

RESEARCH ARTICLE

Feasibility and Outcomes of Left Main to Branch Vessel PCI with Novel Tapered Coronary Stent in a Tertiary Care Centre: A Real World Experience

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Abstract: Objective: To assess the safety and efficacy of Novel tapered (BioMime™ Morph) sirolimus-eluting stent (SES) for left main PCI in a real-world scenario.

Background: Currently, no data is available on clinical usefulness of tapered ultrathin stents in left main PCI.

Methods: This was a prospective, non-randomised, single centre study carried out between February 2018 and May 2020 at a tertiary cardiac care centre in southern India. The study included patients treated with BioMime Morph tapered stent for distal de novo LMB lesion or ostial LAD/LCX lesions with significant size disparity between reference segments based on the eligibility criteria. Primary endpoint of the study was the cumulative incidence of major adverse cardiovascular events (MACE) composed of cardiac death, myocardial infarction, and clinically driven target-lesion revascularisation at follow-up.

Results: A total of 41 patients (average age of 54.83±9.81 years) were included in the study. Average SS-2 score was 23.17±5.42. Majority of the lesions (n=31; 75.61%) were of medina class (0.1.0). Provisional single stent strategy was adopted for treatment of LMB lesions. TIMI flow-3 was achieved in 40 patients (97.56%). Median clinical follow-up was 20 months (range 6-34 months). There was no periprocedural complication or MACE during follow-up.

Conclusions: Tapered stents may be an acceptable alternative for LM intervention in an anatomical subset of patients with tapered vessels.

Keywords: Coronary artery disease, left main coronary artery, percutaneous coronary intervention, tapered coronary stents, provisional stenting.

1. INTRODUCTION

Coronary angiography identifies significant stenosis (>50%) in the left main coronary artery (LMCA) in 4% to 6% patients, with involvement of left main bifurcation (LM-B) in nearly 80% of the patients [1]. Percutaneous coronary intervention (PCI) has been increasingly adopted as the treatment strategy for LMCA disease.

The diameter of coronary arteries is reduced along the length direction of vessels, geometrically tapered structure. Angiographic studies have shown that 19% of blood vessels taper 0.5 to 0.9 mm over a 20 mm length from the proximal to distal reference segment, and 23% of vessels taper ≥1 mm over the same distance [2]. Significant segmental coronary

artery tapering presents a unique challenge for interventional cardiologists, creating a dilemma for the optimal balloon and stent sizing during PCI. As conventional stents are available in cylindrical shapes, they can lead to stent size mismatch and may not be able to adapt effectively in long tapered vessels [3]. Implantation of multiple overlapping stents of varying diameters in tapered vessels may solve the issue of stent size mismatch. However, the use of overlapping stents leads to increased metal and drug delivery, causing more vessel injury, stent fracture due to vessel rigidity, side branch jailing, increased cost of treatment, delayed healing and increased very-late stent thrombosis (ST) resulting in impaired short-term and long-term angiographic and clinical outcome, including death or myocardial infarction (MI) [4, 5]. Implantation of single tapered stent may overcome the drawbacks of implanting multiple stents in tapered vessels. Tapered balloons also reduce the foreshortening of stent.

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The BioMime™ Morph (Meril Life Sciences Pvt. Ltd., India) is the world's first and the only tapered biodegradable polymer-coated sirolimus-eluting coronary stent (SES) system that has been developed to address pathology in vessels with significant size discrepancy and the shortcomings of conventional stents in treating such vessels. The stent has also received "Conformite Europeene" (CE) mark-approval. The results of previous studies have demonstrated the safety and feasibility of BioMime Morph SES for treating tapered diffusely diseased vessels with favourable procedural success and device success, and with excellent angiographic and clinical follow-up results [6-10]. However, the studies on this tapered stent are very limited and have restricted their usage only to non-LMCA lesions. Hence, this study has been designed to assess the safety and efficacy of BioMime Morph SES for the treatment of LMB lesions in a real-world scenario.

2. MATERIALS AND METHODS

2.1. Patient Selection and Study Design

This was a prospective, non-randomised and single centre study, which included patients who were treated with BioMime Morph SES tapered stent for LM bifurcation lesion between February 2018 and May 2020 at Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru, India Fig. (1).

Inclusion criteria for PCI with the BioMime Morph stent if:

- 1) There was significant distal LMCA (>50%) disease extending into left anterior descending (LAD)/ left circumflex (LCX) artery/ ramus intermedius; or
- 2) Significant ($\geq 70\%$ stenosis) ostio-proximal LAD/LCX/ramus disease with marked segmental vessel tapering which was difficult to treat with a single conventional stent; and
- 3) Visually estimated target lesion reference vessel diameter of 3.0-4.5 mm in the LM and 2.5-3.5 mm in LAD/LCx.

Exclusion criteria

- 1) Patients in whom LMB lesions were (priorly) qualified to be treated with a two-stent technique;
- 2) Patients with LMB lesion with Medina class 1.1.1 or high SYNTAX score; and
- 3) Vessels without significant segmental size disparity.

The study was conducted in accordance with good clinical practice and Declaration of Helsinki. Informed consent was obtained from all the participants prior to the procedure.

2.2. Study Device

The BioMime Morph is a novel long-tapered biodegradable polymer coated ultrathin SES system for the treatment of long diffuse coronary lesions. It has a classical BioMime hybrid design, which has an intelligent mix of closed cells at the edges and open cells articulating along the length of the

stent Fig. (2). Despite ultrathin strut thickness (65 μm strut thickness), strut width variability ensures optimal radial strength. Moreover, non-linear S links & Y connectors allow high flexibility and facilitate adequate side branch access. The cobalt-chromium platform of the stent is uniformly coated with a biocompatible, biodegradable co-polymer combination of poly-L-lactic acid (PLLA) and poly-lactic-co-glycolic acids (PLGA), which elute anti-proliferative drug, sirolimus (1.25 $\mu\text{g}/\text{mm}^2$) for 30 - 40 days after the implantation. Currently available lengths of the BioMime Morph are 30 mm, 40 mm, 50 mm and 60 mm. The stent inflation is guided by the tapered balloon and is estimated to achieve the diameters (proximal to distal) of 2.75 - 2.25 mm, 3.0 - 2.50 mm, and 3.50 - 3.0 mm.

2.3. Procedure

PCI was performed according to the clinical practice guideline of the institute by an experienced operator. Lesion morphology suitable for provisional single stent strategy with significant size discrepancy between proximal and distal reference segments were treated with the study device. The cases in which we implanted stent across LCX/ramus, its size was comparable to that of LAD. Hence, they could be considered as the main branch. The procedure was initiated with the engagement of guide and insertion of wires into both branches. Stenosed segments were pre-dilated with the semi-compliant balloon. The stent selection was based on visual estimation or quantitative coronary angiography (QCA). Tapered stent is used only if the proximal and distal reference diameter difference is 1 mm and above. The most appropriate diameter and length stent are implanted across LM to LAD or LM to ramus or LM to LCX according to the lesion distribution. After crossover stent deployment, re-wiring to the jailed side branch was performed only if there was ostial pinching >50% or reduced TIMI flow. Final kissing-balloon inflation (FKBI) was performed as per the requirement. Fig. (3) demonstrated successful implantation of BioMime Morph SES for treatment of LMB lesions. Proximal optimisation technique with appropriate sized non-complaint (NC) balloon was carried out in all the cases. The use of optical coherence tomography (OCT) was left at the discretion of the operator. In the present study, OCT guided PCI was performed in 5 patients Fig. (4). All the patients undergoing PCI were administered Aspirin (75mg) and Ticagrelor (180mg) and continued for at least one year. After one year, aspirin (150mg/daily) was continued indefinitely.

2.4. Study Endpoints

Primary endpoint of the study was the cumulative incidence of major adverse cardiovascular events (MACE) composed of cardiac death, MI, and clinically driven target-lesion revascularisation (CD-TLR) at follow-up. The secondary endpoints included ST and device success.

Cardiac death was defined as any death due to an acute MI, stroke or heart failure related to the procedure or unknown cause or unwitnessed death. MI was divided into Q-wave MI (defined as the development of new pathological Q

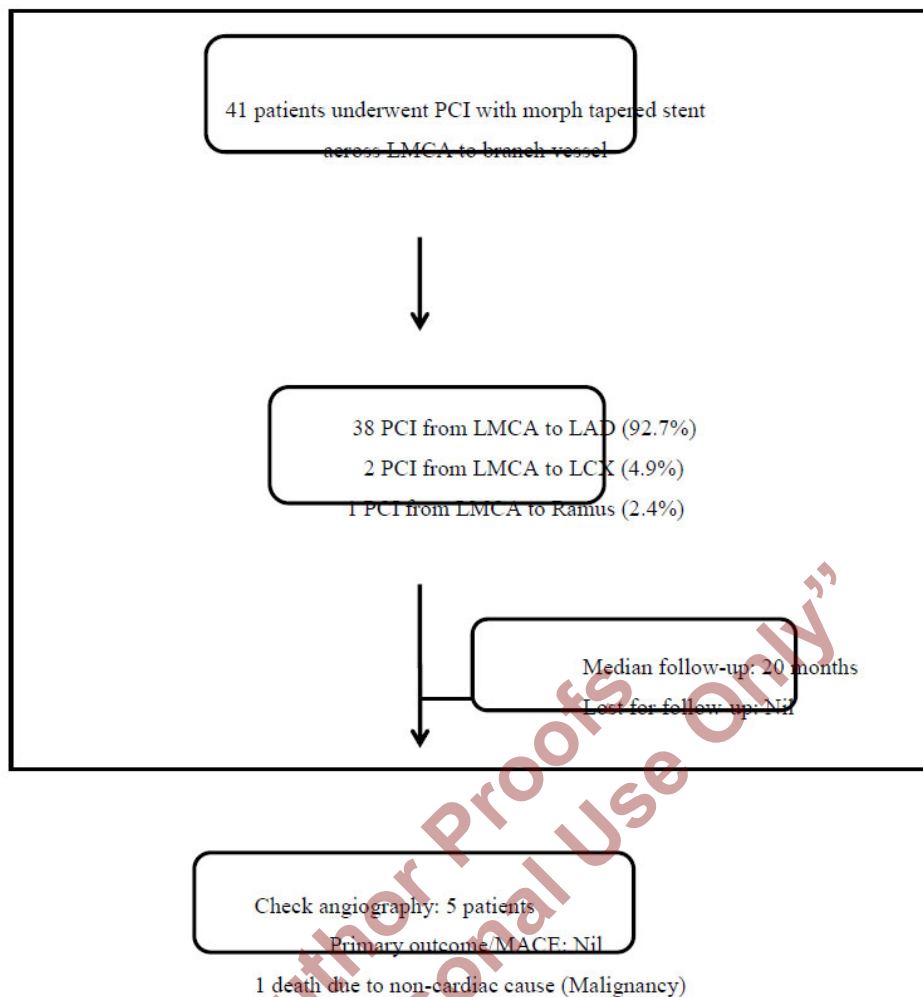


Fig. (1). Study flow chart. PCI: percutaneous coronary intervention; LMB: left main bifurcation; LAD: left anterior descending; LCX: left circumflex; MACE: major adverse cardiac events.

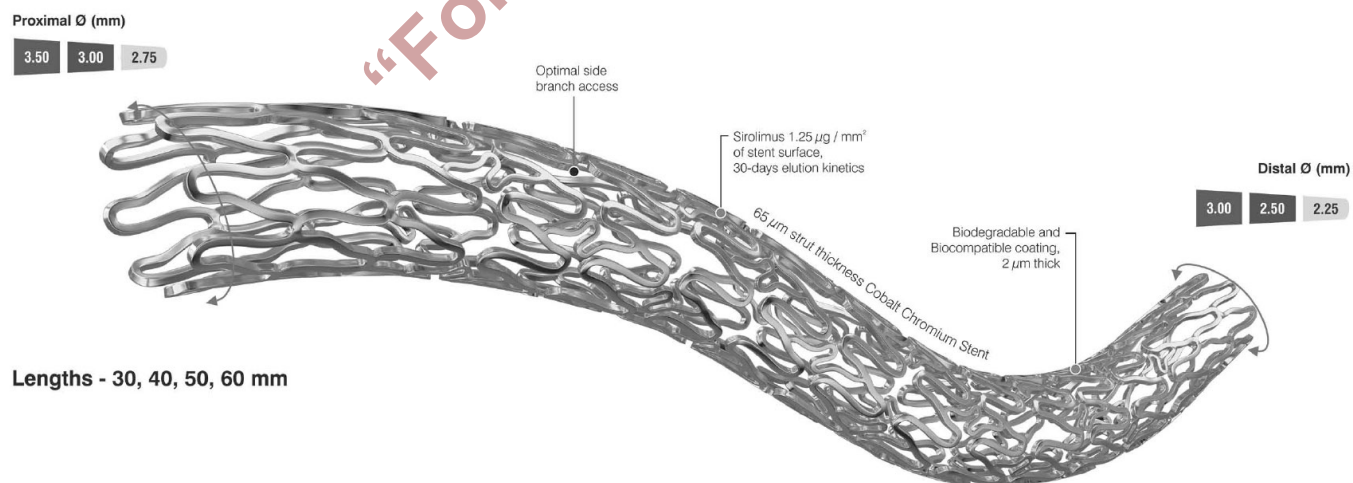


Fig. (2). BioMime Morph. (A higher resolution / colour version of this figure is available in the electronic copy of the article).

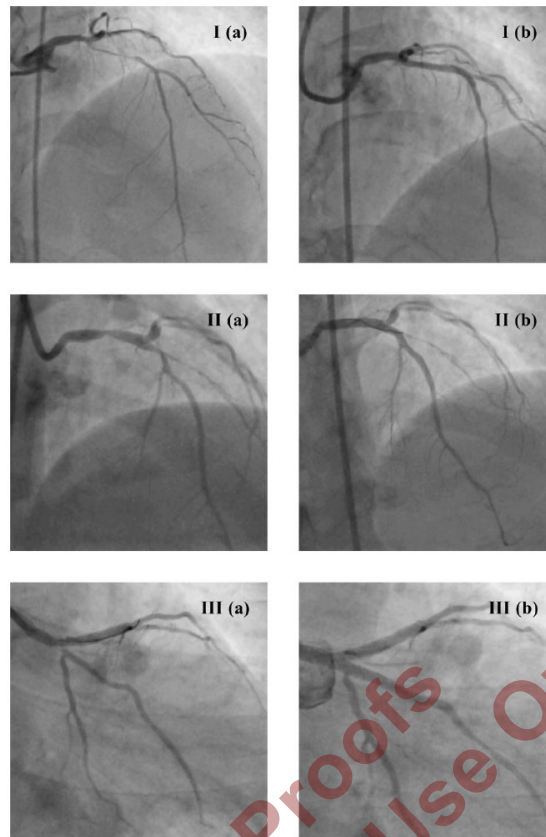


Fig. (3). (ia) Pre-procedural coronary angiogram showing distal LMCA disease and long segment LAD disease; (ib). Postprocedural coronary angiogram showing good coronary flow after implantation of 3.5x3.0x40 mm BioMime Morph SES across LMCA to LAD; (iia) Pre-procedural coronary angiogram showing mid LMCA stenosis and proximal LAD stenosis; (iib) Post-procedural coronary angiogram showing good coronary flow after implantation of 3.5x3.0x40 mm BioMime Morph SES across LMCA to LAD; (iiia) Pre-procedural coronary angiogram showing ostial LCX critical stenosis; (iiib) Post-procedural coronary angiogram showing good coronary flow after implantation of 3.5x3.0x30 mm BioMime Morph SES across LMCA to LCX. (A higher resolution / colour version of this figure is available in the electronic copy of the article).

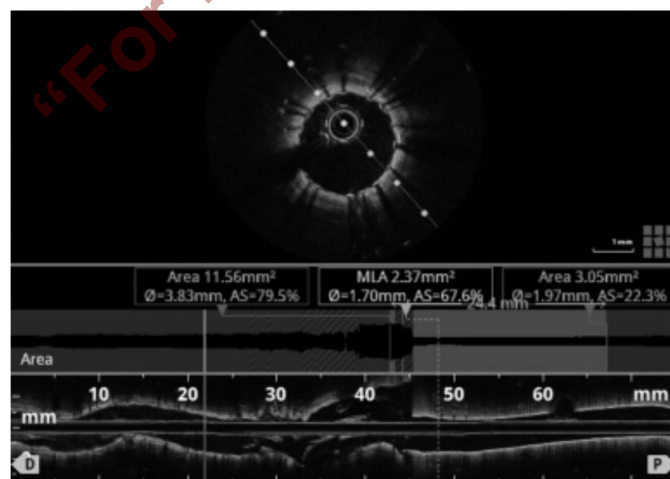


Fig. (4). Post procedure optical coherence tomography showing well opposed stent. (A higher resolution / colour version of this figure is available in the electronic copy of the article).

Table 1. Demographics and baseline clinical characteristics of the study population.

Characteristics	n=41 Patients
Age (years), Mean \pm SD	54.83 \pm 9.81
Gender, n (%)	
Male	29 (70.73)
Female	12 (29.27)
Smoker, n (%)	07 (17.07)
Medical History, n (%)	
Diabetes Mellitus	21 (51.22)
Hypertension	17 (41.46)
Left ventricular ejection fraction, Mean \pmSD	0.51 \pm 0.08
Creatinine clearance, Mean \pmSD	97.63 \pm 15.49
Risk Stratification¹, n (%)	
Low-risk (<23)	37(90.24)
Intermediate-risk (23-32)	04(9.76)
SS 2, Mean \pm SD	23.17 \pm 5.42

¹Based on Syntax score.

waves of more than 0.04 sec in two or more contiguous leads with an elevation of creatinine kinase (CK) or CK-MB levels) or non-Q-wave MI (absence of Q wave but elevation of CK levels to >3 times the upper limit of normal together with elevation of CK-MB or troponin levels). ST and CD-TLR were classified according to the definitions of the Academic Research Consortium [11]. Device success was defined as successful deployment of the stent in the site without residual stenosis of >20% with TIMI flow-3.

3. RESULTS

A total of 41 patients with an average age of 54.83 \pm 9.81 years were included in the study. The study population predominantly included male patients (n=29; 70.73%). Based on Syntax-score, 37 (90.24%) patients belonged to low score (<22) and 4 (9.76%) patients were in the intermediate score (23-32). Baseline clinical characteristics of the study population are depicted in Table 1.

Table 2 shows bifurcation lesion data and procedural characteristics of the study population. American College of Cardiology/American Heart Association (ACC/AHA) classified 15 (36.59%) lesions as type-B and 26 (63.41%) lesions as type-C. Right coronary dominance was observed in 31 (75.61%) patients. The ostio-proximal LAD was the most common site of lesion location. All the LMB lesions belonged to Medina classes (1.1.0), (0.1.0), (0.0.1) and (1.0.0.1). Majority of the procedures were performed through a transfemoral approach, mainly using a provisional one-stent strategy. FKBI was performed on 3 (7.32%) patients. None of the patients required another stent implantation in the side branch. Of the treated patients, 22 (53.66%) patients were treated with 30 mm BioMime Morph SES. All the patients were treated with proximal optimization technique. Majority of them (n=37) were treated with 4 mm balloon inflated at 14-16 atm pressure, whereas the remaining patients (n=4) were treated with 3.5 mm balloon (inflated at 14-16 atm pressure). Device success was 97.56%. TIMI flow-3 was achieved in all the patients except one, in whom

the procedure was complicated due to LMCA dissection. However, the complication could be overcome with the implantation of another stent. The hospital stay of the patient was uneventful.

Median clinical follow-up was 20 months. During follow-up, coronary angiography was performed in four patients who had symptoms of angina or angina equivalents and none of them had in-stent restenosis. One patient died after three months of the index procedure due to pancreatic cancer. Hence, at follow-up, there was no incidence of MACE. None of the patients experienced ST.

4. DISCUSSION

The present study evaluated the safety and efficacy of BioMime Morph SES, a novel tapered ultrathin-stent, for LMB stenting in a real-world scenario. The procedures were performed by a single experienced operator at a tertiary care centre. It is noteworthy that there was no restriction with regard to tortuosity of the vessel, the complexity of the lesions (chronic total occlusion, type B/C lesions) or lesion length. Despite it, device success was achieved in 97.56% cases. The safety and efficacy of BioMime Morph SES have been ascertained in this real-world scenario with no incidence of MACE or ST at a median follow-up period of 17 months.

Until recent years, Coronary artery bypass grafting (CABG) has been considered a treatment strategy for LMCA disease. Recently, evidence confirmed similar outcomes with PCI or CABG for treating LMCA disease in patients with low and intermediate SYNTAX scores [12, 13]. European revascularization guidelines also upgraded indication of PCI for treatment of LMCA disease in low-risk and intermediate-risk patients as class-I and class-IIa, respectively [14].

PCI of LMCA disease is still challenging owing to the higher incidence of repeat revascularization, especially when a lesion is located in the distal part of the LMCA where it frequently involves bifurcation segments. It is note-

Table 2. Lesion and procedural characteristics of the study population.

Angiographic Characteristics	Total Lesions N=41
Lesion Location, n (%)	
Ostial LAD ²	05 (12.20)
Ostio-proximal LAD	26 (63.41)
Ostio-proximal LCX ³	02 (4.88)
LMCA ⁴ to proximal LAD	07 (17.07)
LMCA to ostial ramus	01 (2.44)
Medina classification, n (%)	
0.1.0	31 (75.61)
0.0.1	02 (4.88)
1.1.0	07 (17.07)
1.0.0.1	01 (2.44)
ACC/AHA classification, n (%)	
B	15(36.59)
C	26 (63.41)
Calcified lesion, n (%)	04 (9.76)
Tortuous vessel, n (%)	01 (2.44)
Access site, n (%)	
Femoral	38 (92.68)
Radial	02 (4.88)
Ulnar	01 (2.44)
DOMINANCE, n (%)	
Co-dominant	03(7.32)
LCX	07 (17.07)
RCA ⁵	31 (75.61)
Bifurcation angle, n (%)	
>70	15 (36.59)
<70	26 (63.41)
Average stent length (mm), Mean ±SD	36.83±8.79
Stent Length (mm), n (%)	
30mm	22 (53.66)
40 mm	12 (29.27)
50 mm	05 (12.20)
60 mm	02 (4.88)
Proximal stent diameter (mm), Mean ±SD	3.74±0.32
Distal stent diameter (mm), Mean ±SD	2.88±0.24
Bifurcation lesion treatment, n (%)	
Double wiring	13 (31.71)
Pre-dilation of main vessel	39 (95.12)
Stent implantation in main branch only	41 (100)
Final kissing balloon	03 (7.32)
Dissection requiring an additional stent in main vessel	1 (2.44)
Proximal optimization technique	41 (100)
Post-procedure TIMI⁶ flow, n (%)	
1	01 (2.44)
3	40 (97.56)

¹Left anterior descending. ²Left circumflex ³Left main coronary artery ⁴Right coronary artery ⁵Thrombolysis in Myocardial Infarction.

worthy that these bifurcation lesions are rarely focal. Examination with intravascular ultrasound demonstrated that

atherosclerotic plaques extend from LMCA to LAD artery in 90% of patients and to LCX artery in 66.4% of patients

and to both the vessels in 62% of patients [15]. The complexity of these lesions is mainly attributed to the tapered geometry of the vessels.

Shen *et al.* assessed biomechanical behaviour of a cylindrical stent during deployment inside the tapered arteries using the finite element method. The authors observed that stent radial recoil increases with an increase of vessel tapering. Moreover, the cylindrical stents were more likely to damage tapered artery at distal end, which might ultimately result in in-stent restenosis [16]. The hemodynamic performance of cylindrical and tapered stents in a tapered artery also discourages the use of conventional stents in tapered vessels as their implantation may lead to atherosclerotic plaque formation (in-stent restenosis) as a consequence of reduced blood flow velocity and wall shear stress. In contrast to a cylindrical balloon, tapered balloon also lessens the foreshortening of the stent (7.69%) and also the stress concentration in the artery and stent (4.17% and 8.61%, respectively) [17]. These observations are translated clinically while treating carotid stenosis with conventional and tapered stents [18]. The results of a prospective study which included 148 patients, reported a significantly higher incidence of hemodynamic complications in the patients treated with a straight stent as compared to those treated with tapered stents (36% vs. 21%; $p=0.04$) [18]. Continuous pressure on the carotid sinus attributed to the straight design of the stent could explain higher hemodynamic complications. It is noteworthy that the rate of restenosis was numerically but not statistically significantly higher in patients treated with straight stents (4% vs 1%) at a six-month follow-up. [18]. However, none of the studies explored the safety and efficacy of the tapered stent for the treatment of LM bifurcation lesions.

BioMime Morph SES has been designed to achieve optimal clinical outcomes for the treatment of lesions of tapered coronary arteries. Till date, BioMime Morph SES has not been evaluated to treat LMB lesions. To the best of our knowledge, this is the first real-world experience of PCI with BioMime Morph SES for the treatment of LMB disease extending into branch vessels with significant tapering in the vessel diameter. Moreover, the single-stent strategy shows favourable long-term clinical outcomes than the two-stent approach in the management of LMB lesions [19-21]. Therefore, in real-world practice, the single-stent crossover technique is used most commonly (about 60% of all LMB lesions). In the present study also, all the patients were treated with a provisional single stent strategy.

5. LIMITATIONS OF THE STUDY

The biggest limitation of our study is a small sample size of 41 patients with no control group. The other major limitation being, the lack of use of Intravascular ultrasound (IVUS)/ OCT in unprotected left main interventions due to financial constraints. Multivariable regression analysis was not possible due to small sample size and none of our patients experienced the primary outcome.

CONCLUSION

Tapered stents may be an acceptable alternative to conventional stents for the intervention of left main bifurcation lesions. The present study provides evidence for the feasibility of BioMime Morph tapered SES for the treatment of selected LMB lesions. It is specially useful in intervention of left main lesions with discrepant sizes of proximal branching vessels.

Short-term clinical outcomes are favourable. However, large studies with IVUS imaging and long-term clinical and angiographic follow-up studies are needed to establish the device as an alternative to conventional stents in treating LMB lesions in tapered vessels.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

- [1] Ragosta, M.; Dee, S.; Sarembock, I.J.; Lipson, L.C.; Gimple, L.W.; Powers, E.R. Prevalence of unfavorable angiographic characteristics for percutaneous intervention in patients with unprotected left main coronary artery disease. *Catheter. Cardiovasc. Interv.*, **2006**, *68*(3), 357-362. <http://dx.doi.org/10.1002/ccd.20709> PMID: 16892431
- [2] Banka, V.S.; Baker, H.A., III; Vemuri, D.N.; Voci, G.; Maniet, A.R. Effectiveness of decremental diameter balloon catheters (tapered balloon). *Am. J. Cardiol.*, **1992**, *69*(3), 188-193. [http://dx.doi.org/10.1016/0002-9149\(92\)91303-L](http://dx.doi.org/10.1016/0002-9149(92)91303-L) PMID: 1731458
- [3] van Geuns, R.-J.; Awad, K.; IJsselmuiden, A.; Koch, K. The role of self-expanding stents in patients with atypical coronary anatomy. *Interv. Cardiol.*, **2014**, *9*(1), 11-16. <http://dx.doi.org/10.15420/icr.2011.9.1.11> PMID: 29588771
- [4] Räber, L.; Jüni, P.; Löffel, L.; Wandel, S.; Cook, S.; Wenaweser, P.; Togni, M.; Vogel, R.; Seiler, C.; Eberli, F.; Lüscher, T.; Meier, B.; Windecker, S. Impact of stent overlap on angiographic and long-term clinical outcome in patients undergoing drug-eluting

- stent implantation. *J. Am. Coll. Cardiol.*, **2010**, 55(12), 1178-1188.
<http://dx.doi.org/10.1016/j.jacc.2009.11.052> PMID: 20298923
- [5] Ellis, S.G.; Holmes, D.R. *Strategic approaches in coronary intervention*, 3rd; Ellis, S.G.; Holmes, D.R., Eds.; Lippincott Williams and Wilkins: Philadelphia, PA, **2005**.
- [6] Valero, E.; Consuegra-Sánchez, L.; Miñana, G.; García-Blas, S.; Rodríguez, J.C.; Moyano, P.; Sanchis, J.; Núñez, J. Initial experience with the novel BioMime 60 mm-long sirolimus-eluting tapered stent system in long coronary lesions. *EuroIntervention*, **2018**, 13(13), 1591-1594.
<http://dx.doi.org/10.4244/EIJ-D-17-00616> PMID: 28870879
- [7] Matchin, Y.G.; Atanesyan, R.V.; Kononets, E.N.; Danilov, N.M.; Bubnov, D.S.; Ageev, F.T. The first experience of using very long stents covered with sirolimus (4060 mm) in the treatment of patients with extensive and diffuse lesions of the coronary arteries. *Kardiologiya*, **2017**, 57(4), 19-26.
 PMID: 28762901
- [8] Patted, S.V.; Jain, R.K.; Jiwani, P.A.; Suryavanshi, S.; Raghu, T.R.; Raveesh, H.; Rajalakshmi, S.; Thakkar, A.S.; Turiya, P.K.; Desai, P.J.; Patted, A.S.; Sharma, K.H. Clinical outcomes of novel long-tapered sirolimus-eluting coronary stent system in real-world patients with long diffused *de novo* coronary lesions. *Cardiol. Res.*, **2018**, 9(6), 350-357.
<http://dx.doi.org/10.14740/cr795> PMID: 30627285
- [9] Zivelonghi, C.; van Kuijk, J.P.; Nijenhuis, V.; Poletti, E.; Suttorp, M.J.; van der Heyden, J.A.S.; Eefting, F.D.; Rensing, B.J.; Ten Berg, J.M.; Azzalini, L.; van den Brink, F.S.; Ribichini, F.; Colombo, A.; Henriques, J.P.S.; Agostoni, P. First report of the use of long-tapered sirolimus-eluting coronary stent for the treatment of chronic total occlusions with the hybrid algorithm. *Catheter. Cardiovasc. Interv.*, **2018**, 92(5), E299-E307.
<http://dx.doi.org/10.1002/ccd.27539> PMID: 29411523
- [10] Podolec, J.; Skubera, M.; Niewiara, L.; Podolec, M.; Pieniżek, P.; Bartuś, K.; Żmudka, K.; Legutko, J. Clinical experience with 12-month follow-up in patients after implantation of a novel long-tapered sirolimus drug-eluting stent. *Postępy Kardiol. Interwencyjne*, **2019**, 15(1), 46-51.
<http://dx.doi.org/10.5114/aic.2019.83648> PMID: 31043984
- [11] Cutlip, D.E.; Windecker, S.; Mehran, R.; Boam, A.; Cohen, D.J.; van Es, G.-A.; Steg, P.G.; Morel, M.-A.; Mauri, L.; Vranckx, P.; McFadden, E.; Lansky, A.; Hamon, M.; Krucoff, M.W.; Serruys, P.W. Clinical end points in coronary stent trials: a case for standardized definitions. *Circulation*, **2007**, 115(17), 2344-2351.
<http://dx.doi.org/10.1161/CIRCULATIONAHA.106.685313> PMID: 17470709
- [12] Stone, G.W.; Sabik, J.F.; Serruys, P.W.; Simonton, C.A.; Généreux, P.; Puskas, J.; Kandzari, D.E.; Morice, M.-C.; Lembo, N.; Brown, W.M., III; Taggart, D.P.; Banning, A.; Merkely, B.; Horkay, F.; Boonstra, P.W.; van Boven, A.J.; Ungi, I.; Bogáts, G.; Mansour, S.; Noiseux, N.; Sabaté, M.; Pomar, J.; Hickey, M.; Gershlick, A.; Buszman, P.; Bochenek, A.; Schampaert, E.; Pagé, P.; Dressler, O.; Kosmidou, I.; Mehran, R.; Pocock, S.J.; Kappetein, A.P. Everolimus-eluting stents or bypass surgery for left main coronary artery disease. *N. Engl. J. Med.*, **2016**, 375(23), 2223-2235.
<http://dx.doi.org/10.1056/NEJMoa1610227> PMID: 27797291
- [13] Mäkikallio, T.; Holm, N.R.; Lindsay, M.; Spence, M.S.; Erglis, A.; Menown, I.B.A.; Trovik, T.; Eskola, M.; Romppanen, H.; Kellerth, T.; Ravkilde, J.; Jensen, L.O.; Kalinauskas, G.; Linder, R.B.A.; Pentikainen, M.; Hervold, A.; Banning, A.; Zaman, A.; Cotton, J.; Eriksen, E.; Margus, S.; Sørensen, H.T.; Nielsen, P.H.; Niemelä, M.; Kervinen, K.; Lassen, J.F.; Maeng, M.; Oldroyd, K.; Berg, G.; Walsh, S.J.; Hanratty, C.G.; Kumsars, I.; Stradins, P.; Steigen, T.K.; Fröbert, O.; Graham, A.N.J.; Endresen, P.C.; Corbascio, M.; Kajander, O.; Trivedi, U.; Hartikainen, J.; Anttila, V.; Hildick-Smith, D.; Thuesen, L.; Christiansen, E.H. Percutaneous coronary angioplasty versus coronary artery bypass grafting in treatment of unprotected left main stenosis (NOBLE): a prospective, randomised, open-label, non-inferiority trial. *Lancet*, **2016**, 388(10061), 2743-2752.
[http://dx.doi.org/10.1016/S0140-6736\(16\)32052-9](http://dx.doi.org/10.1016/S0140-6736(16)32052-9) PMID: 27810312
- [14] Sousa-Uva, M.; Neumann, F.-J.; Ahlsson, A.; Alfonso, F.; Banning, A.P.; Benedetto, U.; Byrne, R.A.; Collet, J.-P.; Falk, V.; Head, S.J.; Jüni, P.; Kastrati, A.; Koller, A.; Kristensen, S.D.; Niebauer, J.; Richter, D.J.; Seferovic, P.M.; Sibbing, D.; Stefanini, G.G.; Windecker, S.; Yadav, R.; Zembala, M.O. 2018 ESC/EACTS guidelines on myocardial revascularization. *Eur. J. Cardiothorac. Surg.*, **2019**, 55(1), 4-90.
<http://dx.doi.org/10.1093/ejcts/ezy289> PMID: 30165632
- [15] Oviedo, C.; Maehara, A.; Mintz, G.S.; Araki, H.; Choi, S.-Y.; Tsujita, K.; Kubo, T.; Doi, H.; Templin, B.; Lansky, A.J.; Dangas, G.; Leon, M.B.; Mehran, R.; Tahk, S.J.; Stone, G.W.; Ochiai, M.; Moses, J.W. Intravascular ultrasound classification of plaque distribution in left main coronary artery bifurcations: where is the plaque really located? *Circ. Cardiovasc. Interv.*, **2010**, 3(2), 105-112.
<http://dx.doi.org/10.1161/CIRCINTERVENTIONS.109.906016> PMID: 20197513
- [16] Shen, X.; Deng, Y.-Q.; Xie, Z.-M.; Ji, S. Assessment of coronary stent deployment in tapered arteries: impact of arterial tapering. *J. Mech. Med. Biol.*, **2016**, 16(08), 1640015.
<http://dx.doi.org/10.1142/S0219519416400157>
- [17] Shen, X.; Jiang, J.; Zhu, H.; Lu, K.; Dong, P.; Gu, L. Comparative study of tapered versus conventional cylindrical balloon for stent implantation in stenotic tapered artery. *Artif. Organs*, **2020**, 44(7), 727-735.
<http://dx.doi.org/10.1111/aor.13661> PMID: 32017159
- [18] Liu, J.; Han, J.; Yang, L.; Li, Y. Short-term outcome of straight vs tapered carotid stenting for symptomatic carotid artery stenosis: a prospective study. *J. Endovasc. Ther.*, **2018**, 25(6), 765-770.
<http://dx.doi.org/10.1177/1526602818801319> PMID: 30296887
- [19] Takagi, K.; Naganuma, T.; Chieffo, A.; Fujino, Y.; Latib, A.; Tahara, S.; Ishiguro, H.; Montorfano, M.; Carlino, M.; Kawamoto, H.; Kurita, N.; Hozawa, K.; Nakamura, S.; Nakamura, S.; Colombo, A. Comparison between 1- and 2-stent strategies in unprotected distal left main disease: the milan and new-tokyo registry. *Circ. Cardiovasc. Interv.*, **2016**, 9(11), e003359.
<http://dx.doi.org/10.1161/CIRCINTERVENTIONS.116.003359> PMID: 27810964
- [20] Karrowni, W.; Makki, N.; Dhaliwal, A.S.; Vyas, A.; Blevins, A.; Dughman, S.; Girotra, S.; Cram, P.; Horwitz, P.A. Single versus double stenting for unprotected left main coronary artery bifurcation lesions: a systematic review and meta-analysis. *J. Invasive Cardiol.*, **2014**, 26(6), 229-233.
 PMID: 24907076
- [21] Palmerini, T.; Marzocchi, A.; Tamburino, C.; Sheiban, I.; Margheri, M.; Vecchi, G.; Sangiorgi, G.; Santarelli, A.; Bartorelli, A.; Briguori, C.; Vignali, L.; Di Pede, F.; Ramondo, A.; Inglese, L.; De Carlo, M.; Falsini, G.; Benassi, A.; Palmieri, C.; Filippone, V.; Sangiorgi, D.; Barlocco, F.; De Servi, S. 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(3), 185-192.
<http://dx.doi.org/10.1161/CIRCINTERVENTIONS.108.800631> PMID: 20031677