procedure time, greater contrast volume, and greater radiation dose. These findings represented the technical limitations of the DK crush technique. Nevertheless, despite the higher contrast agent dose, renal function remained unchanged between the DK crush and PS groups before and after the intervention. Similarly, as observed in other studies, the 2-stent technique, compared with PS, results in increased contrast use and radiation exposure.[11,31] Furthermore, during procedural execution, the DK crush technique involves more steps, posing challenges for clinical practitioners. Operators using the DK crush stenting technique must be fully proficient in every procedural step and must acknowledge the associated limitations and challenges. Undoubtedly, this approach involves more laborious steps, but it is essential to ensure good quality outcomes in achieving optimal stent placement. The DK crush stenting technique requires a significantly steeper learning curve than the PS technique and is currently considered a challenging aspect of bifurcation stenting worldwide.[32,33]

Limitations

Our study had several limitations. This was a single-center study with a small sample size at a hospital in Vietnam, which may introduce selection bias. Another limitation in our sampling process was the lack of randomization. Owing to Vietnam's limited income levels, the DK crush technique, which requires 2 stents, leads to higher treatment costs. Consequently, we needed to explain the procedure and associated expenses to patients and their families, with the final decision on the treatment approach depending on their informed choice before the intervention. Additionally, we reported only the 1-year outcomes, limiting conclusions regarding the long-term safety of either approach. Because of resource constraints, we could not compare the coronary artery bypass grafting technique with the DK crush technique, although the coronary artery bypass grafting technique remains a viable treatment option for managing coronary artery disease. Furthermore, our study focused solely on clinical benefits without evaluating the cost-effectiveness of the DK crush stenting technique compared with conventional methods in Vietnam. Further health economic studies are necessary to address this gap.

Conclusion

Compared with the provisional approach, the DK crush technique has superior outcomes, with lower 1-year MACE rates. However, the DK crush technique still has some limitations regarding procedure time, radiation exposure, and contrast dose. It is important to weigh the benefits and drawbacks of both techniques to choose the most suitable one based on the local conditions.

Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethics statement and patient consent

This research was conducted in accordance with the guidelines outlined in the Declaration of Helsinki and received approval from the Institutional Ethics Committee of Hue University (Approval No: H2022/448). Written informed consent was obtained from each participant after providing detailed information about the study, with consent forms signed by all participants before their inclusion.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the *Journal of the Society for Cardiovascular Angiography & Interventions* at 10.1016/j.jscai.2024.102500.

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