bioresorption of the device. These observations suggest that longer-term follow-up (≥5 years) is essential to understand the effect of bioresorbable scaffold in coronary artery disease.

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RESEARCH CORRESPONDENCE

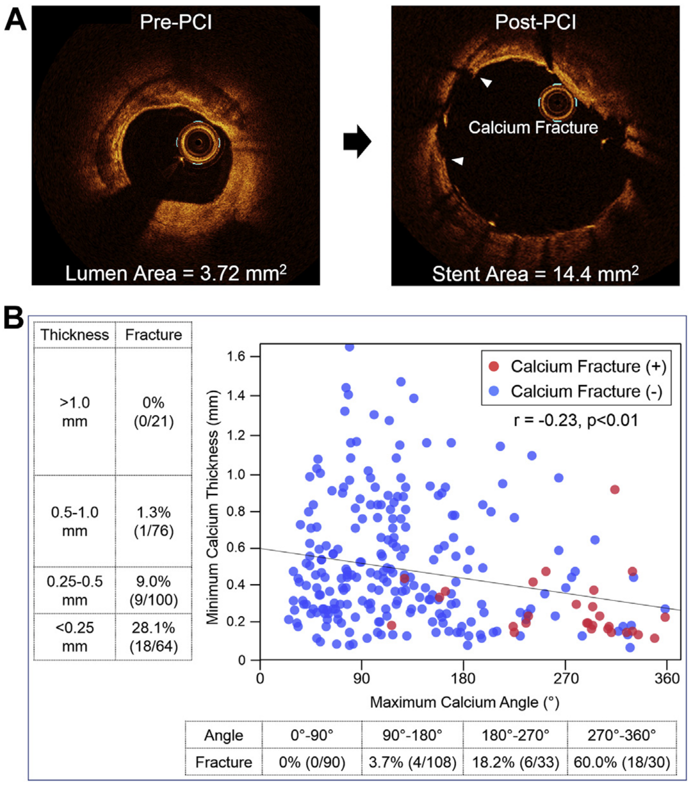
Predictors of Calcium Fracture Derived From Balloon Angioplasty and its Effect on Stent Expansion Assessed by Optical Coherence Tomography

Calcium fracture during percutaneous coronary intervention (PCI) is associated with better stent expansion (1,2). Optical coherence tomography (OCT) can penetrate calcium, evaluate calcium thickness, and identify the severity and pattern of calcium requiring additional lesion modification. Maejima et al. (2) reported OCT thresholds for predicting calcium fracture in lesions treated with rotational atherectomy as a maximum calcium angle of 227° and a minimum calcium thickness of 0.67 mm; however, there are no data regarding the thresholds for predicting calcium fracture using only pre-dilation followed by stent implantation and, therefore, the threshold for plaque modification pre-stenting.

We studied 261 calcified, de novo, native coronary artery lesions in 261 patients treated at St. Francis Hospital (Roslyn, New York) (n = 128) or Tsuchiura Kyodo General Hospital (Ibaraki, Japan) (n = 133) in which pre- and post-PCI OCT evaluations were performed and a stent was implanted using only balloon pre-dilation (i.e., no rotational, orbital, or laser atherectomy). OCT images were acquired with the ILUMIEN OPTIS system with the Dragonfly Duo or Dragonfly OPTIS imaging catheter (Abbott Vascular, Santa Clara, California) with a frame interval of 0.2 mm.

Each target lesion calcium deposit was evaluated by pre-PCI OCT including maximum calcium angle, maximum and minimum calcium thickness, and calcium length. The analysis was performed on a per-calcium deposit basis as well as on a per-target lesion basis; if there was more than 1 calcium deposit, the one with the largest maximum calcium angle was chosen to represent target lesion calcium. Individual calcium deposits within a single target lesion were separated by at least 1 mm of noncalcified plaque. Calcium fracture was defined as a slit or complete break in the calcium plate that was identified in the post-PCI OCT (**Figure 1A**). Stent

FIGURE 1 Calcium Fracture Assessed by OCT



(A) A representative case of calcium fracture assessed with optical coherence tomography. **(B)** The relationship between maximum calcium angle and minimum calcium thickness. Calcium fracture was seen in lesions with large-angled, but thin, calcified plaque. OCT = optical coherence tomography; PCI = percutaneous coronary intervention.

expansion (the smallest stent area divided by the average of the proximal and distal reference lumen area × 100) within the target lesion calcium was calculated.

Calcium fracture was observed in 10.7% (28 of 261) of the lesions, and 85.7% (24 of 28) of the calcium fracture was observed in lesions with a maximum calcium angle >180°. Calcium fracture occurred in lesions with greater maximum calcium angle (295° vs. 109°; $p < 0.01$) and smaller minimum calcium thickness (0.20 mm vs. 0.45 mm; $p < 0.01$) (Figure 1B). The area under the curve of maximum calcium angle to predict calcium fracture was 0.92 ($p < 0.01$), with the best cutoff 225° (sensitivity 85.7%, specificity 90.1%, positive predictive value 51.1%, negative predictive value 98.1%); the area under the curve of minimum calcium thickness was 0.75 ($p = 0.03$), with the best cutoff 0.24 mm (sensitivity 80.3%, specificity 64.3%, positive predictive value 28.1%, negative predictive value 94.9%).

Among lesions with maximum calcium angle >180°, lesions with calcium fracture had better stent expansion than those without (85.7% vs. 73.4%; $p < 0.01$). In a logistic regression model that included maximum calcium angle, maximum and minimum calcium thickness, calcium length, number of calcium deposits, total stent length, maximum balloon pressure, and balloon-to-artery ratio as covariates, maximum calcium angle (per 90°) (odds ratio 5.14, 95% confidence interval [CI]: 2.76 to 10.7; $p < 0.0001$) and minimum calcium thickness (per 0.5 mm) (odds ratio −3.33, 95% CI: −13.5 to −1.09; $p = 0.03$) were independently associated with the presence of calcium fracture. A multivariable linear regression model to predict stent expansion that included all the covariates in the preceding text demonstrated that calcium fracture (regression coefficient 5.74, 95% CI: 2.62 to 8.86; $p < 0.001$) was strongly associated with better stent expansion, whereas maximum calcium angle (per 90°) (regression coefficient 6.51, 95% CI: −8.99 to −4.04; $p < 0.0001$), maximum calcium thickness (per 0.5 mm) (regression coefficient −3.10, 95% CI: −6.06 to −0.15; $p = 0.04$), and calcium length (per 5 mm) (regression coefficient −2.04, 95% CI: −3.27 to −0.82; $p < 0.01$) were significantly associated with poor stent expansion.

In our study, the threshold of minimum calcium thickness to predict calcium fracture in lesions treated with only balloon angioplasty before stent implantation was 0.24 mm, thinner compared with lesions treated pre-PCI with rotational atherectomy (0.67 mm) with a similar maximum calcium angle threshold (2). Currently, there are no practical guidelines available to indicate calcium modification by an atherectomy or atherotomy device. The current results suggest the use of such a device in a lesion with a large angle (>225°) of thick calcium (no thickness <0.24 mm) to avoid stent underexpansion.

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