BIFURCATION STENTING: CURRENT STATUS

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I DEFINITION AND CLASSIFICATION

- **Definition:** A coronary bifurcation lesion is a coronary artery narrowing adjacent to and/or involving the origin of a significant side branch (SB)—defined as a branch that the operator must preserve, typically having a reference diameter of **2.25 mm or greater** or supplying a large myocardial territory.
- **The Medina Classification:** The universal binary classification recording the presence (**1**) or absence (**0**) of significant stenosis (greater than 50 percent) in three sequential segments separated by commas: **(Proximal Main Vessel [PMV], Distal Main Vessel [DMV], Side Branch [SB])**. **"True" Bifurcation Lesions** involve both the main vessel and the side branch: Medina **(1,1,1)**, **(1,0,1)**, or **(0,1,1)**.
- **Criteria for Complex Bifurcations (DEFINITION Criteria):** Complexity is primarily driven by a **Side Branch lesion length greater than 10 mm** (with SB stenosis >=70% in Left Main or >=90% in non-LM) and **bifurcation angle** (narrow angles less than 70 degrees increase the risk of carinal shift, whereas wide angles make side-branch wiring and stent delivery more challenging).

II DEDICATED BIFURCATION STENTS

- **Concept:** Specialized scaffolds engineered to overcome the mechanical limitations of deploying tubular stents in Y-shaped bifurcations (such as carinal shift, ostial geographic miss, or multi-layer metal overlap):
- **Side-Branch Access Stents (e.g., Tryton):** Deployed in the side branch with a transition zone that permits a standard DES to be deployed across the main vessel.
- **Main-Vessel Tapering Stents (e.g., BiOSS):** Stepped-diameter balloons/stents accommodating the physiological step-down in vessel caliber from the proximal to the distal main vessel (**Murray's Law / Finet's Law**).
- **Self-Expanding Conical Carinal Stents (e.g., Axxess):** Deployed at the level of the carina to scaffold the bifurcation core while leaving both daughter branches unobstructed.
- **Current Clinical Reality:** Dedicated bifurcation stents have **not** demonstrated superiority over standard **Provisional Stenting** using contemporary Drug-Eluting Stents (DES) in randomized trials and are rarely used in routine practice.

III CLINICAL STRATEGIES AND TECHNIQUES

- **The Stepwise Provisional Strategy (Default Gold Standard — Class I):**
  - **Principle:** Stent the **Main Vessel (MV) across the Side Branch (SB)** first (sizing the stent diameter 1:1 to the **distal** main vessel) while keeping a jailed protection wire in the SB.
  - **Bailout Trigger:** If the side branch maintains **TIMI 3 flow, less than 75 percent ostial stenosis, and no flow-limiting dissection**, no further SB stenting is needed; if the SB is compromised, a second stent is implanted via **T-stenting** (when angle is near 90 degrees), **TAP (T-and-Small Protrusion)**, or **Culotte**.
  - **The DK-CRUSH (Double Kissing Crush) Technique (Preferred Upfront Two-Stent Technique for Complex True Bifurcations — ESC 2018 Class IIb for true LM bifurcations):**
  - **Principle:** Designed for **complex True Bifurcations (Medina 1,1,1 or 0,1,1) with long Side Branch disease (greater than 10 mm)**. The SB stent is deployed with 2 to 3 mm protrusion into the MV, crushed with a balloon in the MV, **rewired and subjected to a First Kissing Balloon Inflation (KBI)**, followed by MV stent deployment, POT, **distal-cell rewiring, a Second KBI**, and Final POT—ensuring complete ostial SB scaffolding and high rates (>99%) of successful final kissing inflation.
  - **The Culotte Technique:**
  - **Principle:** Ideal when the **Main Vessel and Side Branch have similar diameters** and a narrow angle; one stent is deployed into the more angulated branch, rewired through its struts to deploy the second stent into the other branch, and finished with KBI and Final POT (leaving a two-layer metal overlap in the proximal main vessel).

IV COMPARISON OF PROVISIONAL VS. UPFRONT TWO-STENT STRATEGIES

Feature	Stepwise Provisional (Single-Stent Default)	Upfront Two-Stent Strategy (e.g., DK-CRUSH)
Guideline Indication	**Class I** for the vast majority of bifurcation lesions (including non-complex distal LM)	**Class IIb** (ESC 2018) for complex **True Bifurcations (Medina 1,1,1 / 0,1,1)** with **SB lesion length > 10 mm**
Key Advantages	Simpler, faster procedure; lower contrast volume & radiation; single metal layer; lower long-term stent thrombosis	Secures SB patency upfront in long, heavily diseased SB anatomy; lower target lesion revascularization in complex LM (**DKCRUSH-V**)
Key Disadvantages	Risk of acute SB occlusion from plaque/carinal shift; bailout second stent may be technically difficult	Technically demanding; longer procedure time & contrast load; mandatory precise **POT, distal rewiring, and 2x KBI**

V EUROPEAN BIFURCATION CLUB (EBC) FIVE-STEP EXECUTION PROTOCOL

- **Step 1 — Dual Wiring and Vessel Preparation:** Wire both the Main Vessel and the Side Branch; the jailed SB wire maintains patency, widens the bifurcation angle, and serves as a fluoroscopic marker if the SB occludes. Stent diameter must be sized **1:1 to the Distal Main Vessel** to prevent carinal shift.
- **Step 2 — Proximal Optimization Technique (POT — Mandatory):** Immediately after deploying the crossover MV stent, inflate a short, larger **Non-Compliant (NC) balloon sized 1:1 to the Proximal Main Vessel** with its distal shoulder positioned **just at the carina**. POT apposes the proximal stent struts to the larger PMV wall, prevents wire passage behind the stent struts, and expands the stent cells facing the SB ostium.
- **Step 3 — Distal-Strut Rewiring (When SB Intervention is Required):** Advance a guidewire into the Side Branch strictly through the **distal-most strut cell** overlaying the SB ostium (confirmed by OCT/IVUS or pullback technique), which pushes the stent strut scaffolding outward onto the upper SB ostium without creating a metallic neocarina.
- **Step 4 — Kissing Balloon Inflation (KBI):** Simultaneously inflate two short **Non-Compliant balloons** (sized 1:1 to the DMV and SB) with minimal proximal overlap to center the carina and expand the SB ostium.
- **Step 5 — Final POT (Re-POT):** Perform a final proximal optimization inflation in the Proximal Main Vessel (stopping proximal to the carina) to correct the elliptical bottle-shaped proximal stent distortion created by the two kissing balloons.

VI CURRENT STATUS AND LANDMARK TRIAL EVIDENCE

- **EBC MAIN Trial (*European Heart Journal* 2021):** Randomized 467 patients with **true distal Left Main bifurcations** (predominantly shorter SB lesion lengths ~7 mm) to a stepwise **Provisional strategy versus a planned Two-Stent strategy** (mostly Culotte/DK-minicrush); showed **no statistically significant difference in the primary composite of death, MI, or target lesion revascularization at 1 and 3 years**, validating **Stepwise Provisional Stenting as the default strategy** for non-complex true Left Main bifurcations.
- **DKCRUSH-V Trial (*JACC* 2017 / *Circulation* 2019):** Randomized 482 patients with **complex true distal Left Main bifurcations (Medina 1,1,1 or 0,1,1 with mean SB lesion length 16 mm)** to **DK-CRUSH versus Provisional Stenting**; **DK-CRUSH significantly reduced 1-year and 3-year Target Lesion Failure (TLF), target-vessel MI, and definite/probable stent thrombosis**, establishing **DK-CRUSH** as the preferred technique when an upfront two-stent strategy is required for complex distal Left Main disease.
- **Mandatory Intravascular Imaging Guidance (IVUS / OCT — Class I in ESC 2024):** Randomized trials (**OCTOBER, ULTIMATE, RENOVATE-COMPLEX-PCI**) prove that **IVUS or OCT guidance** significantly reduces MACE in complex bifurcation PCI by verifying optimal landing zones, calcium fracture, distal-cell rewiring, and full stent expansion.

KEY REFERENCES

- **Chen SL, Zhang JJ, Han Y, et al. (DKCRUSH-V Investigators):** Double Kissing Crush Versus Provisional Stenting for Left Main Distal Bifurcation Lesions: DKCRUSH-V Randomized Trial, *Journal of the American College of Cardiology*.
- **Hildick-Smith D, Egred M, Banning A, et al. (EBC MAIN Investigators):** The European bifurcation club Left Main Coronary Stent study: a randomized comparison of stepwise provisional vs. systematic dual stenting strategies (EBC MAIN), *European Heart Journal*.
- **Burzotta F, Lassen JF, Lefèvre T, et al.:** Percutaneous coronary intervention for bifurcation coronary lesions: the 15th consensus document from the European Bifurcation Club, *EuroIntervention*.