Treatment of bifurcation coronary lesions in the era of drug-eluting stents. The 'crush', 'reversed crush' and 'skirt' techniques

GHADA W MIKHAIL, FLAVIO AIROLDI, ANTONIO COLOMBO

Abstract

Percutaneous treatment of bifurcation coronary lesions is less successful than treatment of non-bifurcation lesions, with a higher incidence of side branch occlusion and restenosis.

The 'crush technique' was developed to ensure complete coverage of the ostium of the side branch, where restenosis frequently occurs. Drug-eluting stents are deployed in both side and main branches. The main branch stent crushes the side branch stent against the wall of the main vessel.

The 'reversed crush' is used when the side branch result is unsatisfactory following stenting of the main branch, or when a 6F guiding catheter is needed.

The 'skirt technique' was designed to treat pseudobifurcation lesions (lesions in the main branch which are immediately proximal to a bifurcation). It involves sandwiching two balloons in one stent.

Preliminary results using the crush technique in 35 patients show angiographic success in all lesions.

Key words: percutaneous angioplasty, drug-eluting stents, bifurcation coronary lesions, crush technique, reversed crush technique, skirt technique.

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Introduction

Various techniques have been described for the percutaneous treatment of bifurcation lesions.[1-9] The procedure is, however, associated with a lower success rate, a higher incidence of side branch occlusion and an increased rate of restenosis compared to non-bifurcation lesions.[10-14] Despite improved techniques and operator experience, the treatment of such lesions continues to be technically challenging. The question remains as to whether, with the advent of drug-eluting stents, we could significantly improve both the procedure itself and the clinical outcome.

Recent trials have shown a significant reduction in the rate of in-stent restenosis using drug-eluting stents.[15-17] These trials have mainly been conducted in simple lesions, and data are currently awaited on the use of such stents in more complex lesions. The BIFURCATION study (an evaluation of the sirolimus-coated Bx Velocity stent in the treatment of patients with true bifurcation lesions) showed that restenosis occurred mainly at the ostium of the side branch.[18] A new technique was therefore designed by our group for treating bifurcation lesions in order to ensure complete stent coverage of the ostium of the side branch. This technique has been named the 'crush' technique since it results in crushing of three layers of metal on one side of the main vessel. It is designed for use only with drug-eluting stents.

Figure 1. Schematic illustration of the positioning of both the left anterior descending (LAD) and the diagonal branch stents. Both stents are positioned so that the LAD stent is more proximal to the diagonal branch. The diagonal stent should protrude approximately 4–5 mm into the LAD so that the ostium of the diagonal branch is circumferentially covered

The crush technique

Let us take the example of treating a bifurcation lesion involving the left anterior descending artery and the first diagonal branch. For this procedure, an 8 French guiding catheter is needed. Both

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Figure 2. Schematic illustration of deployment of the side branch stent

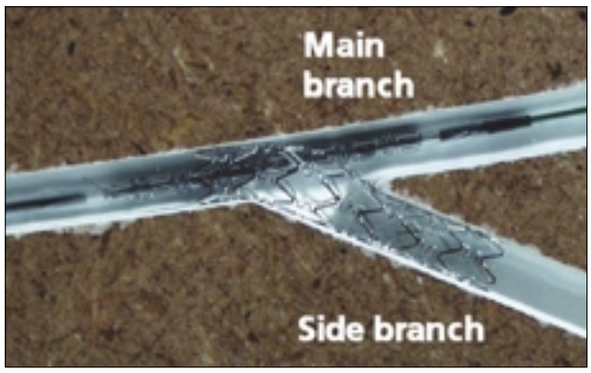


Figure 3. The 'crush technique'. Deployment of the main branch stent results in the crushing of the stent struts of the side branch, that are protruding into the main branch, against the wall of the main vessel

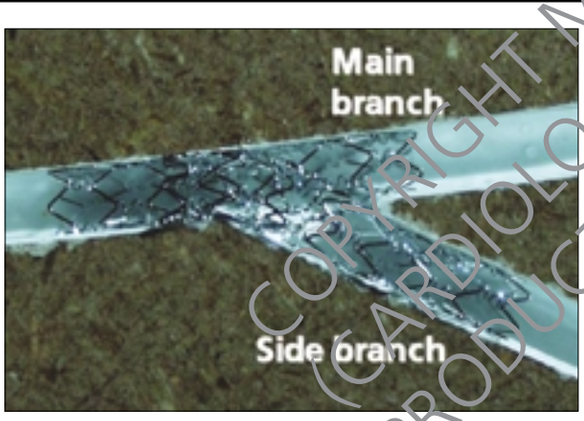
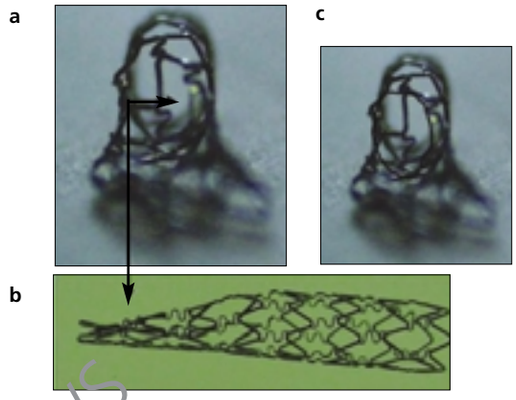


Figure 4. Schematic illustration demonstrating deformation (**a**), (**b**) and resulting lumen (**c**) of the side branch stent after crushing



branches are wired and dilated separately. The first drug-eluting stent (eluting either rapamycin or paclitaxel) is then advanced in the side branch but not expanded. The second drug-eluting stent is advanced in the main branch and positioned in order to cover the bifurcation. The side branch stent is then retracted into the main branch for a distance of 4–5 mm proximal to the carina of the bifurcation (figure 1). This is done in order to ensure that the ostium of the side branch is circumferentially covered with the stent struts.

Stent positioning is crucially important as it may be difficult to reposition the main branch stent in any direction after expansion of the side branch stent. After positioning both stents, the side branch stent is deployed first (figure 2). The delivery balloon is then removed from the side branch and contrast injection is performed in order to ensure that deployment of the stent has been satisfactory and that there is no evidence of distal dissection that may require further stenting. The guide wire is then removed from the side branch.

Following deployment of the side branch stent, the stent in the main branch is expanded. Thus, during balloon inflation the struts of the side branch stent that are protruding into the main branch are crushed against the wall of the main vessel (figure 3). This results in three layers of struts in the proximal part of the bifurcation, close to the ostium of the side branch. The area with three layers of struts can be kept to a minimum by reducing the distance that the side branch stent protrudes into the main branch. Figure 4 demonstrates deformation of the side branch stent, which has been crushed by the main branch stent. The same figure also shows the resulting lumen of the side branch stent.

Currently we always perform additional inflations in the side branch, in the main branch and a kissing inflation. This is achieved by rewiring the side branch and recrossing with a balloon into the side branch. Initially this task may be perceived as demanding but with some practice (three or four cases) it becomes less difficult. The wire is usually a Universal Balance (Guidant, Temecula, CA) or, in complex cases, an Intermediate or CrossIt 100 wire (Guidant, Temecula, CA). In most cases, a balloon which has previously been used to dilate the side branch will cross; if needed, a new balloon can be used. In very complex situations involving trifurcations we have had to use a fixed wire balloon such as the ACE balloon (Boston Scientific, Scimed, MA). We generally recommend a first inflation in the side branch at 12–14 atmospheres (atm) followed by an inflation in the main branch at 12–14 atm and finally a 'kissing' inflation at 8–10 atm.

Reversed crushing

This technique is used when the initial decision is to stent the main branch only but when, following final kissing inflation, the

result of the side branch is found to be unsatisfactory. Another situation in which the reversed crushing technique may be used is when there is the need to use a 6 French guiding catheter.

Both the main vessel and the side branches are rewired. A second drug-eluting stent is then positioned in the side branch but not deployed. A balloon is positioned within the original stent in the main vessel. As in the crush technique, the stent in the side branch is retracted into the main branch for a distance of 4–5 mm proximal to the carina of the bifurcation. This is done in order to ensure that the ostium of the side branch is circumferentially covered with the stent struts, with the additional advantage of a higher dosage of rapamycin near the bifurcational site. Currently this technique is also being used with the TAXUS (Boston Scientific, Scimed, MA) stent. It is imperative that the proximal marker of the balloon in the main branch is more proximal than that of the proximal marker of the stent in the side branch.

The stent in the side branch is deployed and the wire is removed after a satisfactory contrast injection is performed. The balloon in the main branch is then inflated in order to crush the protruding stents from the side branch onto the wall of the main vessel. If a 6 French guiding catheter is used this catheter must have an internal lumen of 0.070 inches (1.8 mm) and the balloon for the main branch needs to be a Maverick II (Boston Scientific, Scimed, MA). Although other balloons can be used in cases of 'reversed crushing', in our experience the Maverick II, a low-profile balloon having a shaft with a maximal size of 2.6 French, is ideal for this technique. Using a 6F guide catheter and with a stent in the side branch and a balloon positioned (within the original stent) in the main branch simultaneously, the latter balloon needs to have a small shaft in order to fit within the guide catheter. If a 7 or 8 French guide catheter is used, however, any low-profile balloon can be used.

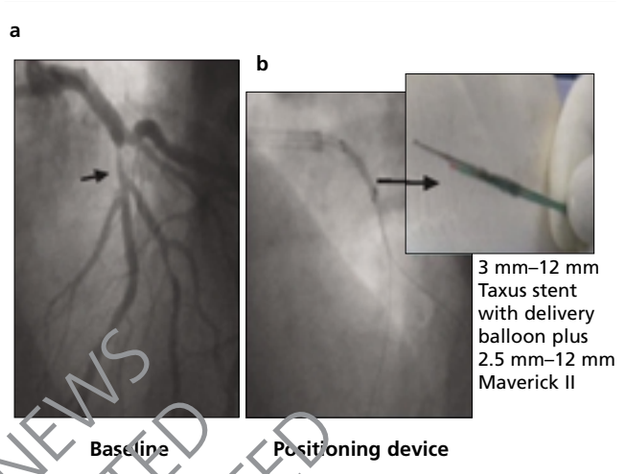
Following the above manoeuvres, rewiring of the side branch is performed and individual and kissing inflations are carried out as described for the crushing technique.

The skirt technique

The skirt technique, using bare metal stents, was initially described approximately three years ago by our group.[9] It was designed to treat pseudobifurcation lesions. These are lesions in the main branch which are located immediately proximal to a bifurcation. In such cases it is generally felt that although the side branch is not itself diseased, deployment of a stent in the main branch is likely to cause plaque shift into the side branch. Figure 5 illustrates this. Even if the ostium of the diagonal branch does not appear to be narrowed, it is very likely that following stent deployment in the main branch the ostium of the diagonal will become compromised. Furthermore, if the stent is placed too proximally, this could result in incomplete lesion coverage, and if it is placed too distally, this could further compromise the side branch.

The procedure involves wiring both the main and the side branches. Before introducing the stent into the guiding catheter, the pre-mounted stent is inflated at 8 atm and immediately deflated. With the open stent, a second balloon can be placed so that both the stent balloon and the second balloon are sandwiched within the original stent. The stent is then crimped onto both balloons. Once this initial preparation is carried out, the stent carrying both balloons is then advanced onto both wires, with each of the main and side branch wires mounting a separate balloon.

Figure 5. (**a**) Angiogram of a pseudobifurcation lesion involving the LAD and the first diagonal branch. The 'skirt technique' procedure involves wiring both the main vessel and the side branch. (**b**) The positioning device is shown in situ



The stent is advanced until the distal portion of the balloon from the stent delivery system is in the main vessel and that of the second balloon is in the side branch. Thus, the stent sits on the carina of the bifurcation. 'Hugging' balloon inflation is then performed with both balloons (figures 5-7).

Preliminary results of the crushing technique

We have recently reported the immediate and six-month clinical outcome from using the crushing technique in 36 consecutive bifurcational lesions from 35 patients using stents that elute rapamycin (Cypher, Cordis Johnson & Johnson).[19] Angiographic success was achieved in all lesions and final kissing balloon inflation was performed in 36% of lesions. During their hospital stay, there were no deaths but two patients had Q-wave myocardial infarction (one due to intra-procedural stent thrombosis, and the other due to occlusion of a septal branch). At six months, there were no deaths and one patient had a myocardial infarction at 28 days as a result of premature discontinuation of clopidogrel. Target lesion revascularisation was performed in four (11%) of patients (on the main branch in two cases, on the side branch in one case and on both branches in one case).

In this initial experience we did not routinely perform final kissing inflation on all patients. Furthermore, the four patients with restenosis who required revascularisation did not have the final kissing balloon procedure performed. From these findings,

Figure 6. Schematic illustration of the 'skirt technique'. Two balloons are sandwiched in one stent. The stent is then positioned in such a way so that the distal portion of the balloon from the stent delivery system is in the main vessel and that of the second balloon is in the side branch

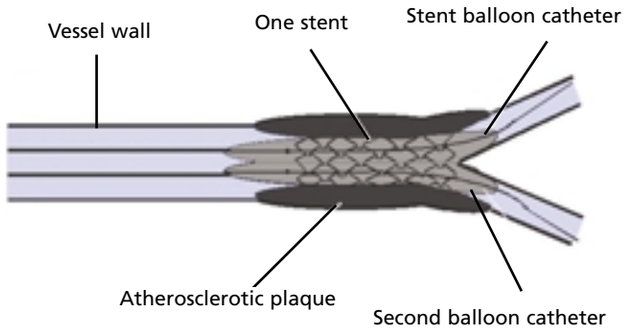
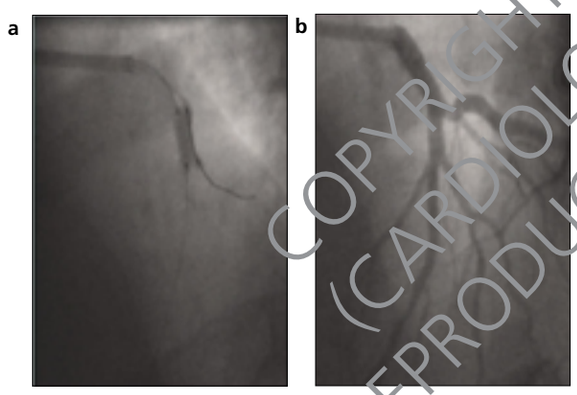


Figure 7. The stent, which has been crimped onto two balloons, is advanced to the carina of the bifurcation. (**a**) A 'hugging' balloon inflation is then performed with both balloons. (**b**) Angiogram showing the final result, after balloon inflation



it appears that with the crush technique, the need for repeat revascularisation is lower than that reported in any previous study on bifurcational lesions without drug-eluting stents. The reason why kissing inflation was performed in only 36% of lesions was not due to difficulties in recrossing into the side branch but because of the perception that this step was not necessarily essential. With the relatively high restenosis rate at the origin of the side branch, we have been made to assume that final kissing inflation may be important in order to optimise strut apposition at the ostium of the side branch.

At present, we do not have the final answer about the helpfulness of this strategy in lowering the restenosis rate at the side branch as angiographic follow-up is still in progress.

Key messages

- Percutaneous treatment of bifurcation coronary lesions is more difficult than that of non-bifurcation lesions
- Drug-eluting stents have allowed the development of new techniques for treatment of these lesions
- The 'crush technique' ensures complete stent coverage of the ostium of the side branch, where restenosis frequently occurs
- The 'skirt technique' may be used for pseudobifurcation lesions
- Initial experience shows good angiographic patency and safety results

Preliminary results of the skirt technique

We have previously reported our experience using the skirt technique with bare metal stents.[9] We applied this technique in 10 patients with lesions immediately proximal to a bifurcation (pseudobifurcation). In all 10 cases, the final angiographic result was good at the lesion site and there was no ostial compromise of the ostium of the side branch.[9] We have recently reported a case of a patient with a pseudobifurcation involving the left anterior descending artery and the first diagonal branch. This was the first case, as far as we are aware, in which a drug-eluting TAXUS (Boston Scientific, Scimed, MA) stent was used to treat a pseudobifurcation using the skirt technique (figures 5 and 7).

Antiplatelet therapy

In all cases, aspirin 100 mg is prescribed according to routine protocol. Clopidogrel 75 mg is prescribed daily for at least six months and periprocedural glycoprotein IIb/IIIa inhibitors are used according to operator discretion.

Conclusions

The percutaneous treatment of bifurcational coronary lesions remains a challenge. Various techniques exist, and no one particular technique has been widely favoured. The introduction of drug-eluting stents has allowed us to develop new methods for treating such lesions. Although the immediate and short-term results are favourable and demonstrate safety, longer term follow-up data are clearly required.

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