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Ultrathin Strut Biodegradable Polymer-Coated Sirolimus-Eluting Coronary Stents: Patient-Level Pooled Analysis From Two Indian Registries

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Abstract

Background

Despite significant evolution in stent technology, female gender, and patients with diabetes mellitus, multivessel disease, total occlusions, long lesions, and small vessels represent the “Achilles' heel” of contemporary percutaneous coronary intervention (PCI). We performed a pooled analysis of high-risk subgroup on patient-level data from the T-Flex registry (1,203 patients) and a real-world Indian registry (1,269 patients), with the aim of assessing one-year safety and clinical performance of ultrathin strut biodegradable polymer-coated Supra family of sirolimus-eluting stents (SES) (Sahajanand Medical Technologies Limited, Surat, India) in the real-world, all-comer population.

Method

We pooled the following high-risk subgroups data from two all-comer registries: female gender (n=678), diabetes mellitus (n=852), multivessel disease (n=406), total occlusions (n=420), long lesions (≥28 mm) (n=1241), and small vessels (≤2.5 mm) (n=726). Both the registries included patients with coronary artery disease who underwent implantation of at least one SES belonging to the Supra family of stents from May 2016 until March 2018, irrespective of lesion complexity and comorbidities. The primary endpoint was the incidence of target lesion failure (TLF), a composite of cardiac death, target vessel myocardial infarction, and clinically indicated target lesion revascularization by percutaneous or surgical methods up to one year. The safety endpoint was stent thrombosis.

Results

According to prespecified high-risk subgroups, one-year rates of TLF and overall stent thrombosis, respectively, were as follows: female gender (4.9% and 0.6%), diabetes mellitus (6.9% and 1.0%), multivessel disease (6.4% and 0.8%), total occlusions (5.2% and 0.5%), long lesions (≥28 mm) (6.6% and 0.8%), and small vessels (≤2.5 mm) (6.1% and 1.3%).

Conclusion

This present pooled analysis demonstrated the one-year safety and clinical performance of ultrathin strut biodegradable polymer-coated Supra family of SES in a real-world, all-comer population, with considerably low rates of TLF and stent thrombosis.

Categories: Cardiology
Keywords: percutaneous coronary intervention, multivessel disease, drug-eluting stents, diabetes, coronary occlusion

Introduction

Percutaneous coronary intervention (PCI) is the frontline treatment for interventional cardiologists in managing coronary artery disease (CAD). Although no universal definition of complex PCI exists [1], there is an emerging consensus that complex PCI and higher-risk indicated populations involve clinical risk factors and characteristics of coronary lesions and PCI procedures. Approximately 30% of all PCI procedures are considered complex depending on the lesion or anatomic factors [2]. The complex PCI population remains at higher risk of mid- to long-term adverse ischemic events [2, 3].

Coronary anatomic complexity serves as an important determinant in the decision-making between PCI and coronary artery bypass graft (CABG). U.S. Food and Drug Administration (USFDA) gave an on-label

indication for the use of drug-eluting stents (DES) in simple, single, de novo coronary lesions in low-risk patients with CAD. Nevertheless, a number of PCIs are currently performed in patients with high-risk clinical and anatomic characteristics [4-8]. It has been reported that the complex PCI with DES is associated with a markedly higher ischemic risk, in a graded fashion, with expected lower procedural success rates with an increased risk of procedural complications [9, 10]. Several clinical trials have shown that DES has limited capability to prevent target lesion revascularization (TLR) in patients with complex lesions, whereas many studies confirmed similar clinical outcomes between patients with complex PCI and those with noncomplex PCI [11-13]. These conflicting findings have driven clinical studies to investigate the safety and effectiveness of the latest-generation DES in complex PCI subsets.

The Supra family of stents (Sahajanand Medical Technologies Limited, Surat, India) are the latest-generation ultrathin strut biodegradable polymer-coated sirolimus-eluting stents (SES). One-year safety and efficacy of the Supra family of SES in real-world, all-comer CAD population has already been addressed in the literature [14-17]. However, there is a lack of data about its safety and efficacy in the most frequently encountered challenging PCI subsets - female gender and patients with diabetes mellitus, multivessel disease, total occlusions, long lesions, and small vessels. Against this background, we aimed to assess the one-year safety and clinical performance of the Supra family of SES in a real-world all-comer population, using a pooled analysis of high-risk subgroups on patient-level data from two all-comer registries [15, 17].

Materials And Methods

Study design and population

We pooled high-risk subgroup data from 2471 CAD patients enrolled in two all-comer registries: T-Flex registry (n=1,203) [15] and a real-world Indian registry (n=1,269) [17]. High-risk subgroups derived from two all-comer registries included female gender (n=678), diabetes mellitus (n=852), multivessel disease (n=406), total occlusions (n=420), long lesions (⩾28 mm) (n=1241), and small vessels (⩽2.5 mm) (n=726). Both the registries comprised patients with CAD who underwent implantation of at least one SES belonging to the Supra family of SES between May 2016 and March 2018, irrespective of lesion complexity and comorbidities. Institutional Ethics Committee (IEC) granted approval for the study protocol and both registries adhered to the tenets of the Declaration of Helsinki. Signed informed consent was obtained from each patient for data collection and analysis for research purposes and the use of anonymized clinical data.

Description of study stent

The study stents were ultrathin strut (60 µm) biodegradable polymer-coated SES designed with a unique long dual-Z link (LDZ-link) between ‘valley-to-valley’ on Tetrinium L-605 cobalt-chromium alloy as its stent platform (Sahajanand Medical Technologies Limited, Surat, India). These latest-generation stents feature a multilayer conformal coating on the surface, which contains 1.4 µg/mm2 of sirolimus in the centre and the innermost layer, amalgamate with a biodegradable polymeric matrix composed of a combination of hydrophobic [PLLA: poly(L-lactide)], PLCL: poly(L-lactide-co-caprolactone)], and outer drug-free hydrophilic polymers (PVP: polyvinylpyrrolidone). Approximately 80% of the drug is released within four weeks in biological media. The remaining drug is programmed to be released at a slow rate in about three months. Once the drug is released, biodegradable polymers progressively degrade into biologically acceptable molecules and excreted from the body. The average coating thickness of SES is between 4 and 6 µm.

Coronary interventional procedure and adjuvant medications

Coronary interventional procedures and adjuvant medications were carried out in accordance with standard practice guidelines. All the patients were recommended for dual antiplatelet therapy (DAPT) for at least up to 12 months (aspirin 75-300 mg daily indefinitely and clopidogrel 75 mg daily or prasugrel 10 mg daily or ticagrelor 90 mg twice daily) after the procedure. Follow-up was obtained either via clinical follow-up or telephonic contact one year after stent implantation.

Clinical endpoint

Both the registries considered incidence of target lesion failure (TLF) as a primary endpoint, which was defined as a composite endpoint of cardiac death, target vessel myocardial infarction (TV-MI), and clinically indicated TLR (CI-TLR) by percutaneous or surgical methods at one-year. Events of stent thrombosis were assessed as an additional safety endpoint.

Statistical analysis

Data analysis was performed using the IBM Statistical Package for Social Sciences for Windows, version 20.0. (IBM Corp., Armonk, USA). Descriptive statistical analysis methods were used to perform data analysis; continuous variables were reported as mean ± standard deviation, and categorical variables were described as frequency and percentages. The TLF event curve was obtained using the Kaplan-Meier method.

Results

The baseline demographic and clinical details of the pooled high-risk subgroups are outlined in Table 1.

Characteristics	Female patients (n=678)	Diabetic mellitus (n=852)	Multivessel disease (n=406)	Total occlusion (n=420)	Long lesion (≥28 mm) (n=1241)	Small vessels (≤2.5 mm) (n=726)
Age (years), mean ± SD	57.7 ± 10.6	55.6 ± 9.8	58.01 ± 10.3	55.3 ± 10.8	56.0 ± 10.8	57.6 ± 10.0
Male, n (%)	-	575 (67.5)	288 (70.9)	302 (71.9)	929 (74.9)	491 (67.6)
Cardiovascular risk, n (%)						
Hypertension	362 (53.4)	566 (66.4)	193 (47.5)	189 (45.0)	578 (46.6)	340 (46.8)
Hypercholesterolemia	229 (33.8)	308 (36.2)	129 (31.8)	147 (35.0)	396 (31.9)	217 (29.9)
Diabetes mellitus	277 (40.9)	852 (100.0)	155 (38.2)	131 (31.2)	417 (33.6)	291 (40.1)
Smoking	86 (12.7)	123 (14.4)	55 (13.5)	79 (18.8)	232 (18.7)	107 (14.7)
Family history of CAD	15 (2.2)	31 (3.6)	6 (1.5)	14 (3.3)	198 (16.0)	24 (3.3)
Previous MI	54 (8.0)	75 (8.8)	28 (6.9)	36 (8.6)	102 (8.2)	60 (8.3)
Previous CABG	9 (1.3)	19 (2.2)	6 (1.5)	5 (1.2)	18 (1.5)	15 (2.1)
Previous PCI	43 (6.3)	74 (8.7)	21 (5.2)	30 (7.1)	91 (7.3)	66 (9.1)
Previous stroke	16 (2.4)	26 (3.1)	9 (2.2)	6 (1.4)	27 (2.2)	20 (2.8)
Renal insufficiency	5 (0.7)	13 (1.5)	5 (1.2)	7 (1.7)	18 (1.5)	16 (2.2)
Cardiogenic shock	19 (2.8)	21 (2.5)	10 (2.5)	8 (1.9)	32 (2.6)	22 (3.0)
Clinical presentation, n (%)						
Stable angina	183 (27.0)	192 (22.5)	77 (19.0)	66 (15.7)	250 (20.1)	133 (18.3)
Unstable angina	234 (34.5)	265 (31.1)	122 (30.0)	106 (25.2)	345 (27.8)	230 (31.7)
STEMI	180 (26.5)	167 (19.6)	94 (23.2)	141 (33.6)	334 (26.9)	175 (24.1)
NSTEMI	81 (11.9)	84 (9.9)	68 (16.7)	51 (12.1)	166 (13.4)	100 (13.8)

TABLE 1: Demographic and clinical characteristics of high-risk subgroups

CAD, Coronary artery disease; MI, Myocardial infarction; CABG, Coronary artery bypass graft; PCI, Percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction.

Briefly, the values of mean age and male predominance closely approached all subgroup populations. ST-elevation myocardial infarction (STEMI) was the most frequent clinical presentation in patients with total occlusions (33.6%). Stable angina (27.0%) and unstable angina (34.5%) were frequently evident in female patients. Non-ST-elevation myocardial infarction (NSTEMI) (16.7%) was the commonest in the multivessel disease subgroup.

The majority of the lesions endangered the left anterior descending artery (LAD) in all pooled high-risk subgroups. The number of stents deployed per patient for high-risk subgroups were as follows: female gender (1.31 ± 0.53), diabetic mellitus (1.3 ± 0.5), multivessel disease (1.96 ± 0.45), total occlusion (1.3 ± 0.5), long lesions (⩾28 mm) (1.2 ± 0.4), and small vessels (⩽2.5 mm) (1.1 ± 0.3). The remaining stent characteristics are elucidated in Table 2.

Characteristics	Female patients	Diabetic mellitus	Multivessel disease	Total occlusions	Long lesions (≥28 mm)	Small vessels (≤2.5 mm)
No. of lesions	802	1024	824	436	1360	771

Disease vessel, n (%)						
Single-vessel disease	341 (50.3)	408 (47.9)	96 (23.6)	203 (48.3)	581 (46.8)	332 (45.7)
Double-vessel disease	264 (38.9)	348 (40.8)	261 (64.3)	178 (42.4)	519 (41.8)	319 (43.9)
Triple-vessel disease	73 (10.8)	96 (11.3)	49 (12.1)	39 (9.3)	141 (11.4)	75 (10.3)
Target-vessel location, n (%)						
LAD	391 (48.8)	487 (47.6)	326 (39.6)	192 (44.0)	684 (50.3)	397 (51.5)
RCA	266 (33.2)	313 (30.6)	265 (32.2)	175 (40.1)	470 (34.6)	145 (18.8)
LCX	142 (17.7)	215 (21.0)	229 (27.8)	67 (15.4)	205 (15.1)	224 (29.1)
Left main	1 (0.1)	2 (0.2)	4 (0.5)	2 (0.5)	0 (0.0)	1 (0.1)
SVG	2 (0.2)	7 (0.7)	0 (0.0)	0 (0.0)	1 (0.1)	4 (0.5)
Lesion details, n (%)						
Type A*	87 (10.8)	98 (9.6)	98 (11.9)	3 (0.7)	48 (3.5)	71 (9.2)
Type B1*	106 (13.2)	110 (10.7)	99 (12.0)	21 (4.8)	80 (5.9)	93 (12.1)
Type B2*	128 (16.0)	151 (14.7)	126 (15.3)	33 (7.6)	118 (8.7)	104 (13.5)
Type C*	481 (60.0)	665 (64.9)	501 (60.8)	379 (86.9)	1114 (81.9)	503 (65.2)
Total occlusion	97 (12.1)	136 (13.3)	71 (8.6)	436 (100.0)	243 (17.9)	122 (15.8)
Pre-dilatation	267 (33.3)	263 (25.7)	291 (35.3)	224 (51.4)	501 (36.8)	155 (20.1)
Post-dilatation	301 (37.5)	342 (33.4)	346 (42.0)	207 (47.5)	573 (42.1)	123 (16.0)
Stent details, n (%)						
Total no. of stents	891	1158	855	524	1441	807
No. of stents deployed per patient, mean ± SD	1.31 ± 0.53	1.3 ± 0.5	1.96 ± 0.45	1.3 ± 0.5	1.2 ± 0.4	1.1 ± 0.3
No. of stents deployed per lesion, mean ± SD	1.11 ± 0.34	1.1 ± 0.3	1.04±0.20	1.2 ± 0.4	1.1 ± 0.2	1.1 ± 0.4
Stent length (mm), mean ± SD	25.1 ± 8.9	25.5 ± 8.7	25.94±9.20	27.3 ± 9.1	34.0 ± 5.8	25.6 ± 9.2
Stent diameter (mm), mean ± SD	2.8 ± 0.3	2.8 ± 0.3	2.84 ± 0.30	2.9 ± 0.3	3.0 ± 0.3	2.5 ± 0.02
Stent length, n (%)						
8 mm	4 (0.4)	3 (0.3)	7 (0.8)	1 (0.2)	-	4 (0.5)
12 mm	60 (6.7)	83 (7.2)	58 (6.8)	21 (4.0)	-	71 (8.8)
16 mm	143 (16.0)	157 (13.6)	121 (14.2)	68 (13.0)	-	122 (15.1)
20 mm	171 (19.2)	217 (18.7)	149 (17.4)	78 (14.9)	-	121 (15.0)
24 mm	159 (17.8)	193 (16.7)	122 (14.3)	92 (17.6)	-	126 (15.6)
28 mm	107 (12.0)	159 (13.7)	128 (15.0)	68 (13.0)	447 (31.0)	116 (14.4)
32 mm	104 (11.7)	142 (12.3)	106 (12.4)	81 (15.5)	435 (30.2)	106 (13.1)
36 mm	54 (6.1)	99 (8.5)	67 (7.8)	43 (8.2)	244 (16.9)	50 (6.2)
40 mm	41 (4.6)	56 (4.8)	41 (4.8)	32 (6.1)	147 (10.2)	45 (5.6)
44 mm	23 (2.6)	24 (2.1)	34 (4.0)	19 (3.6)	95 (6.6)	26 (3.2)
48 mm	25 (2.8)	25 (2.2)	22 (2.6)	21 (4.0)	73 (5.1)	20 (2.5)
Stent diameter, n (%)						
2.25 mm	1 (0.1)	1 (0.1)	1 (0.1)	2 (0.4)	0 (0.0)	6 (0.7)

2.50 mm	263 (29.5)	324 (28.0)	245 (28.7)	130 (24.8)	363 (25.2)	801 (99.3)
2.75 mm	256 (28.7)	339 (29.3)	257 (30.1)	144 (27.5)	441 (30.6)	-
3.00 mm	269 (30.2)	353 (30.5)	252 (29.5)	184 (35.1)	462 (32.1)	-
3.50 mm	102 (11.4)	141 (12.2)	100 (11.7)	64 (12.2)	174 (12.1)	-
4.00 mm	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	-

TABLE 2: Lesion characteristics of high-risk subgroups

*American College of Cardiology (ACC)/American Heart Association (AHA) classification of coronary lesions.

LAD, Left anterior descending artery; RCA, Right coronary artery; LCX, Left circumflex artery; SVG, Saphenous vein grafts.

The one-year follow-up data obtained for high-risk subgroups were as follows (Table 3): 96.6% in female gender, 94.7% in diabetic mellitus, 96.3% in multivessel disease, 96.9% in total occlusions, 95.5% in long lesions (≥28 mm), and 96.6% in small vessels (≤2.5 mm). One-year TLF rates in the predefined high-risk subgroups were: 4.9% in the female gender, 6.9% in diabetes mellitus, 6.4% in multivessel disease, 5.2% in total occlusions, 6.6% in long lesions (≥28 mm), and 6.1% in small vessels (≤2.5 mm). Overall stent thrombosis occurred in 0.6% of female patients, 1.0% in diabetes mellitus, 0.8% in multivessel disease, 0.5% in total occlusions, 0.8% in long lesions (≥28 mm), and 1.3% in small vessels (≤2.5 mm) high-risk subgroups.

Characteristics	Female patients (n=655)	Diabetic Mellitus (n=807)	Multivessel disease (n=391)	Total occlusion (n=407)	Long lesion (≥28 mm) (n=1185)	Small vessels (≤2.5 mm) (n=701)
All-cause death, n (%)	9 (1.4)	14 (1.7)	5 (1.3)	9 (2.2)	19 (1.6)	11 (1.6)
Cardiac death	5 (0.8)	6 (0.7)	3 (0.8)	5 (1.2)	11 (0.9)	5 (0.7)
Non-cardiac Death	4 (0.6)	8 (1.0)	2 (0.5)	4 (1.0)	8 (0.7)	6 (0.9)
TV-MI	15 (2.3)	19 (2.4)	9 (2.3)	7 (1.7)	36 (3.0)	20 (2.9)
TLR	12 (1.8)	31 (3.8)	13 (3.3)	9 (2.2)	31 (2.6)	18 (2.6)
Non-TL TVR	6 (0.9)	11 (1.4)	9 (2.3)	5 (1.2)	8 (0.7)	7 (1.0)
Overall stent thrombosis, n (%)	4 (0.6)	8 (1.0)	3 (0.8)	2 (0.5)	10 (0.8)	9 (1.3)
Target lesion failure, n (%)	32 (4.9)	56 (6.9)	25 (6.4)	21 (5.2)	78 (6.6)	43 (6.1)

TABLE 3: One-year clinical outcomes of high-risk subgroups

TV-MI, Target vessel myocardial infarction; TLR, Target lesion revascularization; Non-TL TVR, Non-target lesion target vessel revascularisation.

One-year cumulative TLF rates for stated high-risk subgroups determined by the Kaplan-Meier method are depicted in Figures 1-3.

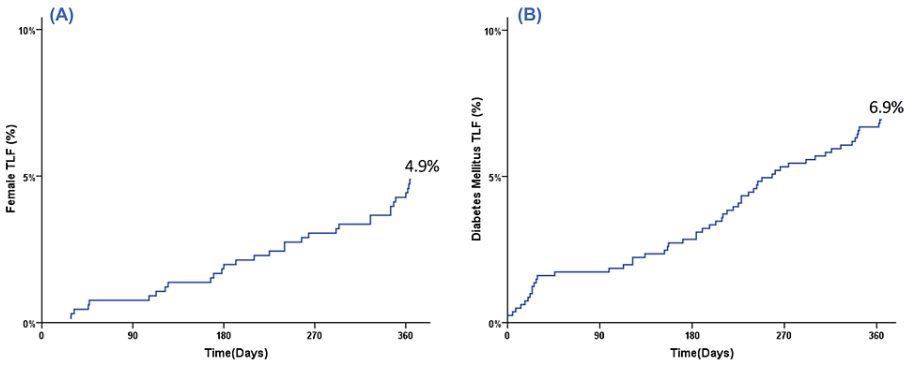


FIGURE 1: Kaplan-Meier event curve for cumulative target lesion failure (TLF) during one-year follow-up for (A) female patients and (B) diabetic mellitus

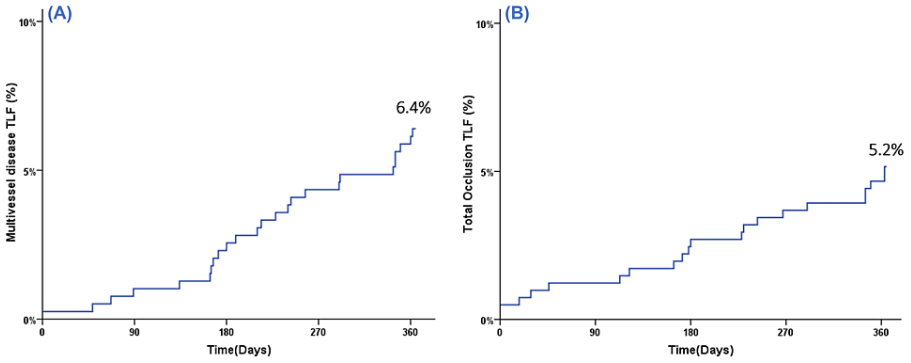


FIGURE 2: Kaplan-Meier event curve for cumulative target lesion failure (TLF) during one-year follow-up for (A) multivessel disease and (B) total occlusions

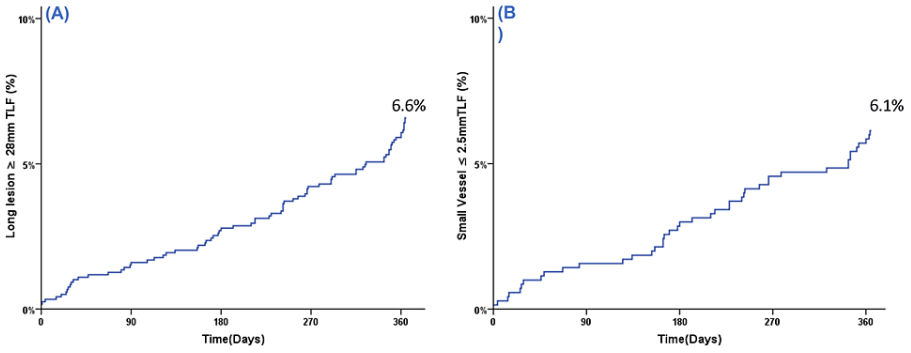


FIGURE 3: Kaplan-Meier event curve for cumulative target lesion failure (TLF) during one-year follow-up for (A) long lesions (≥28 mm) and (B) small vessels (≤2.5 mm)

Discussion

As expected, findings emerged from the present pooled analysis demonstrated that one-year safety and clinical performance of ultrathin strut (60 µm) biodegradable polymer-coated SES was favourable in treating complex PCI subsets, including female gender, diabetes mellitus, multivessel disease, total occlusions, long lesions, and small vessels, with low events of TLF and stent thrombosis.

Many previous studies asserted that gender disparities significantly affect the clinical outcomes of PCI. Compared to males, females are more prone to major cardiovascular adverse events (including death) and target vessel failure after PCI [18-22]. These higher event rates in females are mainly attributed to postmenopausal states, smaller coronary arteries [23], and smaller radial arteries [24]. Hormonal changes after menopause, as such, low plasma estrogen levels and elevated luteinizing hormone (LH) and follicle-stimulating hormone (FSH) levels, have a significant impact on the metabolism of plasma lipids and lipoproteins, ultimately leading to cardiac-related diseases [25, 26]. Smaller coronary artery diameter has proved to be associated with low PCI success rate and higher incidence of subsequent in-hospital major adverse events [23]. Smaller radial arteries are more susceptible to vascular spasms, which is a primary cause of radial procedure failure [24]. Briefly, females designate one of the challenging subsets of the complex PCI population. Our study demonstrated a lower death rate (1.4%) in females than that of earlier reported rates in the Melbourne Interventional Group (MIG) PCI registry (6.4%) [27] as well as earlier published studies by Bugiardini et al. (10.5%) [28] and Otten et al. (5.3%) [29].

Diabetes is often viewed as a “dreadful threat” in patients with CAD. It has been allied with adverse events such as increased incidence of restenosis, repeat revascularization, stent thrombosis (ST), and all-cause mortality after PCI. Of concern, diabetes patients exhibit diverse anatomical patterns of CAD, including multivessel stenosis, smaller vessel size, left main involvement, and rapidly progressing, more diffuse, and longer atherosclerotic lesions [30], which make revascularization more challenging. A subgroup analysis of the SIRIUS trial [31] and the DIABETES trial [32] paved the way for beginning a new SES era in CAD patients with diabetes. However, safety-related concerns are raised with SES implantation as diabetic patients have increased thrombocyte aggregation and thrombotic events [33]. We found a 6.9% one-year TLF rate with ultrathin strut biodegradable polymer-coated SES in the diabetic population. This figure was numerically comparable with the values reported for Supraflex SES (5.8%) and Xience everolimus-eluting stents (EES) (Abbott Vascular, Santa Clara, California) (8.5%) in the TALENT trial [14], amphilimus SES (5.9%) and zotarolimus-eluting stents (ZES) (7.5%) in a study reported by Rozemeijer et al. [34], Orsiro SES (Biotronik, Bulach, Switzerland) from the BIOFLOW III Italian Satellite Registry (6.9%) [35], DES [i.e. ridaforolimus-eluting stents (RES) and ZES] from BIONICS trial (7.8%) [36], and Resolute Integrity ZES (Medtronic Inc., Santa Rosa, CA, USA) in the International Global Resolute Program (6.6%) [37] (Table *4*).

Trial name/Author	Study design	N	Stent	Manufacturer	TLF
Diabetic subgroup					
Present pooled analysis	-	852	Ultrathin-strut biodegradable polymer-coated SES	SMT	6.9%
Talent trial [14]	Prospective, randomised, single-blind, multicentre study	157 178	Supraflex SES; Xience EES	SMT; Abbott Vascular, Santa Clara, California	5.8% 8.5%
Rozemeijer et al. [34]	Single-center retrospective analysis	85 80	A-SES ZES	-	5.9% 7.5%
Bioflow-III Italian Satellite registry [35]	Nationwide, prospective, all-comer registry	192	Orsiro SES	Biotronik, Bulach, Switzerland	6.9%
International Global Resolute Program [37]	Pooled patient-level data for 5,130 patients from 5 controlled studies, with 1 randomized and 4 single-arm	878	Resolute Integrity ZES	Medtronic Inc., Santa Rosa, CA, USA	6.6%
Multivessel disease					
Present pooled analysis	-	406	Ultrathin-strut biodegradable polymer-coated SES	SMT	6.4%
e-Ultimaster registry [40]	Prospective, multicentre, observational registry	5,852	Ultimaster SES	Terumo Corporation, Tokyo, Japan	4.2%
Talent trial [14]	Prospective, randomised, single-blind, multicentre study	311	Supraflex SES; Xience EES	SMT; Abbott Vascular, Santa Clara, California	10% 5.7%
Total occlusions					
Present study	Pooled subgroup analysis of two real-world, all-comers, multicentre registries	420	Ultrathin-strut biodegradable polymer-coated	SMT	5.2%

			SES		
e-Ultimaster registry [40]	Prospective, multicentre, observational registry	1774	Ultimaster SES	Terumo Corporation, Tokyo, Japan	3.3%
Bioflow-III Italian Satellite Registry [35]	Nationwide, prospective, all-comer registry	38	Orsiro SES	Biotronik, Bulach, Switzerland	5.3%
Long lesions					
Present pooled analysis	-	1241	Ultrathin-strut biodegradable polymer-coated SES	SMT	6.6%
Talent trial [14]	Prospective, randomised, single-blind, multicentre study (>18 mm lesion)	518 511	Supraflex SES; Xience EES	SMT; Abbott Vascular, Santa Clara, California	5.7% 7%
Sinha et al. [50]	Prospective, single-arm, investigator-initiated study (≥40 mm lesion)	684	Supralimus Grace SES	SMT	6.1%
e-Ultimaster registry [40]	Prospective, multicentre, observational registry (≥60 mm lesion)	3146	Ultimaster SES	Terumo Corporation, Tokyo, Japan	4.8%
Bioflow V trial [51]	Prospective, randomised, assessor blinded multicentre trial (>26 mm lesion)	78 36	Orsiro SES; Xience EES	Biotronik, Buelach, Switzerland; Abbott Vascular, Santa Clara, California	5% 17%
Spirit Prime Trial (long lesion registry) [54]	Prospective, non-randomized clinical trial (33- and 38-mm stents)	104	Xience Prime EES	Abbott Vascular, Santa Clara, CA	12.5%
Pooled Analysis from the SPIRIT and XIENCE V USA Prospective Multicenter trials [55]	Pooled analysis of Spirit II, III, IV, V, Spirit small vessel and XIENCE V USA (≥35 mm lesion)	323	Xience V EES	Abbott Vascular, Santa Clara, CA	8.9%
Small vessels					
Present pooled analysis	-	726	Ultrathin-strut biodegradable polymer-coated SES	SMT	6.1%
Talent trial [14]	Prospective, randomised, single-blind, multicentre study (≤2.75 mm vessel size)	518 511	Supraflex SES; Xience EES	SMT; Abbott Vascular, Santa Clara, California	8% 5.8%
Xience V USA Condition of Approval Post-Market study [57]	Single-arm, prospective multicenter study (2.5 mm stent size)	838	Xience V	Abbott Vascular, Santa Clara, CA	5.7%
Bioflow V trial [51]	Prospective, randomised, assessor blinded multicentre trial (≤2.75mm vessel size)	554 290	Orsiro SES; Xience EES	Biotronik, Buelach, Switzerland; Abbott Vascular, Santa Clara, CA	8% 11%
Century JSV study [58]	Prospective, multicenter, single-arm study (2.25 mm stent size)	70	Ultimaster SES	Terumo Corporation, Tokyo, Japan	4.3%
Spirit small vessel trial [59]	Prospective, single-arm, open-label study (<2.5 mm vessel size)	150	Xience V EES	Abbott Vascular, Santa Clara, CA	8.1%
Restore SVD China randomized trial [60]	Prospective, randomized, open-label, multicenter (≥2.0–<2.75 mm vessel size)	114	Resolute Integrity ZES	Medtronic Inc., Santa Rosa, CA, USA	5.0%

TABLE 4: Summary of one-year target lesion failure rates for high-risk subgroups from the present study and previously reported studies

SES, Sirolimus-eluting stent; EES, Everolimus-eluting stent; A-SES,Amphilimus SES; RES, Ridaforolimus-eluting stents; ZES, Zotarolimus-eluting stent; CTO, Chronic total occlusions; SVD, Small vessel disease; SMT: Sahajanand Medical Technologies Limited

With a growing number of aging population with various comorbidities, including diabetes and obesity, the prevalence of multivessel disease has been projected to rise, representing 30% to 40% of CAD patients [38]. Patients with multivessel disease are more likely to have worse clinical outcomes than those with single-vessel disease [39]. PCI and CABG are the established revascularization strategies in patients with multivessel CAD. Nonetheless, the selection of optimal revascularization strategies remains a subject of intense discussion and debate. The discovery of DES has greatly enriched the conventional PCI era with promising outcomes in complex lesions, including multivessel disease. Consistent with one-year TLF rate for multivessel disease with the Ultimaster SES (Terumo Corporation, Tokyo, Japan) in e-Ultimaster registry (4.2%) [40] and Supraflex SES (10%) and Xience EES (5.7%) in TALENT trial [14], the present study demonstrated 6.4% one-year TLF rate with ultrathin strut biodegradable polymer-coated SES in multivessel disease subgroup (Table *4*).

Labeled as the most challenging and growing subset of the complex PCI population, total occlusions have been plagued by a number of procedural complications including coronary perforation, periprocedural myocardial infarction, arrhythmias, cardiogenic shock, stroke, major bleeding, donor vessel thrombosis, contrast-induced nephropathy, radiation damage, and death and adverse clinical events [41]. It has been stated that chronic total occlusions (CTO-PCI) are high-risk procedures with low success rates than standard PCI. A significant breakthrough in recanalization techniques, the introduction of dedicated equipment and the development of systematic algorithmic approaches have significantly improved procedural success and reduced the occurrence of major complications [42, 43]. Numerous risk factors including sex, hypertension, smoking, and diabetes can affect the prognosis in patients with CTO lesions, which could lead to an increase in the frequency of adverse cardiovascular events. Control of these influential risk factors should be encouraged with routine follow-up. Despite the presence of multiple comorbidities/history, such as hypertension (45.0%), hypercholesteremia (35.0%), diabetes mellitus (31.2%), and previous revascularization (1.2% CABG and 7.1% PCI), we observed a 5.2% one-year TLF rate with ultrathin strut biodegradable polymer-coated SES in total occlusions subgroup. These values were in accordance with the values reported for Ultimaster SES in the e-Ultimaster registry (3.3%) [40], and Orsiro SES in BIOFLOW III Italian Satellite Registry (5.3%) [35] (Table *4*).

Long lesions are associated with more adverse events after DES implantation, including higher rates of restenosis, periprocedural myocardial infarction, and stent thrombosis, which portrays the Achilles' heel of PCI. Despite refinement in devices and techniques, the intervention of long lesions poses technical difficulties such as stent deliverability, stent overlap, geographical miss, and prolonged intracoronary manipulation because of the multiple and overlapping stent placement which may impair the vessel wall integrity [44]. Mounting evidence supports the concept that multiple stent implantations in long lesions appear to have similar clinical outcomes to that of single long stent implantation [45-48]. The implantation of a single long stent yield reduction in catheterization time, dye volume for the patient, radiation exposure for both patient and operator, and procedural costs, compared to multiple stent implantations [48]. Long lesions have been frequently under-represented in clinical trials because of apparent heterogeneity in published definitions and limited stent length [49]. Latest-generations DES have emerged to treat long lesions in concert with unique stent characteristics, such as low loss rate to reduce restenosis risks, thin struts to enhance deliverability and reduce the risk of periprocedural infarction, and availability of long lengths to minimize overlap and avoid geographical miss [44].

The present study highlighted the safety and efficacy of a single ultrathin-strut biodegradable polymer-coated SES in treating long lesions (≥28 mm), with an acceptably low TLF rate of 6.6% at one year. This figure was numerically compared with one-year TLF rate documented with long lesions treated with Supraflex SES (5.7%) and Xience EES (7%) in TALENT trial [14], Supralimus Grace SES in a study reported by Sinha et al. (6.1%) [50], Ultimaster SES in e-Ultimaster registry (4.8%) [40], Orsiro SES (5%) and Xience EES (17%) in BIOFLOW V trial [51], Xience EES family (Xience EES and Xpedition EES) (2.6%) in the study reported by Sim et al. [52] and DES (SES and EES) (2.9%) in the study reported by Rajesh et al. [53], Xience Prime EES in the SPIRIT PRIME study (12.5%) [54], Xience V EES (8.9%) in a pooled analysis from the SPIRIT and XIENCE V USA prospective multicenter trials [55] (Table *4*).

Although the history of PCI has been transitioned from plain old balloon angioplasty and bare metal stents to a variety of DES generations, clinical outcomes in small vessels remain far from satisfactory than those with large vessels. Higher incidences of in-stent restenosis and overall recurrent ischemic events have been reported after PCI of small vessels, which mainly occurs due to neointimal hyperplasia and inflammation [56]. There is a lack of standardized definitions for small vessel CAD. At one year, the TLF occurred in 6.1% of patients with ultrathin strut biodegradable polymer-coated SES in our subgroup of small vessels (≤2.5 mm reference vessel diameter). This TLF rate compared favourably with previous data wherein small lesions treated with Supraflex SES (8%) and Xience EES (5.8%) in the TALENT trial [14], Xience V EES from Xience V USA Condition of Approval Post-Market study (5.7%) [57], Orsiro SES (8%) and Xience EES (11%) from BIOFLOW V trial [51], Ultimaster SES in CENTURY JSV study (4.3%,) [58] Xience V EES in SPIRIT Small Vessel Trial (8.1%) [59], and Resolute Integrity ZES in the RESTORE SVD China Randomized Trial (5.0%) [60] (Table *4*).

The rates of stent thrombosis in all six subgroups were also comparable with other similar studies [36, 41, 52] - 0.6% in female patients, 1% in patients with diabetes mellitus, 0.8% in patients with multi-vessel disease, 0.5% in patients with total occlusion, 0.8% in patients with long coronary lesions (⩾28 mm), and 1.3% in patients with small diameter vessels (⩽2.5 mm).

The key strength of this pooled subgroup analysis is that we focused exclusively on complex-PCI populations from two large-scale, multicentre, real-world Indian registries with adequate patient sizes in each subgroup; hence, the results can be generalized to the overall population.

Thankful to the latest-generation DES, which has appreciably improved procedural success rates in complex PCI. Overall, the results with the ultrathin strut SES in this pooled analysis were favourable in terms of low rates of TLF rate and stent thrombosis at one year. The Supra family of SES demonstrated favourable clinical outcomes in challenging lesion subsets and patient population, which is mainly attributable to stent design innovation, including ultrathin strut (60 µm) along with biodegradable polymer matrix and unique LDZ-link design.

Conclusions

This pooled subgroup analysis confirmed the one-year safety and clinical performance of ultrathin strut biodegradable polymer-coated Supra family of SES in a real-world, all-comer Indian population, with markedly low rates of TLF and stent thrombosis.

The Supra family of SES has already been established as highly deliverable drug-eluting stents with low clinical event rates. This analysis covered an extensive range of complex and heterogenous PCI population in real-world settings providing additional data on efficacy and safety in complex patient and lesion subsets.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Institutional Ethics Committee, Ramesh Hospitals, Vijayawada, India issued approval ECR/81/INST/AP/2013/RR/2016. The Institutional Ethics Committee (IEC) granted approval for the study protocol. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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References

1. Wang H-Y, Wang Y, Yin D, et al.: Percutaneous coronary intervention complexity and risk of adverse events in relation to high bleeding risk among patients receiving drug-eluting stents: insights from a large single-center cohort study. J Interv Cardiol. 2020, 2020:2985435. 10.1155/2020/298543
2. Baber U: Defining PCI complexity in the contemporary DES era: clarity or confusion? . Int J Cardiol. 2018, 268:94-5. 10.1016/j.ijcard.2018.05.044
3. Piccolo R, Giustino G, Mehran R, et al.: Stable coronary artery disease: revascularisation and invasive strategies. . Lancet. 2015, 386:702-13. 10.1016/S0140-6736(15)61220-X
4. Pamidimukkala V, Polavarapu AR, Polavarapu NR, et al.: Impact of ultra-long sirolimus-eluting stents on coronary artery lesions: one-year results of real-world FLEX-LONG study. Minerva Med. 2020, 111:529-35. 10.23736/S0026-4806.20.06333-8
5. Chandwani P, Verma P, Saxena S, et al.: Comparison of clinical outcomes following single versus multivessel percutaneous coronary intervention using biodegradable polymer coated sirolimus-eluting stent in an all-comers patient population. Cardiovasc Hematol Agents Med Chem. 2016, 14:39-48. 10.2174/1871525714666151120111839
6. Hudec M, Kupec A, Gazdič P: E-9 | prospective evaluation of ultrathin-strut biodegradable polymer-coated sirolimus-eluting stents in an all-comers patient population: Slovakia registry with a subgroup analysis. J Soc Cardiovasc Angiogr Interv. 2022, 1:4-5. 10.1016/j.jscai.2022.100269
7. Sinha SK, Kumar P, Pandey U, et al.: Twelve-month clinical outcomes of "nano-crush technique" for the treatment of bifurcation lesions using ultra-thin (60 µm) sirolimus-eluting coronary stents. Minerva Cardiol Angiol. 2023, 71:51-60. 10.23736/S2724-5683.21.05875-0
8. Katoh H, Yamane M, Muramatsu T, et al.: Safety of percutaneous coronary intervention for chronic total

occlusion in patients with multi-vesel disease: sub-analysis of the Japanese retrograde summit registry. Cardiovasc Revasc Med. 2021, 25:36-42. 10.1016/j.carrev.2020.10.007
9. Giustino G, Chieffo A, Palmerini T, et al.: Efficacy and safety of dual antiplatelet therapy after complex PCI . J Am Coll Cardiol. 2016, 68:1851-64. 10.1016/j.jacc.2016.07.760
10. Généreux P, Giustino G, Redfors B, et al.: Impact of percutaneous coronary intervention extent, complexity and platelet reactivity on outcomes after drug-eluting stent implantation. Int J Cardiol. 2018, 268:61-7. 10.1016/j.ijcard.2018.03.103
11. Takahashi K, Serruys PW, Fuster V, et al.: Redevelopment and validation of the SYNTAX score II to individualise decision making between percutaneous and surgical revascularisation in patients with complex coronary artery disease: secondary analysis of the multicentre randomised controlled SYNTAXES trial with external cohort validation. Lancet. 2020, 396:1399-412. 10.1016/S0140-6736(20)32114-0
12. Endo H, Dohi T, Miyauchi K, et al.: Clinical impact of complex percutaneous coronary intervention in patients with coronary artery disease. Cardiovasc Interv Ther. 2020, 35:234-41. 10.1007/s12928-019-00608-7
13. Kirtane AJ, Doshi D, Leon MB, et al.: Treatment of higher-risk patients with an indication for revascularization: evolution within the field of contemporary percutaneous coronary intervention. Circulation. 2016, 134:422-31. 10.1161/CIRCULATIONAHA.116.022061
14. Zaman A, de Winter RJ, Kogame N, et al.: Safety and efficacy of a sirolimus-eluting coronary stent with ultra-thin strut for treatment of atherosclerotic lesions (TALENT): a prospective multicentre randomised controlled trial. Lancet. 2019, 393:987-97. 10.1016/S0140-6736(18)32467-X
15. Pothineni RB, Vijan V, Potdar A, Inamdar MK, Pathak A, Mantravadi SS, Ajmera P: Clinical outcomes of ultrathin biodegradable polymer-coated sirolimus-eluting stents in an all-comer population: one-year results from the T-FLEX registry including high-risk subgroups. Anatol J Cardiol. 2021, 25:706-15. 10.5152/AnatolJCardiol.2021.78291
16. Lemos PA, Chandwani P, Saxena S, et al.: Clinical outcomes in 995 unselected real-world patients treated with an ultrathin biodegradable polymer-coated sirolimus-eluting stent: 12-month results from the FLEX Registry. BMJ Open. 2016, 6:e010028. 10.1136/bmjopen-2015-010028
17. Ajmera P, Pothineni R, Chawla KK, Mantravadi SS, Jariwala P, Vijan V, Vijan V: Twelve months clinical outcomes of ultrathin strut sirolimus-eluting stent in real-world Indian patients with coronary artery disease. Am J Cardiovasc Dis. 2022, 12:262-71.
18. Argulian E, Patel AD, Abramson JL, et al.: Gender differences in short-term cardiovascular outcomes after percutaneous coronary interventions. Am J Cardiol. 2006, 98:48-53. 10.1016/j.amjcard.2006.01.048
19. Lansky AJ, Ng VG, Mutlu H, et al.: Gender-based evaluation of the XIENCE V everolimus-eluting coronary stent system: clinical and angiographic results from the SPIRIT III randomized trial. Catheter Cardiovasc Interv. 2009, 74:719-27. 10.1002/ccd.22067
20. Ellis SG, Roubin GS, King SB 3rd, Douglas JS Jr, Weintraub WS, Thomas RG, Cox WR: Angiographic and clinical predictors of acute closure after native vessel coronary angioplasty. Circulation. 1988, 77:372-9. 10.1161/01.cir.77.2.372
21. Park DW, Kim YH, Yun SC, et al.: Sex difference in clinical outcomes after percutaneous coronary intervention in Korean population. Am Heart J. 2014, 167:743-52. 10.1016/j.ahj.2013.12.027
22. Kunadian V, Qiu W, Lagerqvist B, et al.: Gender differences in outcomes and predictors of all-cause mortality after percutaneous coronary intervention (data from United Kingdom and Sweden). Am J Cardiol. 2017, 119:210-6. 10.1016/j.amjcard.2016.09.052
23. Schunkert H, Harrell L, Palacios IF: Implications of small reference vessel diameter in patients undergoing percutaneous coronary revascularization. J Am Coll Cardiol. 1999, 34:40-8. 10.1016/s0735-1097(99)00181-3
24. Rao SV, Hess CN, Barham B, et al.: A registry-based randomized trial comparing radial and femoral approaches in women undergoing percutaneous coronary intervention: the SAFE-PCI for Women (Study of Access Site for Enhancement of PCI for Women) trial. JACC Cardiovasc Interv. 2014, 7:857-67. 10.1016/j.jcin.2014.04.007
25. Varu D, Vegad D, Jani D, et al.: A comparative study of serum lipid profile between premenopausal and postmenopausal women. Nat J Integr Res Med. 2012, 3:43-5.
26. Deepthi S, Naidu J, Narayan AR: Relationship between estrogen and lipid profile status in postmenopausal women. Inte J Applied Biol Pharm Tech. 2012, 3:230-4.
27. Al-Fiadh AH, Andrianopoulos N, Farouque O, et al.: Contemporary outcomes in women undergoing percutaneous coronary intervention for acute coronary syndromes. Int J Cardiol. 2011, 151:195-9. 10.1016/j.ijcard.2010.05.018
28. Bugiardini R, Yan AT, Yan RT, Fitchett D, Langer A, Manfrini O, Goodman SG: Factors influencing underutilization of evidence-based therapies in women. Eur Heart J. 2011, 32:1337-44. 10.1093/eurheartj/ehr027
29. Otten AM, Maas AH, Ottervanger JP, et al.: Is the difference in outcome between men and women treated by primary percutaneous coronary intervention age dependent? Gender difference in STEMI stratified on age. Eur Heart J Acute Cardiovasc Care. 2013, 2:334-41. 10.1177/2048872612475270
30. O'Donoghue ML, Vaidya A, Afsal R, et al.: An invasive or conservative strategy in patients with diabetes mellitus and non-ST-segment elevation acute coronary syndromes: a collaborative meta-analysis of randomized trials. J Am Coll Cardiol. 2012, 60:106-11. 10.1016/j.jacc.2012.02.059
31. Holmes DR Jr, Leon MB, Moses JW, et al.: Analysis of 1-year clinical outcomes in the SIRIUS trial: a randomized trial of a sirolimus-eluting stent versus a standard stent in patients at high risk for coronary restenosis. Circulation. 2004, 109:634-40. 10.1161/01.CIR.0000112572.57794.22
32. Sabaté M, Jiménez-Quevedo P, Angiolillo DJ, et al.: Randomized comparison of sirolimus-eluting stent versus standard stent for percutaneous coronary revascularization in diabetic patients: the diabetes and sirolimus-eluting stent (DIABETES) trial. Circulation. 2005, 112:2175-83. 10.1161/CIRCULATIONAHA.105.562421
33. Moreno PR, Fuster V: New aspects in the pathogenesis of diabetic atherothrombosis . J Am Coll Cardiol. 2004, 44:2293-300. 10.1016/j.jacc.2004.07.060

34. Rozemeijer R, Benedetto D, Kraaijeveld AO, et al.: Clinical outcomes of complex real-world diabetic patients treated with amphilimus sirolimus-eluting stents or zotarolimus-eluting stents: A single-center registry. Cardiovasc Revasc Med. 2018, 19:521-5. 10.1016/j.carrev.2017.10.011
35. Bartorelli AL, Versaci F, Briguori C, et al.: The BIOFLOW-III Italian Satellite Registry: 18-month results of the Orsiro stent in an all-comer high-risk population. J Cardiovasc Med (Hagerstown). 2019, 20:464-70. 10.2459/JCM.0000000000000795
36. Konigstein M, Ben-Yehuda O, Smits PC, et al.: Outcomes among diabetic patients undergoing percutaneous coronary intervention with contemporary drug-eluting stents: analysis from the BIONICS randomized trial. JACC Cardiovasc Interv. 2018, 11:2467-76. 10.1016/j.jcin.2018.09.033
37. Silber S, Serruys PW, Leon MB, et al.: Clinical outcome of patients with and without diabetes mellitus after percutaneous coronary intervention with the resolute zotarolimus-eluting stent: 2-year results from the prospectively pooled analysis of the international global RESOLUTE program. JACC Cardiovasc Interv. 2013, 6:357-68. 10.1016/j.jcin.2012.11.006
38. Norhammar A, Malmberg K, Diderholm E, Lagerqvist B, Lindahl B, Rydén L, Wallentin L: Diabetes mellitus: the major risk factor in unstable coronary artery disease even after consideration of the extent of coronary artery disease and benefits of revascularization. J Am Coll Cardiol. 2004, 43:585-91. 10.1016/j.jacc.2003.08.050
39. Sorajja P, Gersh BJ, Cox DA, et al.: Impact of multivessel disease on reperfusion success and clinical outcomes in patients undergoing primary percutaneous coronary intervention for acute myocardial infarction. Eur Heart J. 2007, 28:1709-16. 10.1093/eurheartj/ehm184
40. Mohamed MO, Polad J, Hildick-Smith D, et al.: Impact of coronary lesion complexity in percutaneous coronary intervention: one-year outcomes from the large, multicentre e-Ultimaster registry. EuroIntervention. 2020, 16:603-12. 10.4244/EIJ-D-20-00361
41. Riley RF, Sapontis J, Kirtane AJ, et al.: Prevalence, predictors, and health status implications of periprocedural complications during coronary chronic total occlusion angioplasty. EuroIntervention. 2018, 14:e1199-206. 10.4244/EIJ-D-17-00976
42. Brilakis ES, Grantham JA, Rinfret S, et al.: A percutaneous treatment algorithm for crossing coronary chronic total occlusions. JACC Cardiovasc Interv. 2012, 5:367-79. 10.1016/j.jcin.2012.02.006
43. Maeremans J, Walsh S, Knaapen P, et al.: The hybrid algorithm for treating chronic total occlusions in Europe: the RECHARGE registry. J Am Coll Cardiol. 2016, 68:1958-70. 10.1016/j.jacc.2016.08.034
44. Loutfi M, Sadaka M, Sobhy M: TCT-651 feasibility and clinical outcomes of⩾ 38 mm long drug eluting stent treatment for diffuse coronary artery disease in Egyptian population. J Am Coll Cardiol. 2012, 60:B189. 10.1016/j.jacc.2012.08.688
45. Amirzadegan A, Hasanabadi M, Saadatagah S, et al.: Single long stents versus overlapping multiple stents in the management of very long coronary lesions: comparisons of procedures and clinical outcomes. J Tehran Heart Cent. 2019, 14:94-102.
46. Jurado-Román A, Abellán-Huerta J, Requena JA, et al.: Comparison of clinical outcomes between very long stents and overlapping stents for the treatment of diffuse coronary disease in real clinical practice. Cardiovasc Revasc Med. 2019, 20:681-6. 10.1016/j.carrev.2018.09.009
47. Hoffmann R, Herrmann G, Silber S, et al.: Randomized comparison of success and adverse event rates and cost effectiveness of one long versus two short stents for treatment of long coronary narrowings. Am J Cardiol. 2002, 90:460-4. 10.1016/s0002-9149(02)02514-6
48. De Scheerder IK, Wang K, Kostopoulos K, Dens J, Desmet W, Piessens JH: Treatment of long dissections by use of a single long or multiple short stents: clinical and angiographic follow-up. Am Heart J. 1998, 136:345-51. 10.1053/hj.1998.v136.89578
49. Claessen BE, Smits PC, Kereiakes DJ, et al.: Impact of lesion length and vessel size on clinical outcomes after percutaneous coronary intervention with everolimus- versus paclitaxel-eluting stents pooled analysis from the SPIRIT (clinical evaluation of the XIENCE V everolimus eluting coronary stent system) and COMPARE (second-generation everolimus-eluting and paclitaxel-eluting stents in real-life practice) randomized trials. JACC Cardiovasc Interv. 2011, 4:1209-15. 10.1016/j.jcin.2011.07.016
50. Sinha SK, Aggarwal P, Pandey U, Razi M, Kumar A, Krishna V: Ultrathin (60 µm), ultralong (⩾40 mm) sirolimus-eluting stent: study of clinical and safety profiles among real-world patients. Anatol J Cardiol. 2021, 25:111-9. 10.14744/AnatolJCardiol.2020.40909
51. Kandzari DE, Mauri L, Koolen JJ, et al.: Ultrathin, bioresorbable polymer sirolimus-eluting stents versus thin, durable polymer everolimus-eluting stents in patients undergoing coronary revascularisation (BIOFLOW V): a randomised trial. Lancet. 2017, 390:1843-52. 10.1016/S0140-6736(17)32249-3
52. Sim HW, Thong EH, Loh PH, et al.: Treating very long coronary artery lesions in the contemporary drug-eluting-stent era: single long 48 mm stent versus two overlapping stents showed comparable clinical outcomes. Cardiovasc Revasc Med. 2020, 21:1115-8. 10.1016/j.carrev.2020.02.005
53. Rajesh GN, Sulaiman S, Vellani H, Sajeev CG: One-year clinical outcome of percutaneous coronary intervention with very long (⩾ 40mm) drug-eluting stent. Indian Heart J. 2018, 70 Suppl 3:S285-9. 10.1016/j.ihj.2018.05.016
54. Bouras G, Jhamnani S, Ng VG, et al.: Clinical outcomes after PCI treatment of very long lesions with the XIENCE V everolimus eluting stent; Pooled analysis from the SPIRIT and XIENCE V USA prospective multicenter trials. Catheter Cardiovasc Interv. 2017, 89:984-91. 10.1002/ccd.26711
55. Krucoff MW, Rutledge DR, Gruberg L, et al.: A new era of prospective real-world safety evaluation primary report of XIENCE V USA (XIENCE V everolimus eluting coronary stent system condition-of-approval post-market study). JACC Cardiovasc Interv. 2011, 4:1298-309. 10.1016/j.jcin.2011.08.010
56. van der Heijden LC, Kok MM, Danse PW, et al.: Small-vessel treatment with contemporary newer-generation drug-eluting coronary stents in all-comers: Insights from 2-year DUTCH PEERS (TWENTE II) randomized trial. Am Heart J. 2016, 176:28-35. 10.1016/j.ahj.2016.02.020
57. Hermiller JB, Rutledge DR, Mao VW, et al.: Clinical outcomes in real-world patients with small vessel disease treated with XIENCE V® everolimus-eluting stents: one year results from the XIENCE V® USA condition of approval post-market study. Catheter Cardiovasc Interv. 2014, 84:7-16. 10.1002/ccd.25325

58. Wöhrle J, Markovic S, Rottbauer W, et al.: Bioresorbable polymer sirolimus-eluting coronary stent compared with permanent polymer everolimus-eluting coronary stent implantation for treatment of small vessel coronary artery disease: CENTURY II trial. EuroIntervention. 2016, 12:e167-74. 10.4244/EIJV12I2A30
59. Cannon LA, Simon DI, Kereiakes D, et al.: The XIENCE nano™ everolimus eluting coronary stent system for the treatment of small coronary arteries: the SPIRIT small vessel trial. Catheter Cardiovasc Interv. 2012, 80:546-53. 10.1002/ccd.2339
60. Price MJ, Saito S, Shlofmitz RA, et al.: first report of the Resolute Onyx 2.0-mm zotarolimus-eluting stent for the treatment of coronary lesions with very small reference vessel diameter. JACC Cardiovasc Interv. 2017, 10:1381-8. 10.1016/j.jcin.2017.05.004