SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY

THIRUVANANTHAPURAM, KERALA, INDIA – 695011

"Analysis of Intracoronary optical coherence tomography (OCT) parameters during percutaneous coronary intervention (PCI) in stable ischemic heart disease"

PROJECT REPORT

Submitted during the course of
DM Cardiology

Dr. HIREN TULSIBHAI KEVADIYA

DM (Cardiology) Trainee

DEPARTMENT OF CARDIOLOGY

Jan 2015 – Dec 2017

DECLARATION

I, **Dr. Hiren Tulsibhai Kevadiya**, hereby declare that the project in this book, titled "**Analysis of Intracoronary optical coherence tomography (OCT) parameters during percutaneous coronary intervention (PCI) in stable ischemic heart disease"** was undertaken by me under the supervision of the faculty, Department of Cardiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology.

Thiruvananthapuram
Date

Dr. Hiren Tulsibhai Kevadiya
DM Trainee

Forwarded

The candidate, **Dr. Hiren Tulsibhai Kevadiya** has carried out the minimum required project.

Thiruvananthapuram — ***Prof. Dr. Ajit Kumar V.K.***

Date — *Head of Department of Cardiology*

CERTIFICATE

I hereby certify that the work in this dissertation titled "**Analysis of Intracoronary Optical Coherence Tomography (OCT) parameters during Percutaneous Coronary Intervention (PCI) in stable ischemic heart disease" is** a certified record of original research work undertaken by Dr Hiren Tulsibhai Kevadiya in partial fulfilment of requirement for the purpose of award of D.M. cardiology degree under my guidance and supervision.

Guide:

Dr. Ajit Kumar V.K.,

Professor and Head

Department of Cardiology

Sree Chitra Tirunal Institute for Medical Science and Technology,

Trivandrum-695011

TITLE

"Analysis of Intracoronary Optical coherence tomography (OCT) parameters during percutaneous coronary intervention (PCI) in stable ischemic heart disease"

Primary Investigator:
Dr. Hiren Tulsibhai Kevadiya,
Senior Resident,
Department of Cardiology, SCTIMST

Guide:
Dr. Ajit Kumar V.K.,
Professor and Head
Department of Cardiology, SCTIMST

Co-guide:
Dr. Sanjay G.,
Additional Professor,
Department of Cardiology, SCTIMST

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Hiren Tulsibhai Kevadiya

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INTRODUCTION

Over the past decade, cardiovascular disease (CVD) has emerged as the single most important cause of death worldwide. In 2010, CVD caused an estimated 16 million deaths and led to 293 million disability-adjusted life years (DALYs) lost[1] accounting for approximately 30% of all deaths and 11% of all DALYs lost that year. Like many high-income countries (HICs) during the past century, now low- and middle-income countries (LMICs) are seeing an alarming and accelerating increase in CVD rates. Based on data from the Framingham Heart Study, the lifetime risk for the development of symptomatic CAD after 40 years of age is 49% for men and 32% for women. In 2010, IHD accounted for 48% of all deaths caused by cardiovascular disease and was the single most frequent cause of death in American men and women; it resulted in more than one in six deaths in the United States.[2] The economic cost of IHD is formidable, and in the United States in 2010 it was estimated to be $204.4 billion.[2] Despite a steady decline in age-specific mortality from CAD over the past several decades, IHD is now the leading cause of death worldwide, and it is expected that the rate of CAD will only accelerate in the coming decades with the burden shifting progressively to lower socioeconomic groups; contributory factors include aging of the population, increases in the worldwide prevalence of

obesity and type 2 diabetes, and a rise in cardiovascular risk factors in younger generations. The World Health Organization has estimated that by 2020, the global number of deaths from CAD will have risen from 7.6 million in 2005 to 11.1 million.[3]

Stable ischemic heart disease (SIHD) is most commonly caused by atheromatous plaque that obstructs or gradually narrows one or more of the epicardial coronary arteries. Stable ischemic heart disease patient typically presents with effort related angina pectoris which results from myocardial ischemia caused by an imbalance between myocardial O2 requirements and myocardial O2 supply. The clinical examination and non-invasive techniques are extremely valuable in establishing the diagnosis of CAD, however, definitive diagnosis of CAD and precise assessment of its anatomic severity still require cardiac catheterization and coronary arteriography. In patients with chronic stable angina referred for coronary arteriography, approximately 25% each have single-, double-, or triple-vessel anatomically significant CAD (i.e., >70% luminal diameter narrowing). Five percent to 10% have obstruction of the left main coronary artery, and in at least 15% and as high as 30% in some series, no critical obstruction is detectable. Coronary angiography provides information principally about the degree of luminal stenosis of the coronary arteries. It is generally accepted that a stenosis involving more than 60% of the luminal

diameter is hemodynamically significant in that it may be responsible for a reduction in exercise-induced myocardial blood flow that causes ischemia. The immediate functional significance of obstruction of intermediate severity (≈50% diameter stenosis) is less well established. Coronary angiographic determinants of the severity of stenosis are based on a decrease in the calibre of the lumen at the site of the lesion relative to adjacent reference segments, which are considered, often erroneously, to be relatively free of disease. This approach may lead to significant underestimation of the severity and extent of atherosclerosis. The most serious limitation to the routine use of coronary angiography for prognosis in patients with SIHD is its inability to identify which coronary lesions can be considered to be at high risk, or vulnerable, for future events, such as MI or sudden death.

Advanced invasive imaging techniques such as intravascular ultrasonography (IVUS) and optical coherence tomography (OCT) provide a cross-sectional view of the coronary artery and have substantially enhanced the detection and quantification of coronary atherosclerosis, as well as the potential to characterize the vulnerability of coronary atheroma.[4] Intravascular optical coherence tomography has evolved as an additional tools for more complete characterization of coronary atheroma. OCT is an innovative catheter based imaging technology that uses light and fiberoptic

technology to obtain unique details of the vessels on a microscopic scale. OCT provides real-time, full tomographic views of the coronary arteries with accurate measurements. OCT is used to quickly map the extension and type of coronary artery disease, guiding precise percutaneous coronary interventions (PCI) in complex patient and lesion cohorts immediately and over time, increasing safety. Because of its unique properties and high axial imaging resolution, OCT is able to overcome many of the limitations of coronary angiography and intravascular Ultrasound (IVUS) for evaluating calcium, plaque at risk of rupture, and stent strut coverage. Additionally, OCT provides quantitative indices that can be used to assess the effectiveness of therapy. OCT can reliably assess and quantify atherosclerotic plaque characteristics (thin fibrous cap, thrombus, neovessels, lipid pool, foamy macrophage), differentiating early from advanced coronary lesions, with close correlation with pathology. OCT can easily detect and penetrate calcium, revealing spiky superficial calcification that can block stent progression into the vessel and measuring thickness and circumferential distribution. Based on accurate vessel mapping, a procedural plan, including stent length, size, and landing zone, can be generated. In complex interventional settings in which risk of PCI failure is increased (e.g., complex bifurcation, late stent thrombosis, in-stent restenosis, neoatherosclerosis), OCT may add critical information and orient more

precise treatment. Frequency-domain OCT (FD-OCT) systems produce a clear vision of very long segments of coronary arteries in only a few seconds, with a more complete picture of the vessel involvement and easier image interpretation compared with standard methods. Three-dimensional (3D) reconstruction of OCT images automatically detects, quantifies, and displays features of interest, such as the shape of the lumen and the longitudinal position of the minimal luminal area (MLA). Coronary angiography is not adequate for Intermediate lesions (40%–70%) and less accurate for decision making in a complex setting, for example, unclear clinical settings, acute coronary syndromes, in presence of thrombus, diffuse disease, bifurcation, left main coronary artery disease, bioabsorbable scaffolds. OCT helps for preprocedural guidance like full vessel assessment, patient and lesion risk stratification (therapy and prognosis). OCT helps for procedural guidance like procedural plan (mapping culprit lesion, stent size, length, landing zones) and also for procedural assessment (stent expansion, stent malapposition, residual dissections) and late procedural assessment (strut coverage, acquired malapposition, stent fracture, neoatherosclerosis).[5]

REVIEW OF LITERATURE

Plaque Characteristics Evaluated by OCT

Yoshinori Miyamoto et al, [6] have studied 81 coronary lesions with plaque burden >40% by OCT. 56 patients with coronary artery disease (46 stable angina pectoris, 10 acute coronary syndrome) were enrolled in this study. The OCT-derived TCFA was defined as a presence of thin fibrous cap (<65 μm) overlying a signal-poor lesion (>90°) with diffuse border representing a lipid-rich plaque. Plaque with thick fibrous cap (>65 μm) was defined as non-TCFA. Forty plaques (49%) were classified as OCT-derived TCFA (mean fibrous cap thickness by OCT was 51.0 ± 8.4 mm), and the remaining 41 plaques (51%) were diagnosed as non-TCFA (mean fibrous cap thickness by OCT was 209.5 ± 114.0 mm). OCT-derived TCFA had larger plaque burden and positive remodelling with predominant lipid component and less fibrous plaque.

Yasushi Ino et al, [7] have studied 278 patients with 331 lesions who underwent OCT-guided EES implantation and 9-12 months scheduled follow-up angiography. The aim of their study was to assess whether there is an association between plaque type assessed by optical coherence tomography (OCT) and edge restenosis after EES implantation. By using OCT, plaque type at stent edge was classified into the following 4 types:

lipid rich plaque, fibrotic plaque, fibro-calcific plaque, and normal segment. The proportion of plaque type at stent edge was detected as lipid rich; 21%, fibrotic; 45%, fibrocalcific; 19% and normal segment; 15%. The incidence of edge restenosis was 4.7 % (30 of 641 edge segments, 17 in proximal edge, 11 in distal edge, 1 in both edge): 12.8% in lipid rich plaque, 2.8% in in fibrotic plaque, 4.0% in fibrocalcific plaque, and 0% in normal segment, respectively ($p<0.001$). The authors of this study concluded that lipid rich plaque at the stent edge has impact on edge restenosis after EES implantation. The selection of residual plaque except for lipid rich plaque assessed by OCT as landing zone of the stent may allow us to avoid unnecessarily longer stents without increasing the incidence of edge restenosis.

Lei Gao et al, [8] have evaluated a total of 789 lesions in 261 patients. Plaques were categorized into fibrous, fibrocalcific, and fibroatheroma plaques by OCT, and their relative distribution (proximal, mid, and distal) were assessed**.** Aim was to evaluate comprehensive distribution of coronary plaques by 3 vessel optical coherence tomography (OCT) analysis. Authors found out that in right coronary artery (RCA) and left circumflex artery (LCX), thin-cap fibroatheroma (TCFA), fibroatheroma, fibrocalcific, and fibrous plaques were evenly distributed from proximal to distal. Proportion of plaque rupture, calcification, and thrombus did not differ among

proximal, middle, and distal sites. In left anterior descending artery (LAD), TCFA and fibro-atheroma were primarily located in the proximal and middle segments, whereas fibrous plaques were more frequently distributed in the middle and distal segments. The majority of plaque rupture (proximal 21.4%, mid 12.4%, distal 0%, P=0.002), calcification (proximal 71.8%, mid 51.8%, distal 25.5%, P<0.001), and thrombus (proximal 11.7%, mid 8.0%, distal 2.1%, P=0.145) also localized in the proximal site of LAD. Authors concluded that TCFA and fibroatheroma tend to cluster within the proximal segment of LAD, whereas they are relatively evenly distributed throughout the length of RCA and LCX arteries.

Assessment of the acute effects of stent implantation on the vessel wall

Gonzalo, N. et al, [9] have studied 73 patients and 80 vessels with objective to observe and characterise vessel injury after stenting using optical coherence tomography (OCT) and to assess its clinical impact during the hospitalisation period. All consecutive patients in whom OCT was performed after stent implantation were included. OCT was performed after stent implantation and qualitative and quantitative assessment of tissue prolapse, edge dissection were performed. Tissue prolapse within the stented segment was visible in 78/80 vessels (97.5%) with mean (SD) area of 1.04 (0.9) mm^2. Edge dissection was visible in 20 vessels with mean (SD) length of flap 744 (439) μm. There were no events during the hospitalisation

period. Authors of this study concluded that OCT allows a detailed visualisation of vessel injury after stent implantation and enables a systematic classification and quantification in vivo. In this study, frequency of tissue prolapse after stenting was high, and was not associated with clinical events during hospitalisation. However, correlation with clinical events, both early and late, is required to determine whether these OCT observations have clinical significance, and this should be the aim of future studies.

B E Bouma et al, [10] have evaluated 42 stents with objective to evaluate the use of intravascular optical coherence tomography (OCT) to assess the coronary arteries in patients undergoing coronary stenting. OCT images were evaluated for vessel dissection, tissue prolapse, stent apposition, and stent asymmetry. IVUS images were obtained before OCT, using an automatic pull back device. Dissection, prolapse, and incomplete stent apposition were observed more often with OCT than with IVUS. Vessel dissection was identified in eight stents by OCT and two by IVUS. Tissue prolapse was identified in 29(69%) stents by OCT and 12(28%) by IVUS; the extent of the prolapse (mean (SD)) was 242 (156) μm by OCT and 400 (100) μm by IVUS. Incomplete stent apposition was observed in 7(16%) stents by OCT and 3(7%) by IVUS. Irregular strut separation was identified in 18(43%) stents by both OCT and IVUS. Authors concluded

that Intracoronary OCT for monitoring stent deployment is feasible and provides superior contrast and resolution of arterial pathology than IVUS.

OCT guided PCI and clinical outcome studies

Francesco Prati et al (CLI-OPCI study),[11] have hypothesised that angiographic guidance for percutaneous coronary intervention (PCI) has substantial limitations. The superior spatial resolution of optical coherence tomography (OCT) could translate into meaningful clinical benefits. They aimed to compare angiographic guidance alone versus angiographic plus OCT guidance for PCI. Patients undergoing PCI with angiographic plus OCT guidance (OCT group) were compared with matched patients undergoing PCI with angiographic only guidance (Angio group) within 30 days. Primary endpoint was the one-year rate of cardiac death or myocardial infarction (MI). Total of 670 patients were included, 335 in the OCT group and 335 in the Angio group. Findings resulting from OCT led to additional interventions in as many as 34.7% of the subjects. Specifically, further stenting was performed in 12.6% of cases (in 5.4% to treat an edge dissection and in the remaining 7.2% to enlarge a reference lumen area that was <4 mm2). Additional balloon dilatation was needed in 22.1% of cases (in 14.0% to fix stent underexpansion, and in 8.1% to reduce intrastent thrombus). Unadjusted analyses showed that the OCT group had a significantly lower one-year risk of cardiac death (1.2% vs. 4.5%, p=0.010),

cardiac death or MI (6.6% vs. 13.0%, p=0.006), and the composite of cardiac death, MI, or repeat revascularisation (9.6% vs. 14.8%, p=0.044). Angiographic plus OCT guidance was associated with a significantly lower risk of cardiac death or MI even at extensive multivariable analysis adjusting for baseline and procedural differences between the groups (OR=0.49 [0.25-0.96], p=0.037) and at propensity-score adjusted analyses. Authors of this study concluded that this observational study results suggest that the use of OCT can improve clinical outcomes of patients undergoing PCI.

Francesco Prati et al (CLI-OPCI II study),[12] have studied total of 1002 lesions (832 patients) with objective to assess the clinical impact of optical coherence tomography (OCT) findings during percutaneous coronary intervention (PCI). They retrospectively analysed patients undergoing end-procedural OCT assessment and compared the findings with clinical outcomes. Appropriate OCT assessment was obtained in 98.2% of cases and revealed suboptimal stent implantation in 31.0% of lesions, with increased incidence in patients experiencing major adverse cardiac events (MACE) during follow-up (59.2% vs. 26.9%; $p < 0.001$). In particular, in-stent minimum lumen area <4.5 mm^2 (hazards ratio [HR]: 1.64; $p = 0.040$), dissection >200 μm at the distal stent edge (HR: 2.54; $p = 0.004$), and reference lumen area <4.5 mm^2 at either distal (HR: 4.65; $p < 0.001$) or

proximal (HR: 5.73; p < 0.001) stent edges were independent predictors of MACE. In-stent minimum lumen area/mean reference lumen area <70% (HR: 1.21; p = 0.45), stent malapposition >200 μm (HR: 1.15; p = 0.52), intrastent plaque/thrombus protrusion >500 μm (HR: 1.00; p = 0.99), and dissection >200 μm at the proximal stent edge (HR: 0.83; p = 0.65) were not associated with worse outcomes. Using multivariable Cox hazard analysis, the presence of at least 1 significant criterion for suboptimal OCT stent deployment was confirmed as an independent predictor of MACE (HR: 3.53; 95% confidence interval: 2.2 to 5.8; p < 0.001). Authors concluded from this study that Suboptimal stent deployment defined according to specific quantitative OCT criteria was associated with an increased risk of MACE during follow-up.

William Wijns et al (ILUMIEN I study), [13] was one of the largest prospective, non-randomized, observational study of percutaneous coronary intervention (PCI) procedural practice in patients undergoing intra-procedural pre- and post-PCI fractional flow reserve (FFR) and optical coherence tomography (OCT). Aim was to study the impact of OCT on physician decision-making and the association with post-PCI FFR values and early clinical events. OCT and FFR were performed pre- and post-PCI in 418 patients (with 467 stenoses) with stable or unstable angina or NSTEMI. Based on pre-PCI OCT, the procedure was altered in 55% of

patients (57% of all stenoses) by selecting different stent lengths (shorter in 25%, longer in 43%). After satisfactory stent implantation using angiographic guidance, post-PCI FFR and OCT were repeated. Post PCI OCT identified 14.5% malapposition, 7.6% under-expansion, 2.7% edge dissection and prompted further stent optimization based on OCT in 25% of patients (27% of all stenoses) using additional in-stent post-dilatation (81%, 101/124) or placement of 20 new stents (12%). Optimization subgroups were identified post hoc: stent placement without reaction to OCT findings (n = 137), change in PCI planning by pre-PCI OCT (n = 165), post-PCI optimization based on post-PCI OCT (n = 41), change in PCI planning, and post-PCI optimization based on OCT (n = 65). Post-PCI FFR values were significantly different (P = 0.003) between optimization groups (lower in cases with pre- and post-PCI reaction to OCT) but no longer different after post-PCI stent optimization. MACE events at 30 days were low: death 0.25%, MI 7.7%, repeat PCI 1.7%, and stent thrombosis 0.25%. Authors concluded that Physician decision-making was affected by OCT imaging prior to PCI in 57% and post-PCI in 27% of all cases.

Akiko Maehara et al (ILUMIEN II study), [14] was sought to determine whether optical coherence tomography (OCT) guidance results in a degree of stent expansion comparable to that with intravascular ultrasound (IVUS) guidance. Most important predictor of adverse outcomes (thrombosis and

restenosis) after stent implantation with IVUS guidance is the degree of stent expansion achieved. They compared the relative degree of stent expansion (defined as the minimal stent area divided by the mean of the proximal and distal reference lumen areas) after OCT-guided stenting in patients in the ILUMIEN I study (N = 354) and IVUS-guided stenting in patients in the ADAPT-DES (Assessment of Dual Antiplatelet Therapy With Drug-Eluting Stents) study (N = 586). Stent expansion was examined in all 940 patients in a covariate-adjusted analysis as well as in 286 propensity-matched pairs (total N = 572). In the matched-pair analysis, the degree of stent expansion was not significantly different between OCT and IVUS guidance (median 72.8% vs. 70.6 %, respectively, p = 0.29). Although a higher prevalence of post-PCI stent malapposition (76% vs 39%), tissue protrusion (64% vs 27%), and edge dissections (23% vs 5%) was detected by OCT, but the rates of major malapposition, tissue protrusion, and dissections were similar after OCT- and IVUS-guided stenting. Authors concluded that OCT and IVUS guidance resulted in a comparable degree of stent expansion but randomized trials are warranted to compare the outcomes of OCT- and IVUS-guided coronary stent implantation.

Ziad A Ali et al (ILUMIEN III: OPTIMIZE PCI study), [15] was sought to establish whether or not a novel OCT-based stent sizing strategy would

result in a minimum stent area similar to or better than that achieved with IVUS guidance and better than that achieved with angiography guidance alone. This study was done in view of findings from some studies suggested that OCT guided PCI might lead to smaller luminal diameters after stent implantation. This was a multicentre randomised controlled trial. Total of 450 patients were randomly assigned (1:1:1) to OCT guidance, IVUS guidance, or angiography-guided stent implantation. OCT-guided PCI was done using a specific protocol to establish stent length, diameter, and expansion according to reference segment external elastic lamina measurements. All patients underwent final OCT imaging (operators in the IVUS and angiography groups were masked to the OCT images). Primary efficacy endpoint was post-PCI minimum stent area, measured by OCT. The primary safety endpoint was procedural MACE. The final median minimum stent area was 5·79 mm² (IQR 4·54–7·34) with OCT guidance, 5·89 mm² (4·67–7·80) with IVUS guidance, and 5·49 mm² (4·39–6·59) with angiography guidance. OCT guidance was non-inferior to IVUS guidance (one-sided 97·5% lower CI –0·70 mm²; p=0·001), but not superior (p=0·42). OCT guidance was also not superior to angiography guidance (p=0·12). We noted procedural MACE in 3% patients in the OCT group, 1% of IVUS group, and 1% of angiography group (OCT *vs* IVUS p=0·37; OCT *vs* angiography p=0·37). Authors concluded that OCT-guided PCI

using a specific reference segment external elastic lamina-based stent optimisation strategy was safe and resulted in similar minimum stent area to that of IVUS-guided PCI and warrant a large scale randomised trial to establish whether or not OCT guidance results in superior clinical outcomes to angiography guidance**.**

Pratap Chandra Rath et al, [16] have done retrospective single center study on OCT guided PCI. This is the only published Indian study on use of OCT during PCI. Stent malapposition was detected in 24% patients requiring further balloon dilatation. Some amount of tissue prolapse was observed in almost all the patients. In absolute number, strategy was changed in 28 (62%) out of 45 patients after OCT. Alteration of stent length in 14 patients (56% case when evaluated pre PCI), Stent diameter in 9 patients (36% cases when evaluated pre PCI). Treatment of malapposition was done in 11 patients (24.4% of total cases). Further, balloon dilatation for vessel expansion in calcified lesion was done in 7 patients (15.5% of total cases). Edge dissection requiring stenting was seen in 4 patients (8.8% of total cases). Authors concluded that their data confirm that OCT allows for better visualization of lumen, plaque, thrombus, as well as stent apposition, & dissection post PCI and More extensive, long term studies will be needed to assess the clinical outcome of these interventions.

Nieves Gonzalo et al, [17] have studied 25 vessels with the aim to evaluate the morphologic characteristics of stent restenosis by optical coherence tomography (OCT). Quantitative OCT analysis consisted of lumen and stent area measurement and calculation of restenotic tissue area and burden. Qualitative restenotic tissue analysis included assessment of tissue structure, backscattering and symmetry, visible microvessels, lumen shape, and presence of intraluminal material. By OCT, restenotic tissue structure was layered in 52%, homogeneous in 28%, and heterogeneous in 20%. The predominant backscatter was high in 72%. Microvessels were visible in 12%. Lumen shape was irregular in 28% and there was intraluminal material in 20%. Heterogeneous and low scattering restenotic tissue was more frequent in focal (45.5% and 54.5%, respectively) than in diffuse (0 and 11.1%) and margin restenosis (0 and 0%) (P = .005 for heterogeneous, P = .03 for low scattering). Stents implanted ≤12 months ago had more frequently restenotic tissue with layered appearance (84.6% vs 16.7%, P = .003). Authors concluded that OCT has the ability to identify differential patterns of restenotic tissue after stenting that could help in understanding the mechanism of stent restenosis.

Adriaenssens et al (PRESTIGE Consortium), [18] have performed a prospective, multicentre study to evaluate OCT findings in patients with Stent thrombosis(ST) with the expectation that OCT may provide insights

into mechanistic processes leading to stent thrombosis. Total 217 patients presenting with ST were evaluated by OCT imaging. 62 (28.6%) and 155 (71.4%) presented with early and late/very late ST respectively. Mean reference vessel diameter was 2.9±0.6 mm and mean reference vessel area was 6.8±2.6 mm^2. Stent underexpansion (stent expansion index <0.8) was observed in 44.4%. The most common dominant finding adjudicated for acute ST was uncovered struts (66.7% of cases), for subacute ST was uncovered struts (61.7%) and underexpansion (25.5%), for late ST was uncovered struts (33.3%) and severe restenosis (19.1%), and for very late ST was neoatherosclerosis (31.3%) and uncovered struts (20.2%). In patients presenting with very late ST, uncovered stent struts was a common dominant finding in DES, and neoatherosclerosis in bare metal stents. Authors concluded that in patients with ST, uncovered and malapposed struts were frequently observed with the incidence of both decreasing with longer time intervals between stent implantation and presentation. The most frequent dominant observation varied according to time intervals from index stenting: uncovered struts and underexpansion in acute / subacute ST and neoatherosclerosis and uncovered struts in late/very late ST.

Above mentioned studies have shown that OCT is useful for assessing atherosclerotic lesion and its composition. OCT can identify TCFA lesion with larger plaque burden containing predominant lipid component with less fibrous plaque suggest features of vulnerability. OCT helps in measuring lesion length and helps in identifying type of plaque at the stent edge which can predict chance of development of edge restenosis especially if lipid rich plaque at stent edge. Thus OCT helps in identifying disease free landing zones for stent and selecting optimal length of stent. OCT has shown that TCFA and fibroatheroma tend to cluster within the proximal segment of LAD, whereas they are relatively evenly distributed throughout the length of RCA and LCX arteries. OCT is very useful for assessment of the acute effects of stent implantation on the vessel wall especially tissue prolapse and edge dissection. However, correlation with clinical events, both early and late, is required to determine whether these OCT observations have clinical significance, and this should be the aim of future studies. Quantitative OCT parameters assessed during PCI like edge dissection, tissue prolapse, stent apposition, stent asymmetry, stent expansion can predict future adverse cardiac events. OCT guided PCI has been studied in multiple trials to assess its usefulness. It has been found that angiographic guidance for percutaneous coronary intervention (PCI) has substantial limitations. The superior spatial resolution of optical coherence

tomography (OCT) could overcome the limitations of angiographic only guidance and that may translate into meaningful clinical benefits. OCT can identify more stent underexpansion, malapposition, tissue prolapse, edge dissection, and thrombus which may led to additional interventions like further stenting or additional balloon dilatation. Studies have shown that angiographic plus OCT guidance was associated with a significantly lower risk of MACE events and suggest that the use of OCT can improve clinical outcomes of patients undergoing PCI. Suboptimal stent deployment defined according to specific quantitative OCT criteria was associated with an increased risk of MACE during follow-up. Studies have shown that physician decision-making was affected by OCT imaging prior to PCI. OCT-guided PCI using a specific reference segment external elastic lamina-based stent optimisation strategy was safe and resulted in similar minimum stent area to that of IVUS-guided PCI and warrant a large scale randomised trial to establish whether or not OCT guidance results in superior clinical outcomes to angiography guidance**.** OCT also helps to evaluate the morphologic characteristics of stent restenosis and also has ability to identify differential patterns of restenotic tissue after stenting that could help in understanding the mechanism of stent restenosis. OCT may provide insights into mechanistic processes leading to stent thrombosis. Studies have shown that most frequent observation varies according to time intervals

from index stenting like uncovered struts & underexpansion are more commonly found in acute/subacute ST and neoatherosclerosis & uncovered struts in late/very late ST. There is only one published Indian study on use of OCT during PCI. Indian study has concluded that OCT allows for better visualization of lumen, plaque, thrombus, as well as stent apposition, & dissection post PCI but more extensive, long term studies will be needed to assess the clinical outcome of these interventions.

AIMS AND OBJECTIVES

Hypothesis:

Optical coherence tomography (OCT) helps in assessing stenotic lesion characteristics during PCI and in optimization of PCI results

Aim of study:

To observe and characterize optical coherence tomography (OCT) parameters during Percutaneous coronary intervention (PCI)

Study objectives:

1. To assess coronary plaque composition
2. To assess acute vessel wall effect during PCI
3. To assess optical coherence tomographic end results of PCI
4. To assess short term clinical outcomes of OCT guided PCI

MATERIALS & METHODS

Place of study: Department of Cardiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum

Study period: July 2015 to July 2017

Study Design: Retrospective Observational study

Inclusion criteria: All consecutive stable ischemic heart diseases patients, irrespective of sex, who had undergone intracoronary OCT during PCI from Jan 1, 2013 to Dec 31, 2016, were enrolled. Cases were recruited from hospital records. Patient with optimal OCT image recordings were included for analysis.

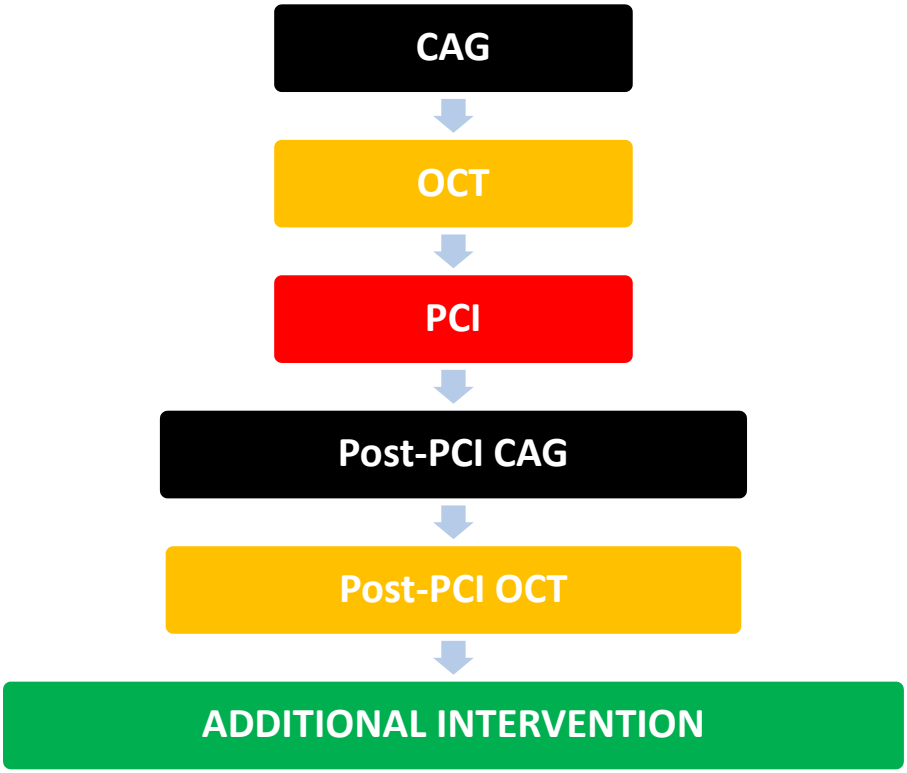
Exclusion Criteria: Patients presented with acute coronary syndrome undergoing OCT guided PCI were excluded from study. Patients with suboptimal OCT image recordings were also excluded from study.

Baseline demographic data: Baseline demographic data of all enrolled patients were taken from medical records including history, symptomatic status, Chest Roentgenogram, Electrocardiogram, Echocardiography, Blood parameters, Drug details, Coronary angiography, PCI details, Optical coherence tomography and follow-up OPD visit details.

Coronary angiography: Coronary angiography were analysed from DICOM images stored in compact disc. Quantitative coronary angiography was performed offline using Siemens Axiom Artis Digital Cathlab software.

Optical coherence tomography (OCT): Optical coherence tomography images of each individual patients were analysed from DICOM images stored in ST JUDE MEDICAL ILUMIEN OPTIS machine storage disc. Quantitative OCT parameter analysis was performed with St Jude Medical Ilumien Optis machine inbuilt software with all standard measures.

Sequence of Procedure performed



Baseline demographic data:

Age (years), Sex: Male/ Female, Height (cm), Weight (kg), BMI

Dyspnoea on exertion: Functional class- I/II/III/IV

Angina on exertion: Functional class- I/II/III/IV

Current presentation: UA / NSTEMI / STEMI / CSA

Past history: Previous ACS, Previous CABG, Previous PCI

Coronary artery disease risk factors: Diabetes, Hypertension, Dyslipidaemia, Smoking, CKD

ECG findings: Rhythm, QRS duration

Chest roentgenogram: CT ratio

ECHO : LVEF, MR, PAH, RWMA

Lab Investigation : Post-PCI troponin T (ng/mL)

Medications (at time of discharge) : Aspirin, Thienopyridine, ACEI, ARB, Statin, CCB, BB, Nitrates

Coronary angiography analysis:

- Lesion locations (SYNTAX coronary segment)
- Target Lesion (Lesion to be assessed by OCT) location (SYNTAX coronary segment)
- Target lesion ACC/AHA type: A / B / C
- Target lesion (In case of ISR) (Mehran Classification): IA / IB / IC / ID / II / III / IV
- TIMI flow (Distal to target lesion): 0 / 1 / 2 / 3

- Target lesion QCA (PRE PCI)
- Lesion Length (mm)
- Minimal lesion lumen diameter (mm)
- Proximal reference diameter (mm)
- Distal reference diameter (mm)
- Average reference diameter, mm
- Diameter Stenosis (%)
- Area Stenosis (%)

POST–PCI CAG ANALYSIS

- TIMI flow grade: 0 / 1 / 2 / 3
- Minimal lumen diameter (mm)
- Diameter stenosis (%)
- Area Stenosis (%)

PCI details:

- Pre-stenting balloon dilatation: (Yes/no)
- Type of stent: BMS / DES / BVS / DEB
- Drug
- Stent diameter (mm)
- Stent length (mm)
- Number of stents
- Overlapping
- Total stent length, mm
- Implantation pressure (atm.)
- Direct stenting
- Post-stenting balloon dilatation:(Yes/no)

- Balloon Length
- Balloon Diameter
- Post-stenting dilatation pressure (atm.)

Optical coherence tomography (OCT) analysis:

PRE-PCI OCT FINDINGS

Target Lesion (Lesion to be assessed by OCT) location (SYNTAX coronary segment)

Assessment of Native Target lesion

- Lesion Length (mm)
- Proximal Reference lumen area, mm2
- Proximal Reference lumen average diameter, mm
- Proximal reference EEM area, mm2
- Distal Reference lumen area, mm2
- Distal Reference lumen average diameter, mm
- Distal reference EEM area, mm2
- Average reference lumen area, mm2
- Average reference lumen diameter, mm
- Minimal lesion lumen area, mm2
- Minimal lesion lumen diameter, mm
- Area stenosis, %
- Diameter stenosis, %

Native Target lesion plaque characteristics

- Plaque type: Fibrous plaque / Fibro calcified plaque / Fibro-fatty plaque

- Lipid-rich plaque
- Maximum lipid arc, °
- Minimum fibrous cap thickness, μm
- Maximum fibrous cap thickness, μm
- TCFA (Yes/no)
- Intimal rupture (Yes/no)
- Calcification (Yes/no)
- Calcification length, mm
- Maximum Calcification arc, °
- Red Thrombus
- White Thrombus

Assessment of Previously stented Target lesion (ISR Lesion)

- Time to OCT evaluation after previous PCI (months)
- Lesion Length (mm)
- Proximal reference lumen area, mm2
- Proximal reference lumen average diameter, mm
- Proximal reference EEM area, mm2
- Distal reference lumen area, mm2
- Distal reference lumen average diameter, mm
- Distal reference EEM area, mm2
- Average reference lumen area, mm2
- Average reference lumen diameter, mm
- Maximal stent area, mm2
- Minimal stent area, mm2
- Minimal In stent lumen area, mm2
- Minimal In stent lumen diameter, mm

- Area stenosis, %
- Diameter stenosis, %
- Stent Underexpansion (%)
- Maximum Neo Intimal Hyperplasia area, mm2
- Maximum Malapposition area, mm2
- No. of malapposed struts
- In stent thrombus
- No. of Uncovered stent strut
- ISR in target lesion (Mehran Classification): IA/IB/IC/ID/II/III/IV

IMMEDIATE POST-PCI OCT FINDINGS

- Proximal reference lumen area, mm2
- Proximal reference lumen diameter, mm
- Distal reference lumen area, mm2
- Distal reference lumen diameter, mm
- Maximal stent diameter
- Maximal stent area
- Minimal stent diameter
- Minimal stent area
- Luminal Area stenosis, %
- Luminal Diameter stenosis, %
- Stent Underexpansion (Y/N)
- Stent Underexpansion (%)
- Maximum Malapposition area, mm2
- No. of malapposed struts
- Optimal lesion coverage(Y/N)
- Red Thrombus

- White Thrombus
- Tissue prolapse visible (Y/N)
- Maximum Tissue prolapse area (mm2)
- Maximum Tissue prolapse length (mcm)
- Edge dissection visible(Y/N): Proximal/Distal
- Depth: Intimal / medial
- Length of edge dissection flap (mcm)
- Edge dissection arc, °

DEFINITIONS

1. **Chronic stable angina:** It is a clinical syndrome characterized by discomfort in the chest, jaw, shoulder, back, or arms, typically elicited by exertion or emotional stress and relieved by rest or nitroglycerin.

2. **Target lesion:** Lesion to be assessed by Optical coherence tomography.

3. **Spontaneous coronary artery dissection (SCAD):** SCAD is defined as a non-traumatic and non-iatrogenic separation of the coronary arterial walls, creating a false lumen giving a pathognomonic angiographic appearance which include multiple radiolucent lines, false lumen, contrast dye staining, and late contrast clearing.[19,33]

4. **In-stent restenosis:** Angiographically detected obstruction of 50% diameter stenosis (DS) or more at the site of a previously stented coronary segment has been defined as In-stent restenosis.[20]

5. **Plaque rupture:** Plaque rupture was defined as a small crater consisting of a discrete luminal widening with luminal irregularity.[21]

6. **Edge dissection:** Edge dissection is defined as angiographic appearance of haziness at stent edges within 5 mm distance either proximal or distal to stent.[30]

7. **Accordion:** Accordion (Concertina phenomenon) is a transient angiographic series of multiple narrowing during percutaneous coronary intervention in a tortuous vessel induced mainly by a stiff guide wire and disappears when the wire is removed also known as pseudolesions.[35,36,37]

8. **Thrombus:** Thrombus was defined as a angiographic discrete intraluminal filling defect.[21]

9. **Reference lumen:** Reference lumen is defined as 5-mm segments beyond the stent edges proximally and distally before a significant side branch (defined as a side branch >1.5 mm in diameter).[30]

10. **Fibrous plaque:** Fibrous plaque appears as a homogeneous area of high reflectivity with low signal attenuation.[29]

11. **Fibro-fatty plaque:** Fibro-fatty plaque appears as a homogeneous area of low reflectivity with high signal attenuation.[29]

12. **Fibro-calcified plaque:** Fibro-Calcified plaque appears as a plaque containing heterogeneous area of high or low reflectivity with low signal attenuation and a sharp demarcating border.[29]

13. **Lipid rich plaque:** Lipid-rich plaque is defined by lipid occupying 2 or more quadrants of the cross-sectional image.[29]

14. **Thin cap fibro-atheroma (TCFA):** Thin-cap fibroatheroma (TCFA) was defined as a lipid-rich plaque with minimum fibrous cap thickness <65 μm.[22]

15. **Calcification:** Calcium defined as a heterogeneous area of high or low reflectivity with low signal attenuation and a sharp demarcating border.[29]

16. **Thrombus:** Thrombus is readily identified by OCT as a protruding mass attached to the arterial wall with measured dimension threshold of greater than or equal to 250 μm.[25,26]

17. **Red thrombus:** Red thrombus is composed primarily of red blood cells and appears as a signal-rich mass with high signal attenuation. [25,26]

18. **White thrombus:** White thrombus consists primarily of white blood cells and platelets and appears as a signal-rich mass with low signal attenuation. [25,26]

19. **Spontaneous coronary artery dissection:** SCAD is defined as a non-traumatic and non-iatrogenic separation of the coronary arterial walls, creating a false lumen giving OCT appearance which include visualization of IMH, double or multiple lumen, and dissection flap at the intimal-medial interface.[33]

20. **Stent expansion:** Stent expansion is calculated as minimum stent area (MSA) divided by the average reference lumen area multiplied by 100.[30]

21. **Optimal stent expansion:** Optimal stent expansion is defined as minimal stent area (MSA) greater than or equal to 90% of distal reference lumen area or MSA greater than or equal to 90% of the average of reference lumen area.[30,31,32]

22. **Stent underexpansion:** Stent underexpansion is defined as minimal stent area (MSA) less than or equal to 90% of distal reference lumen

area or MSA less than or equal to 90% of the average of reference lumen area.[30,31,32]

23. **Stent malapposition:** Stent malapposition can be determined to be present when the distance from the centre of blooming artefact of the stent strut to the surface of the adjacent plaque is greater than the sum of the known strut thickness and polymer thickness.[30]

24. **Stent malapposition area:** Stent malapposition area is defined as lumen area minus stent area at the frame showing maximum malapposition.[30]

25. **Neo-intimal tissue area:** Neo-intimal tissue area was defined as stent area minus lumen area in a particular OCT frame.[34]

26. **Microchannel:** Microchannel have been defined as small black (signal absent) holes within a plaque that measure 50 to 300 mm in diameter and span at least 3 consecutive frames on pullback OCT imaging.[27,28]

27. **Tissue prolapse:** Tissue prolapse is defined as visible tissue seen within the stent struts that can be either thrombus or plaque and the significance of tissue protrusion means percent tissue protrusion area is defined as maximum tissue protrusion area divided by the stent area.[30]

28. **Stent edge:** Stent edges were defined as the 5-mm regions immediately adjacent to the stent borders, both distally and proximally.[24]

29. **Edge dissection:** Edge dissection was defined as disruptions of the arterial lumen surface in the stent edge segment seen in at least 2 consecutive cross-section images.[24]

30. **Intramural hematoma:** intramural hematoma was defined as an accumulation of flushing medium (or blood) within the medial space, displacing the internal elastic membrane inward and the external elastic membrane outward.[23]

31. **All cause death:** All cause of death was defined as death from any cause.[39]

32. **Cardiac death:** Any death due to proximate cardiac cause (MI, low-output failure, fatal arrhythmia), unwitnessed death and death of unknown cause, and all procedure-related deaths, including those related to concomitant treatment, will be classified as cardiac death.[39]

33. **Myocardial infarction (MI):** Myocardial infarction was defined as per the third universal definition of MI.[38,40]

34. **Target vessel MI:** Myocardial Infarction attributable to any segment of Target Vessel is defined as Target vessel MI.[39]

35. **Target lesion MI:** Myocardial Infarction attributable to Target lesion segment is defined as Target lesion MI.[39]

36. **Stent thrombosis:** Stent thrombosis was defined as per standard definition given by Academic Research Consortium (ARC).[39]

37. **Target Lesion Revascularization (TLR):** Target lesion revascularization was defined as repeat revascularization of the treated vessel segment either by PCI or CABG.[39]

38. **Target Vessel Revascularization (TVR):** Target vessel revascularization was defined as repeat revascularization of the treated vessel either by PCI or CABG, including any segments of the same vessel.[39]

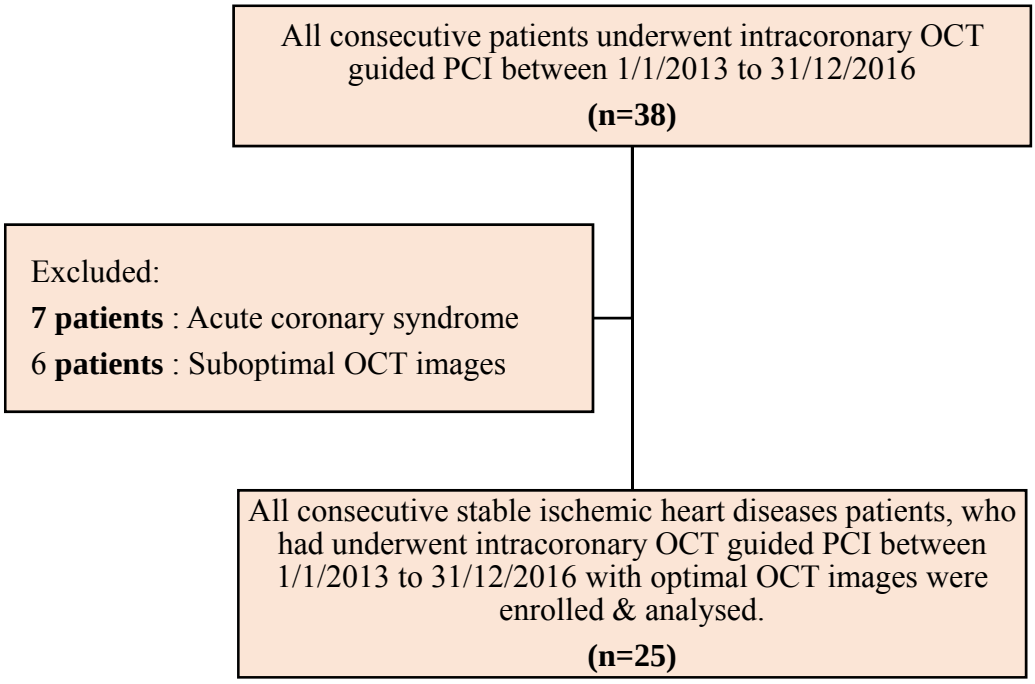
39. **Cerebrovascular stroke:** CV Stroke was defined as a focal neurological deficit lasting >24 hours which resulted in irreversible brain damage or body impairment.

Statistical analysis:

The data will be analysed by the principal investigator. Data would be expressed as mean of Continuous variables with standard deviations. The data would be analysed by the principal investigator with advice from statistician if required. All data will be handled with care to maintain patient confidentiality. Records will be maintained in both computer and paper formats. The closing point for any one patient will be the time of their available last visit to the follow- up clinic. Descriptive summaries will be presented as frequencies and percentages for categorical data, and as means and standard deviations for continuous variables. Continuous variables will be compared using Student's t test or Mann-Whitney U test as appropriate, Group comparisons will be made using $\chi 2$ tests. All statistical analyses were performed using the SPSS statistical software package (release 23.0.0.0, SPSS Inc. Chicago, IL).

RESULTS

Figure 1: Flow chart of the study



A total of 38 patient had underwent OCT guided PCI during study period, out of which 7 patient had presented with acute coronary syndrome and 6 patient were having suboptimal OCT images. Finally total 25 patients with chronic stable angina were included in our study. In our study 24 (96%) were male and 1 (4%) was female. The mean age of the patients was 55 years (range 30-69) and 8 (32%) patients were ≤ 50 years. Mean BMI of patients was 24.2 (SD=4.1). 18 (72%) patient were having functional class II angina on exertion and 6 (24%) were having class III angina on presentation. Clinical presentation of all patient was chronic stable angina.

13 (52%) patient were having history of STEMI in past whereas 5 (20%) and 2 (8%) were having history of unstable angina & NSTEMI in past respectively. 11 (44%) were having PCI in past and one patient was post CABG. Prevalence of diabetes, hypertension, dyslipidaemia and smoking in our study population was 72%, 88%, 100% and 60% respectively(Figure 2). 23 (92%) patient were in sinus rhythm. Mean Ejection fraction was 57 (SD=4). 16 (64%) patient were showing regional wall motion abnormalities on 2D ECHO. All patients were having high sensitivity TROP T evaluation post PCI and 8 (32%) patient were having elevated troponin level post PCI but all values were marginally elevated. All patients were on Aspirin, Thienopyridine, Statins and beta-blockers on discharge (Figure 3). Clopidogrel was most commonly prescribed Thienopyridine. 18 (72%) patients were on ACE inhibitors or ARBs and 7 (28%) were prescribed nitrates at the time of discharge. (Table.1 Baseline characteristics)

Table 1. Baseline characteristics (n=25)

Clinical baseline characteristics (n=25)	
Age (years), mean (SD)	55 (9)
Male (%)	24 (96%)
Height (cm), mean (SD)	165 (6)
Weight (kg), mean (SD)	65 (10)
BMI (kg/m2), mean (SD)	24 (4)
Dyspnoea on exertion - Functional class	
I (%)	17 (68%)
II (%)	8 (32%)
III (%)	0
IV (%)	0
Angina on exertion - Functional class	
I (%)	1 (4%)
II (%)	18 (72%)
III (%)	6 (24%)
IV (%)	0
Current presentation:	
UA (%)	0
NSTEMI (%)	0
STEMI (%)	0
CSA (%)	25 (100%)
Previous ACS:	
Nil (%)	5 (20%)
UA (%)	5 (20%)
NSTEMI (%)	2 (8%)
STEMI (%)	13 (52%)
Previous CABG: (%)	1 (4%)
Previous PCI: (%)	11 (44%)
Diabetes: (%)	18 (72%)
Hypertension: (%)	22 (88%)
Dyslipidaemia: (%)	25 (100%)
Smoking: (%)	15 (60%)
Chronic kidney disease: (%)	0
Rhythm:	
Sinus rhythm (%)	23 (92%)
Complete heart block (%)	2 (8%)
Atrial fibrillation (%)	0
QRS duration: mean (SD)	100 (21)
Cardiothoracic ratio: mean (SD)	52 (4)
LV ejection fraction: mean (SD)	57 (15)
Mitral regurgitation:	
Nil (%)	17 (68%)
Mild (%)	7 (28%)
Moderate (%)	1 (4%)
Severe (%)	0
Pulmonary hypertension:	
Nil (%)	24 (96%)
Mild (%)	1 (4%)
Moderate (%)	0
Severe (%)	0
Regional wall motion abnormality:	
Yes (%)	16 (64%)
No (%)	9 (36%)
Post-PCI troponin:	
Positive (%)	8 (32%)
Negative (%)	17 (68%)
Medications (at time of discharge)	
Aspirin	25 (100%)
Thienopyridine	25 (100%)
ACEI	10 (40%)
ARB	8 (32%)
Statin	25 (100%)
CCB	10 (40%)
BB	25 (100%)
Nitrates	7 (28%)

Figure 2

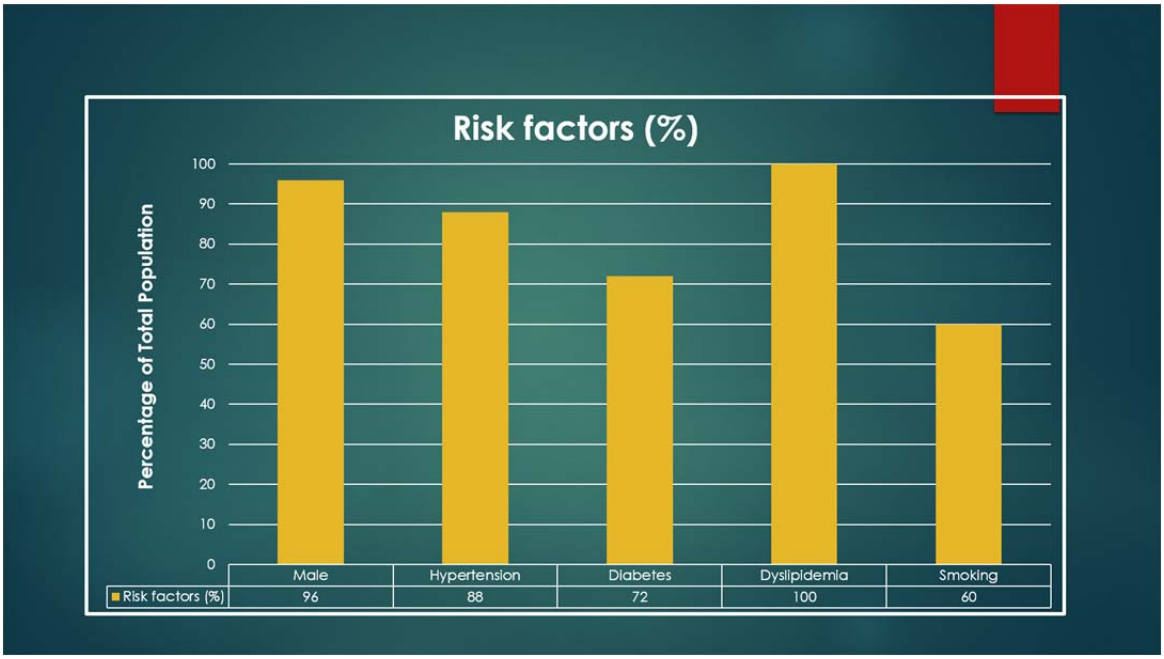
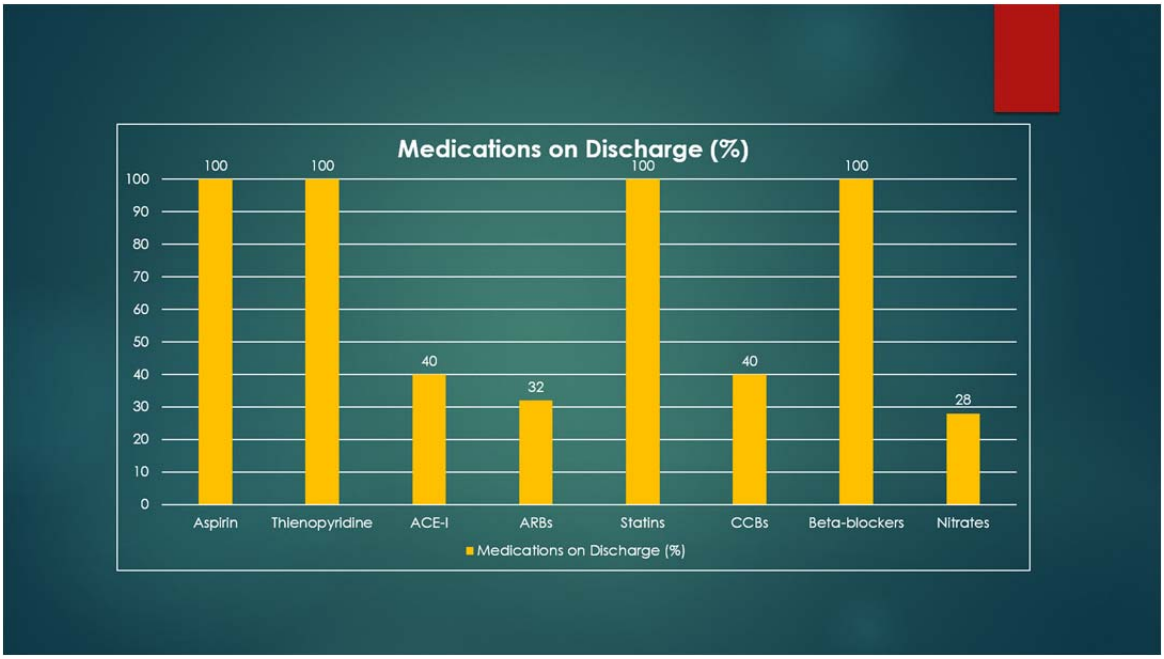


Figure 3



All patient underwent pre-PCI CAG for lesion assessment. 8 (32%), 13 (52%), 4 (16%) patient were having Single vessel, double vessel and

triple vessel disease respectively. Target lesion location has been described as per SYNTAX coronary segments. Target lesion location was most commonly located in segment 6 followed by segment 7 & 2 followed by segment 1. ACC/AHA type B was most common lesion type followed by type C seen in 10(40%) & 9 (36%) respectively. Target lesion with In-stent restenosis (ISR) was evaluated is 8 (32%) patients which was classified based on Mehran classification system. TIMI flow distal to target lesion was TIMI III in 18 (72%) patients and 3 (12%) patient were having CTO. Quantitative angiographic evaluation was done of pre-PCI CAG which was showing mean lesion length of 18.8 mm (SD=13.9). Average reference lumen diameter was 2.55 mm (SD=0.47) and Minimal lesion lumen diameter was 1.07 mm (SD=0.69). Diameter stenosis and Area stenosis was 67% (SD=23.25) and 80% (SD=20.24) respectively. Spontaneous coronary artery dissection (SCAD) was seen in 3 (12%), plaque rupture was suspected in 3 (12%) and thrombus was suspected in one patient. (Table. 2 Pre-PCI CAG characteristics)

Table 2. PRE-PCI CAG CHARACTERISTICS (n=25)

No. of vessel diseased		
Single vessel disease (%)		8 (32%)
Double vessel disease (%)		13 (52%)
Triple vessel disease (%)		4 (16%)
Target Lesion (Lesion assessed by OCT) location (SYNTAX coronary segment)		
LMCA (segment 5) (%)		0
LAD		
Segment 6 (%)		9 (36%)
Segment 7 (%)		8 (32%)
LCX		
Segment 11 (%)		1 (4%)
Segment 12 (%)		1 (4%)
RCA		
Segment 1 (%)		7 (28%)
Segment 2 (%)		8 (32%)
Segment 3 (%)		2 (8%)
Venous grafts (%)		1 (4%)
Target lesion ACC/AHA type		
Type A (%)		6 (24%)
Type B (%)		10(40%)
Type C (%)		9 (36%)
Target lesion (In case of ISR) (Mehran Classification) (n=8)		
IA (%)		0
IB (%)		0
IC (%)		2 (25%)
ID (%)		0
II (%)		4 (50%)
III (%)		0
IV (%)		2 (25%)
TIMI flow (Distal to target lesion)		
TIMI 0 (%)		3 (12%)
TIMI 1 (%)		1 (4%)
TIMI 2 (%)		3 (12%)
TIMI 3 (%)		18(72%)
Target lesion QCA		
Lesion Length (mm)	mean (SD)	18.80 (13.9)
Proximal reference diameter (mm)	mean (SD)	2.66 (0.58)
Distal reference diameter (mm)	mean (SD)	2.45 (0.47)
Average reference diameter, (mm)	mean (SD)	2.55 (0.47)
Minimal lesion lumen diameter (mm)	mean (SD)	1.07 (0.69)
Diameter Stenosis (%)	mean (SD)	67.00 (23.25)
Area Stenosis (%)	mean (SD)	79.67 (20.24)
Special features		
Spontaneous coronary artery dissection (%)		3 (12%)
In-stent restenosis (%)		8 (32%)
Plaque rupture with dissection (%)		3 (12%)
Thrombus (%)		1 (4%)

Total 19 (76%) patient underwent pre-PCI OCT evaluation out of which 11 patient had native coronary artery lesion and 8 patient had In-stent restenosis lesion. Mean lesion length was 29.33 mm (SD=13.36). Average reference lumen diameter and area were 2.79 mm (SD=0.35) and 6.33 mm^2 (SD=1.65) respectively. Minimal lesion lumen diameter and area were 1.41 mm (SD=0.33) and 1.71 mm^2 (SD=0.77) respectively. Diameter stenosis

and area stenosis was 49% (SD=13.3) and 70.9% (SD=13.59) respectively. 10 out of 11 (90%) patients were having fibro-fatty plaque. All plaques were lipid rich plaque with maximum lipid arc of 229^0 (SD= 52). Maximum and minimum fibrous cap thickness were 468 μm (SD=174) and 70 μm (SD=37) respectively. 8 out of 11 (72%) patient were having thin cap fibroatheroma also known as TCFA. 8 (72%) patient were having intimal rupture and calcification was noted in 7 out of 11 (63%) patients with mean calcification length of 2.95 mm (SD=1.73) and maximum calcification arc was 102^0 (SD=47.7). Thrombus was noted in 5 out of 11 (45%) patients. SCAD and Plaque rupture was noted in 3, 3 patients respectively. (Table. 3 Pre PCI OCT parameters)(Figure 4).

Eight patient underwent pre-PCI OCT evaluation for In-stent restenosis lesions. Mean duration of time between PCI and OCT evaluation was 71.5 months (SD=50.5) which ranges from 11-168 months. Mean lesion length was 30.5 mm (SD=14.77) with average reference lumen diameter and area were 2.70 mm (SD=0.35) and 5.90 mm^2 (SD=1.43) respectively. Minimal in stent lumen diameter and area were 1.42 mm (SD=0.18) and 1.66 mm^2 (SD=0.45) respectively with diameter stenosis and area stenosis of 47.1% (SD=6.83) and 71.1% (SD=7.82) respectively. Maximal stent area and minimal stent area were 7.08 mm^2 (SD=2.25) and 5.28 mm^2 (SD=1.74) respectively. Stent underexpansion was detected in all 8 patients which

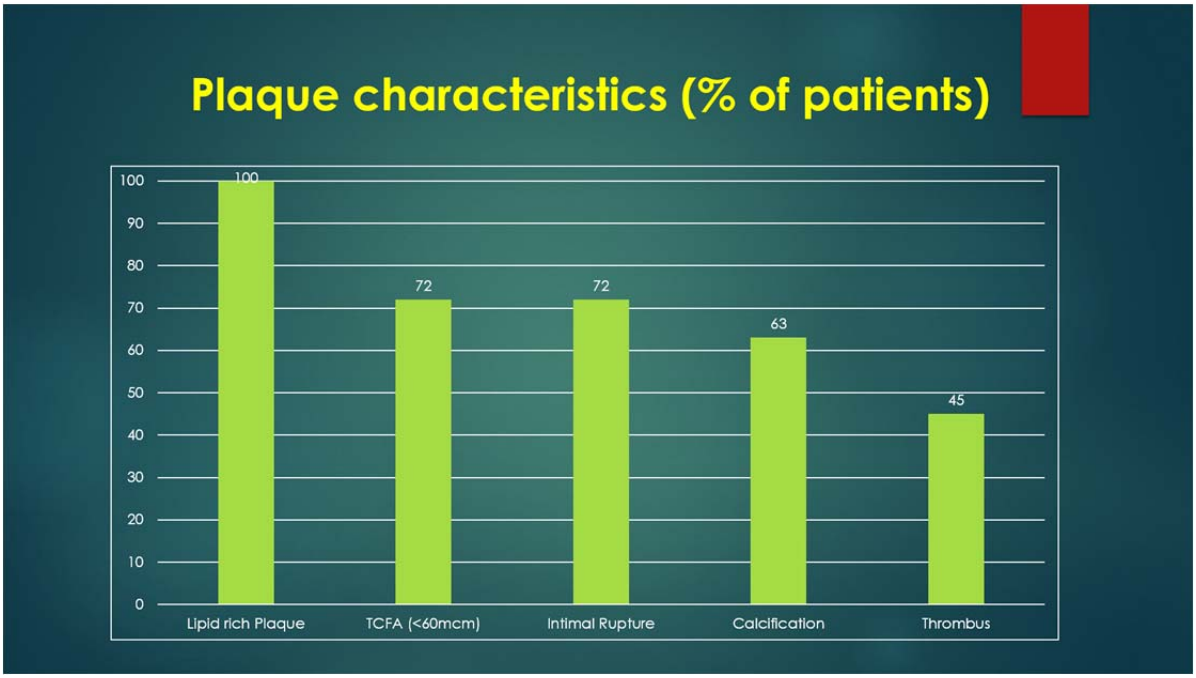
ranges from 9% to 30% underexpansion with mean of 18.83 (SD=7.30). Maximum neointimal tissue area was 4.27 mm^2 (SD=1.64) with Percentage burden of neointimal tissue was 66% (SD=12.2) which ranges from 42% to 80%. ISR tissue structure was noted as homogenous, heterogeneous and layered in 1 (12.5%), 3 (37.5%) and 4 (50%) patients with layered tissue structure as most common pattern with high backscattering in all 8 lesions. Microvessels were seen in 5 (62.5%) lesions. One out of 8 (12.5%) patient was showing malapposed struts (7 struts) with malapposition area of 0.96 mm^2 and all 7 struts were uncovered. All patients were having diffuse ISR on OCT evaluation and ISR pattern type III was most common, also known as proliferative ISR according to Mehran classification. (Table. 3 Pre PCI OCT parameters)

Table 3. PRE-PCI OCT PARAMETERS

Native Target lesion assessment (n=11)		
Lesion Length (mm)	mean (SD)	29.33 (13.36)
Proximal Reference lumen area, mm2	mean (SD)	6.96 (2.45)
Proximal Reference lumen average diameter, mm	mean (SD)	2.92 (0.49)
Proximal reference EEM area, mm2	mean (SD)	9.88 (3.39) **(n=4)**
Distal Reference lumen area, mm2	mean (SD)	5.71 (1.16)
Distal Reference lumen average diameter, mm	mean (SD)	2.67 (0.28)
Distal reference EEM area, mm2	mean (SD)	8.75 (2.08) **(n=5)**
Average reference lumen area, mm2	mean (SD)	6.33 (1.65)
Average reference lumen diameter, mm	mean (SD)	2.79 (0.35)
Minimal lesion lumen area, mm2	mean (SD)	1.71 (0.77)
Minimal lesion lumen diameter, mm	mean (SD)	1.41 (0.33)
Area stenosis, %	mean (SD)	70.91 (13.59)
Diameter stenosis, %	mean (SD)	49.00 (13.30)
Native Target lesion plaque characteristics (n=11)		
Plaque type Fibrous plaque, (%) Fibro calcified plaque (%) Fibro-fatty plaque (%)		 0 1 (9%) 10 (90%)
Lipid-rich plaque (%)		11 (100%)
Maximum lipid arc, °	mean (SD)	229 (52)
Minimum fibrous cap thickness, µm	mean (SD)	70 (37)
Maximum fibrous cap thickness, µm	mean (SD)	468 (174)
TCFA (%)		8 (72%)

Intimal rupture (%)		8 (72%)
Calcification (%)		7 (63%)
Calcification length, mm	mean (SD)	2.95(1.73)
Maximum Calcification arc, °	mean (SD)	102 (47.7)
Red Thrombus (%)		4 (36%)
White Thrombus (%)		1 (9%)
Special features (n=15)		
Spontaneous coronary artery dissection (%)		3 (20%)
Plaque rupture with dissection (%)		3 (20%)
Calcification in neointimal tissue (%)		1 (6.7%)
Calcification outside stent (%)		1 (6.7%)
Assessment of In-stent restenosis(ISR)lesion (n=8)		
Time to OCT after previous PCI (months)	mean (SD)	71.5 (50.5) **(11-168)**
Lesion Length (mm)	mean (SD)	30.5 (14.77)
Proximal reference lumen area, mm2	mean (SD)	6.21 (2.05)
Proximal reference lumen average diameter, mm	mean (SD)	2.76 (0.49)
Proximal reference EEM area, mm2	mean (SD)	10.16 (3.29) **(n=2)**
Distal reference lumen area, mm2	mean (SD)	3.96 (1.93)
Distal reference lumen average diameter, mm	mean (SD)	2.17 (0.56)
Distal reference EEM area, mm2	mean (SD)	5.37 (1.46) **(n=4)**
Average reference lumen area, mm2	mean (SD)	5.90 (1.43)
Average reference lumen diameter, mm	mean (SD)	2.70 (0.35)
Maximal stent area, mm2	mean (SD)	7.08 (2.25)
Minimal stent area, mm2	mean (SD)	5.28 (1.74)
Minimal In stent lumen area, mm2	mean (SD)	1.66 (0.45)
Minimal In stent lumen diameter, mm	mean (SD)	1.42 (0.18)
Area stenosis, %	mean (SD)	71.1 (7.82)
Diameter stenosis, %	mean (SD)	47.1 (6.83)
Stent Underexpansion (%)	mean (SD)	18.83 (7.30) (9-30)
Maximum Neo Intimal tissue area, mm2	mean (SD)	4.27 (1.64)
Burden of Neointimal tissue (%)	mean (SD)	66 (12.2) (42-80)
ISR tissue structure		
Homogenous (%)		1 (12.5%)
Heterogeneous (%)		3 (37.5%)
Layered (%)		4 (50%)
ISR tissue backscattering		
High backscattering (%)		8 (100%)
Low backscattering (%)		0
ISR tissue microvessels (%)		5 (62.5%)
Maximum Malapposition area, mm2	mean (SD)	0.12 (0.0-0.96)
No. of malapposed struts	mean (SD)	0.88 (0.0-7.00)
In stent thrombus (%)		1 (12.5%)
No. of Uncovered stent strut	mean (SD)	0.88 (0.0-7.00)
ISR in target lesion (Mehran Classification)		
IA (%)		0
IB (%)		0
IC (%)		0
ID (%)		0
II (%)		2 (25%)
III (%)		4 (50%)
IV (%)		2 (25%)

Figure 4



Twenty three (92%) patients underwent pre-stenting balloon dilatation. 22 (88%) patients had drug eluting stent implantation with most commonly everolimus (36%) followed by sirolimus (32%) and zotarolimus (24%). Biovascular scaffold (BVS) was implanted in 2 (8%) patients. Mean diameter and length of implanted stent was 2.97 mm (SD=0.32) and 25.6 mm (SD=7.4) respectively. Stent diameter ranges from 2.5 mm to 3.5 mm. Average number of stent implanted per patient was 1.42. Mean stent implantation pressure was 12.88 atmosphere (SD=1.53). All patient underwent post-stenting balloon dilatation with mean balloon diameter of 3.22 mm (SD=0.32) with mean post dilatation pressure of 19.5 atmosphere (SD=3.0). Post dilatation balloon diameter ranges from 2.75 mm to 4.0 mm.

Rotaablation was used in one patient. Post PCI TIMI III flow was achieved in all patients. Minimal luminal diameter was noted to be 2.18 mm (SD=0.43) with mean diameter & mean area stenosis of 14.06 % (SD=8.11) and 23.75 % (SD=12.6) respectively on QCA. Distal edge dissection was suspected in two (8%) and accordion was noted in 1 (4%) patient. Stent underexpansion was suspected in 4 (16%) patients. (Table. 4 PCI & post-PCI CAG details)

Table 4. PCI & POST-PCI CAG DETAILS

Pre-stenting balloon dilatation (%)		23 (92%)	
Type of stent			
BMS (%)		0	
DES (%)		22 (88%)	
BVS (%)		2 (8%)	
DEB (%)		1 (4%)	
Drug			
Everolimus (%)		9 (36%)	
Sirolimus (%)		8 (32%)	
Zotarolimus (%)		6 (24%)	
Paclitaxel (%)		1 (4%)	
Others (%)		1 (4%)	
Stent diameter (mm)	mean (SD)	2.97 (0.32)	(2.5-3.5)
Stent length (mm)	mean (SD)	25.6 (7.4)	(13-40)
Number of stents, average	mean (SD)	1.42	(1-3)
Overlapping (%) (n=7)		7 (100%)	
Total stent length, mm	mean (SD)	34.71 (17.82)	(18-90)
Implantation pressure (atm.)	mean (SD)	12.88 (1.53)	(10-16)
Direct stenting (%)		2 (8%)	
Post-stenting balloon dilatation			
Balloon Length	mean (SD)	12.22 (7.67)	(8-33)
Balloon Diameter	mean (SD)	3.22 (0.32)	(2.75-4.0)
Post-stenting dilatation pressure (atm.)	mean (SD)	19.5 (3.0)	(14-26)
Rotaablation (%)		1 (4%)	
IVUS-guided PCI (%)		0	
FFR (%)		1 (4%)	
Post PCI CAG			
TIMI flow grade			
TIMI III (%)		25 (100%)	
Minimal lumen diameter (mm)	mean (SD)	2.18 (0.43)	(1.68-3.42)
Diameter stenosis (%)	mean (SD)	14.06 (8.11)	(2-30)
Area Stenosis (%)	mean (SD)	23.75 (12.60)	(3-43)
Special features			
Proximal edge dissection (%)		0	
Distal edge dissection (%)		2 (8%)	
Accordion (%)		1 (4%)	
Undermined plaque (%)		1 (4%)	
Suspected Underexpansion (%)		4 (16%)	
Malapposition		0	

Twenty four out of 25 patient underwent post PCI OCT evaluation. Mean proximal reference lumen diameter and area were 3.04 mm (SD=0.44) and 7.42 mm^2 (SD=2.22) respectively. Mean distal reference lumen diameter and area were 2.50 mm (SD=0.36) and 5.04 mm^2 (SD=1.41) respectively. Maximum stent diameter and area were 3.57 mm (SD=1.29) and 7.58 mm^2 (SD=1.82) respectively. Minimal stent diameter and area were 2.39 mm (SD=0.43) and 4.66 mm^2 (SD=1.47) respectively. Luminal diameter and luminal area stenosis post PCI was noted to be 13.1% (SD=11.09) and 23.52% (SD=16.09) respectively by OCT evaluation. Stent underexpansion was detected in 19 out of 23 (82%) patients with 6 (26%) patient having underexpansion of 10-20% range and 13 (56%) patients were having stent underexpansion >20%. Optimal lesion coverage was present in 21 (91%) of patients. Three out of 23 (13%) patients were showing complete absence of malapposition. Twenty out of 23 (87%) patients were showing some amount of malapposition which ranges from minimum 2 struts to maximum 46 struts. Nine out of 23 (40%) patient were showing malapposition of >10 stent struts with mean malapposition area of 1.50 mm^2. Intra stent thrombus was detected in 10 (41%) patient with white thrombus in 6 and red thrombus in 4 patients. All thrombus were non-flow limiting and were attached to stent struts. Tissue prolapse was visible in 22 out of 24 (91%) patients with maximum tissue prolapse area of 0.80 mm^2

(SD=0.61). Significant tissue prolapse with percent tissue protrusion area of more than 10% was seen in 12 (53%) patients with maximum tissue protrusion length towards lumen of 333.1 µm (SD=143.0). Edge dissection was detected in 5 out of 23 (22%) patients with proximal edge dissection in 2 (9%) and distal edge dissection in 3 (13%) patients. Depth of all dissections were limited to intimal layer only with mean longitudinal length of edge dissection flap was 1600 µm (SD=1039.2). Mean edge dissection arc was 61^0 (SD=33.61) which ranges from 20^0 to 90^0. (Table. 5 Immediate post PCI OCT parameters)(Table. 6 Important parameters)

Table 5. IMMEDIATE POST-PCI OCT PARAMETERS (n=24)

Proximal reference lumen area, mm2	mean (SD)	7.42 (2.22)	
Proximal reference lumen average diameter, mm	mean (SD)	3.04 (0.44)	
Distal reference lumen area, mm2	mean (SD)	5.04 (1.41)	
Distal reference lumen average diameter, mm	mean (SD)	2.50 (0.36)	
Maximal stent diameter, mm	mean (SD)	3.57 (1.29)	
Maximal stent area, mm2	mean (SD)	7.58 (1.82)	
Minimal stent diameter, mm	mean (SD)	2.39 (0.43)	
Minimal stent area, mm2	mean (SD)	4.66 (1.47)	
Luminal Area stenosis, %	mean (SD)	23.52 (16.09)	
Luminal Diameter stenosis, %	mean (SD)	13.10 (11.09)	
Stent Underexpansion detected (%)		19 (82%)	
Stent Underexpansion, %	mean (SD)	20.7 (9.86)	(2-39)
Optimal lesion coverage (%)		21 (91%)	
Maximum Malapposition area, mm2	mean (SD)	0.68	(0.00-3.60)
No. of malapposed struts	mean (SD)	11.22	(0-46)
Red Thrombus (%)		4 (16%)	
White Thrombus (%)		6 (25%)	
Tissue prolapse visible (%)		22 (91%)	
Maximum Tissue prolapse area (mm2)	mean (SD)	0.80 (0.61)	(0.07-2.10)
Percent Tissue protrusion area (%)	mean (SD)	11.95 (8.40)	(2-33)
Maximum Tissue prolapse length (mcm)	mean (SD)	333.1 (143.0)	(140-660)
Edge dissection No edge dissection (%) Proximal edge dissection (%) Distal edge dissection (%)		 18 (78.3%) 2 (8.7%) 3 (13%)	
Depth of edge dissection Intimal (%) Medial (%)		 5 (100%) 0	
Longitudinal Length of edge dissection flap (mcm)	mean (SD)	1600 (1039.2)	(800-3400)
Edge dissection arc, °	mean (SD)	61 (33.61)	(20-90)

Table 6. IMPORTANT PARAMETERS

Minimal stent diameter, mm	mean (SD)	2.39 (0.43)
Minimal stent area, mm2	mean (SD)	4.66 (1.47)
Luminal Area stenosis, %	mean (SD)	23.52 (16.09)
Luminal Diameter stenosis, %	mean (SD)	13.10 (11.09)
Underexpansion (N=23) <10% 10-20% >20%		 4 (18%) 6 (26%) 13(56%)
Edge dissection		5 (22%)
Red Thrombus		4 (16%)
White Thrombus		6 (25%)
Malapposition		9 (38%)
Percent Tissue prolapse area <10% 10-20% >20%		 10(44%) 8 (35%) 4 (18%)
Additional intervention (post OCT) No additional intervention Additional balloon post-dilatation Additional stenting		 7 (28%) 17(68%) 1 (4%)

Eighteen out of 25 (72%) patients underwent additional intervention after post PCI OCT assessment. Seventeen out of 25 (68%) patients underwent additional balloon post-dilatation of stent either for significant stent underexpansion or significant tissue protrusion. One patient underwent additional stent implantation due to distal stent edge dissection. Patient with hemodynamically non-significant OCT findings were left untreated. (Table. 6 Important parameters) (Table. 7 Post-PCI assessment : CAG vs OCT parameters)(Figure 5,6,7).

Table 7 : Post-PCI assessment : CAG vs OCT parameters

Immediate Post-PCI assessment		Coronary Angiography	Optical Coherence Tomography
Minimal lumen diameter (mm)	mean (SD)	2.18 (0.43)	2.39 (0.43)
Luminal Diameter stenosis, %	mean (SD)	14.06 (8.11)	13.10 (11.09)
Luminal Area stenosis, %	mean (SD)	23.75 (12.6)	23.52 (16.09)
Edge dissection	No. (%)	2 (8%)	5 (22%)
Tissue prolapse	No. (%)	1 (4%)	10 (44%) (<10% , Percent Tissue prolapse area) 8 (35%) (10-20% , Percent Tissue prolapse area) 4 (18%) (>20% , Percent Tissue prolapse area)
Underexpansion	No. (%)	4 (16%)	4 (18%) (<10% , Percent Underexpansion) 6 (26%) (10-20% , Percent Underexpansion) 13 (56%) (>20% , Percent Underexpansion)
Malapposition	No. (%)	0 (0%)	14 (61%) (<10 struts) 5 (22%) (10-20 struts) 4 (17%) (>20 struts)

Figure 5

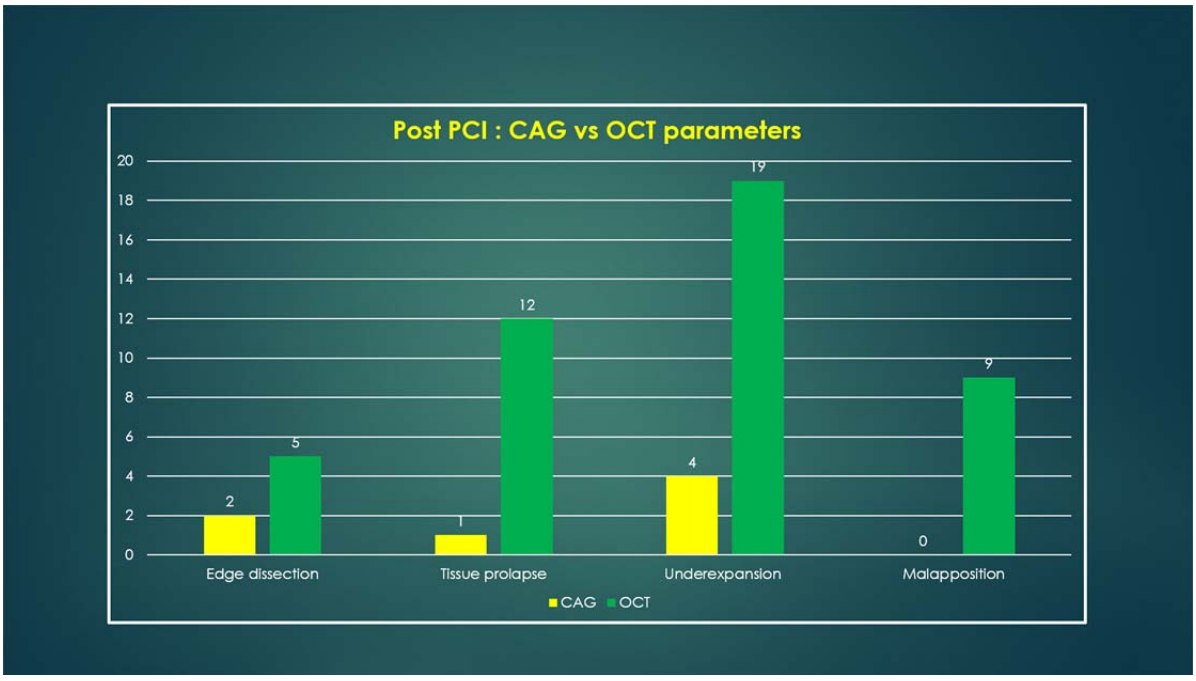
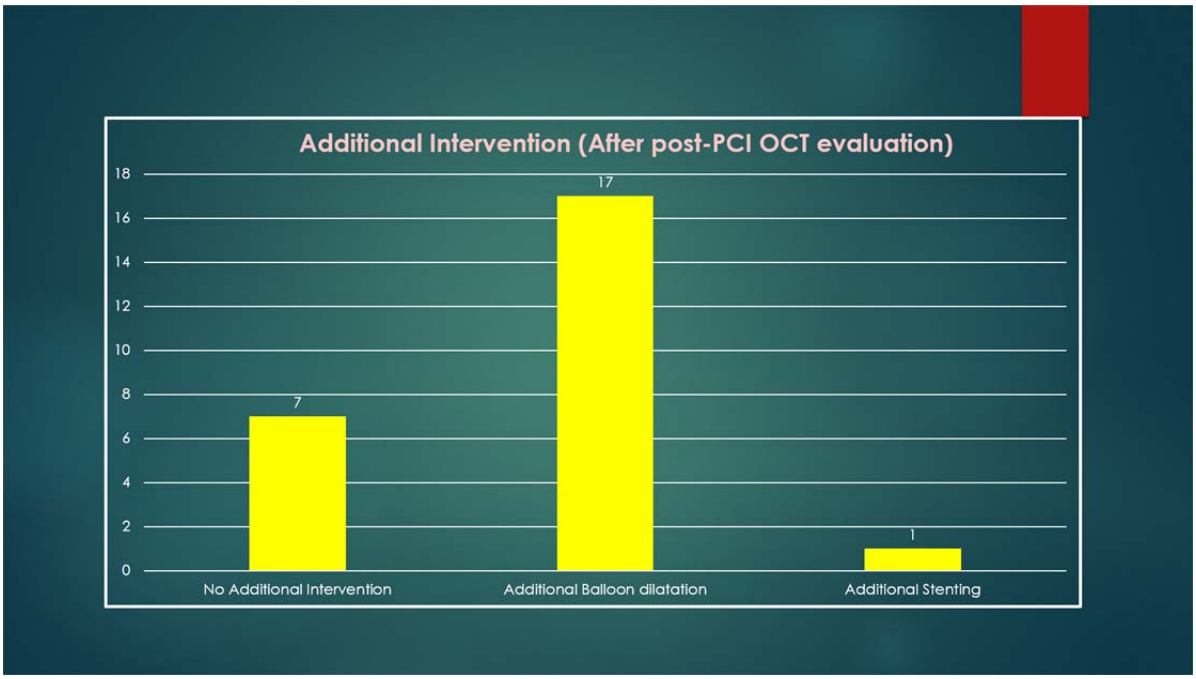


Figure 6

Additional intervention (After Post-PCI OCT evaluation)

Additional intervention (After post-PCI OCT evaluation)	
No additional intervention	7 (28%)
Additional balloon post-dilatation	17 (68%)
Additional stenting	1 (4%)

Figure 7



All patient were discharged and followed up in outpatient department on regular basis. Two patients were lost to follow-up. Clinical follow-up data of 23 (92%) patients were available. Mean duration of follow-up after OCT guided PCI was 18.9 months (SD=6.8) which ranges from 7 months to 32 months (median duration of follow-up was 19 months). Twelve out of 23 (52%) were symptomatic on last follow-up visit with functional class II stable symptoms and all were planned for optimization of medical therapy. None of the patients were having functional class III or IV symptoms over total follow-up duration. Patients were followed up to look for any MACE events during follow-up period which includes All cause death, Cardiac death, Any MI, Target vessel MI, Target lesion MI, Stent thrombosis, Target lesion revascularization (TLR), Target vessel revascularization (TVR) and any Cerebrovascular event. On total mean follow-up duration of 18.9 months (SD=6.8), none of the patient were having any MACE event. So, MACE event rate in our study population was zero. (Table. 8)

Table 8. CLINICAL OUTCOME ON FOLLOWUP (N=23)

Time after OCT guided PCI (months) mean (SD)	18.9 (6.8) (median=19 months) (Range of 7-32 months)
ANGINA FUNCTIONAL CLASS FC I (%) FC II (%)	 16 (70%) 7 (30%)
DYSPNEA FUNCTIONAL CLASS FC I (%) FC II (%)	 18 (78%) 5 (22%)
All cause death (%)	0
Cardiac death (%)	0
Any MI (%)	0
Target vessel MI (%)	0
Target Lesion MI (%)	0
Stent thrombosis (%)	0
Target Lesion Revascularization (%)	0
Target Vessel Revascularization (%)	0
Cerebrovascular event (%)	0

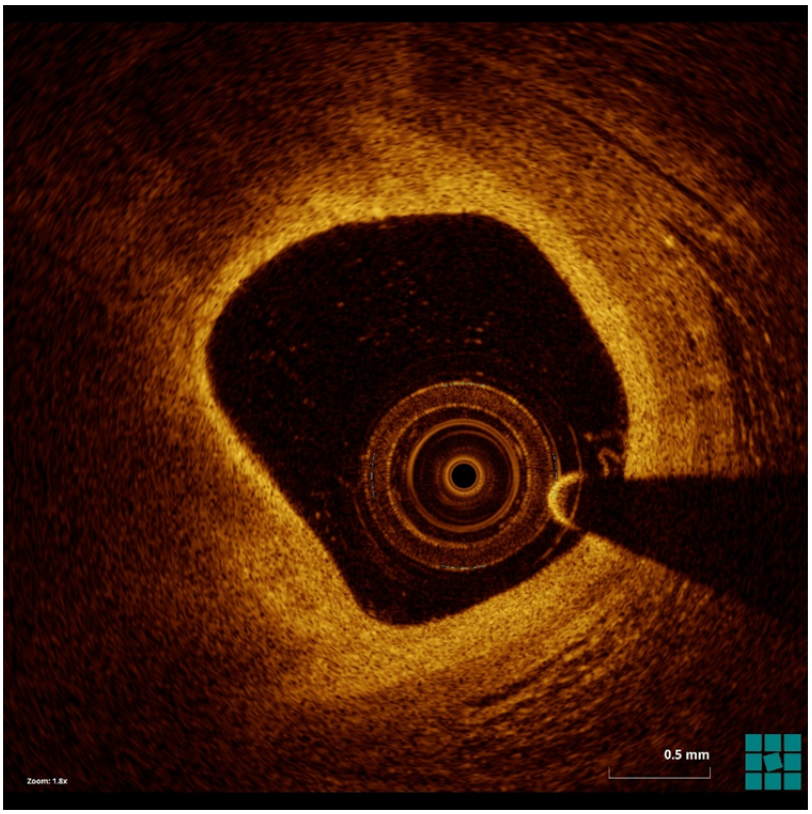


Figure. A

Lipid Rich Plaque

With Lipid Arc of 210°

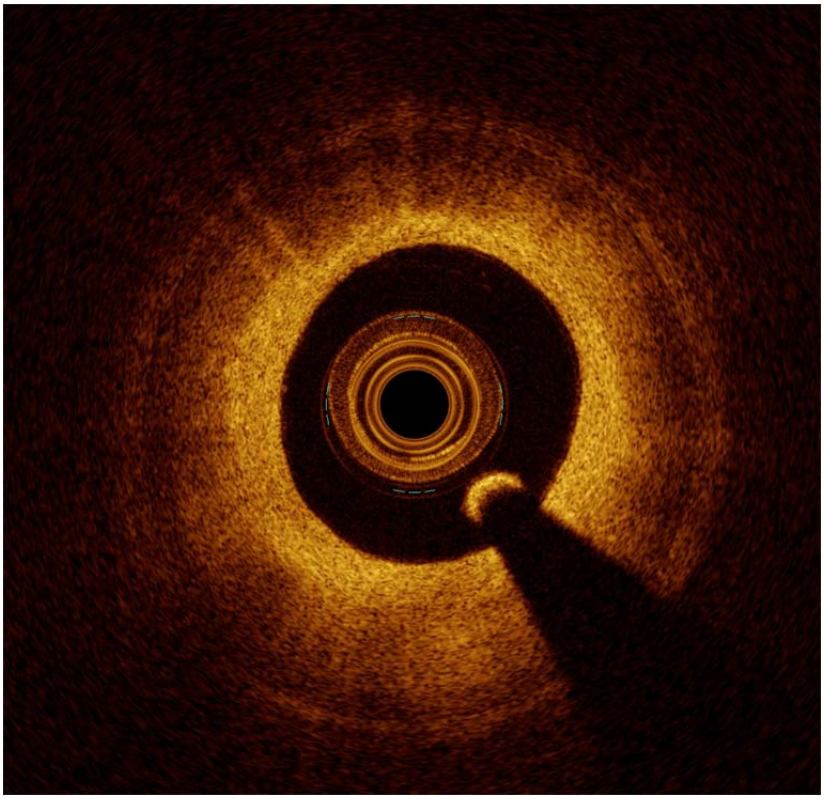


Figure. B

Fibro-fatty Plaque

With Arc of 360°

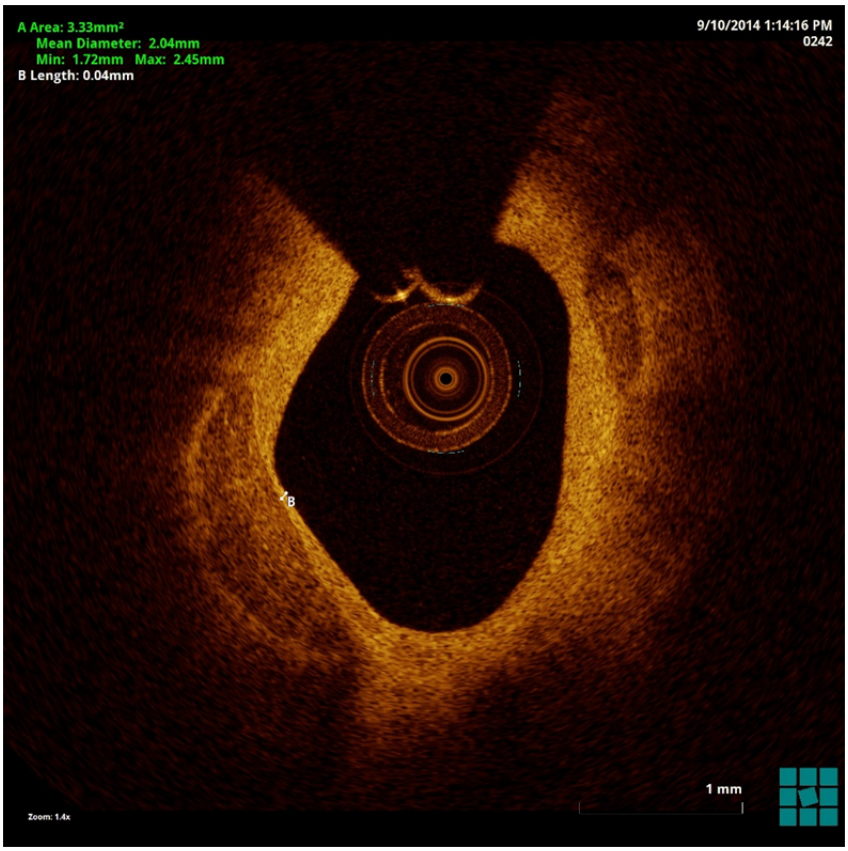


Figure. C

Fibro-Calcified Plaque

With Thin fibrous cap

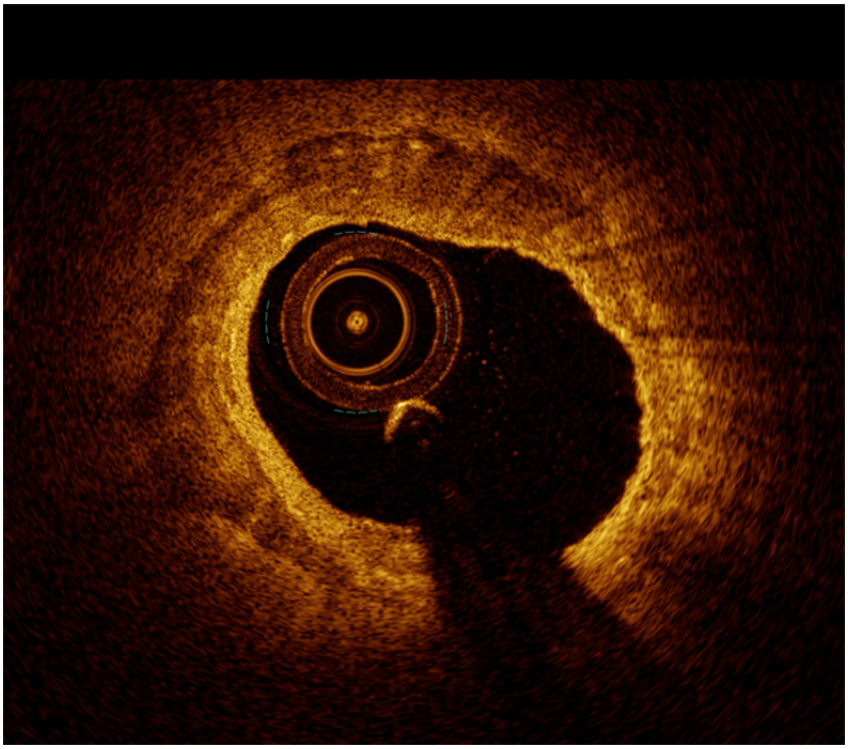


Figure. D

Calcific Plaque

Calcification Arc of 220°

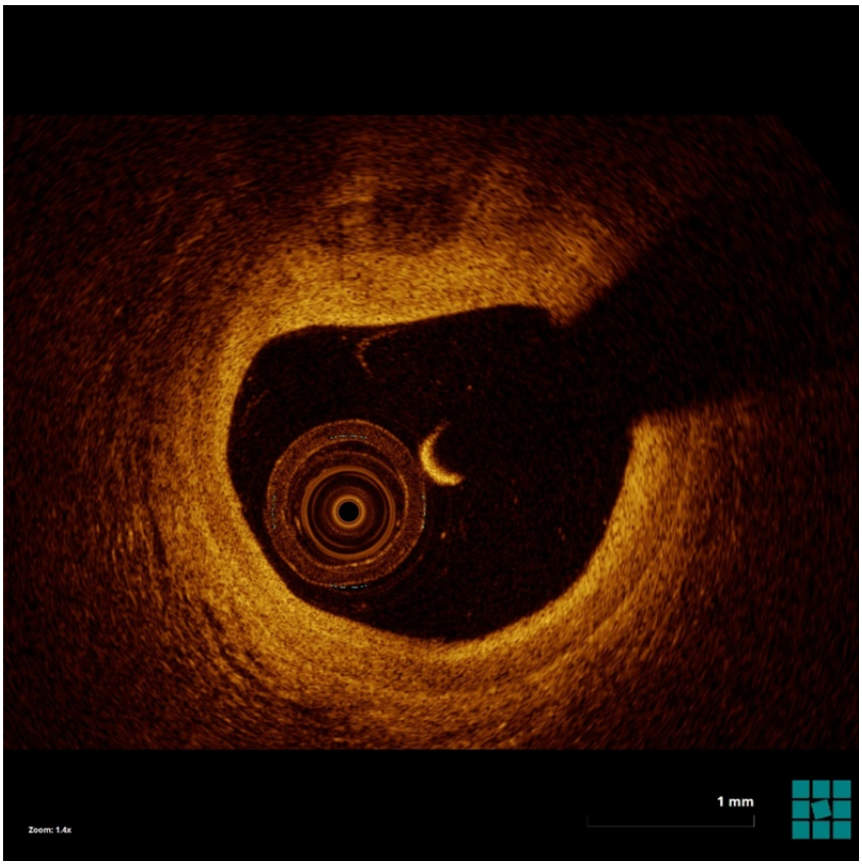


Figure. E

Thick cap Fibroatheroma

Fibrous cap Thickness: >60 µm

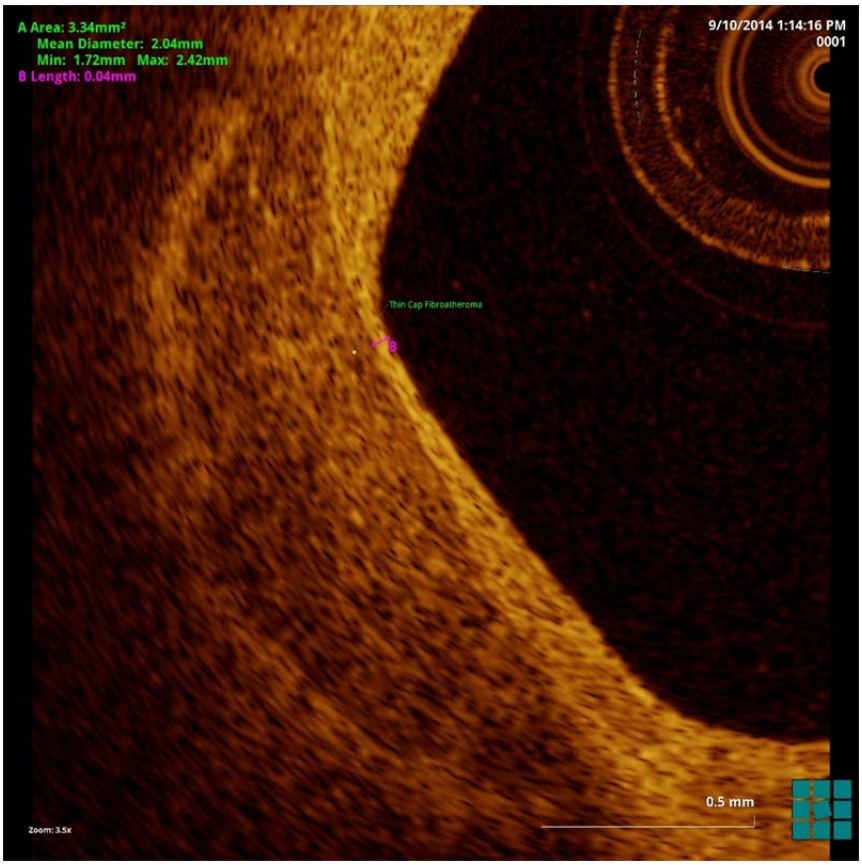


Figure. F

Thin cap Fibroatheroma (TCFA)

Fibrous cap thickness: 40 µm

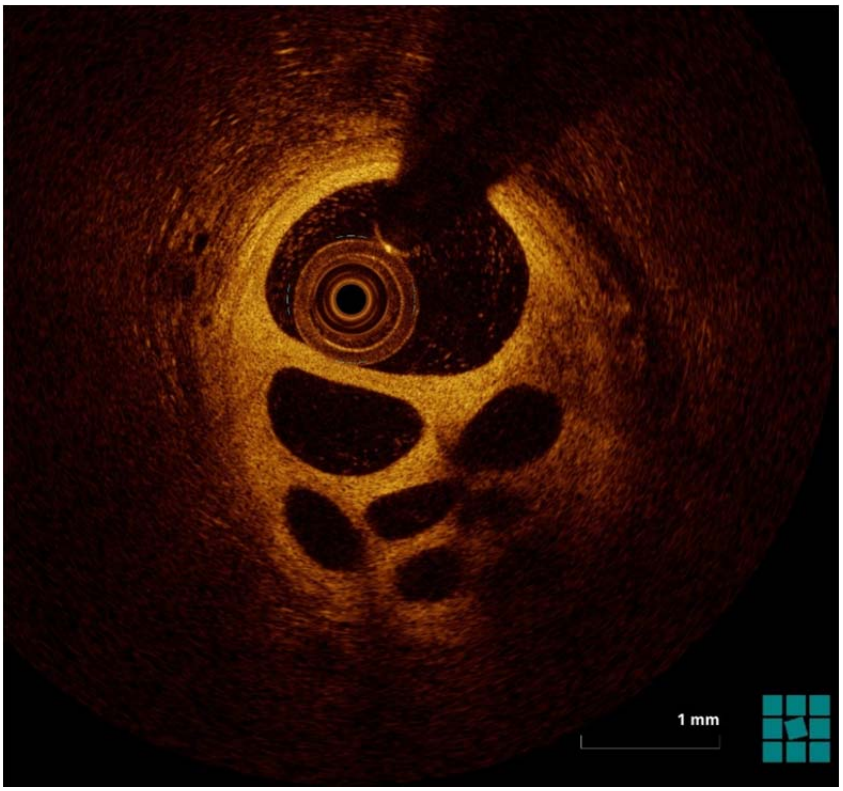


Figure. G

Spontaneous Coronary Artery Dissection (SCAD)

Classical "Lotus-Root" appearance On Optical Coherence Tomography

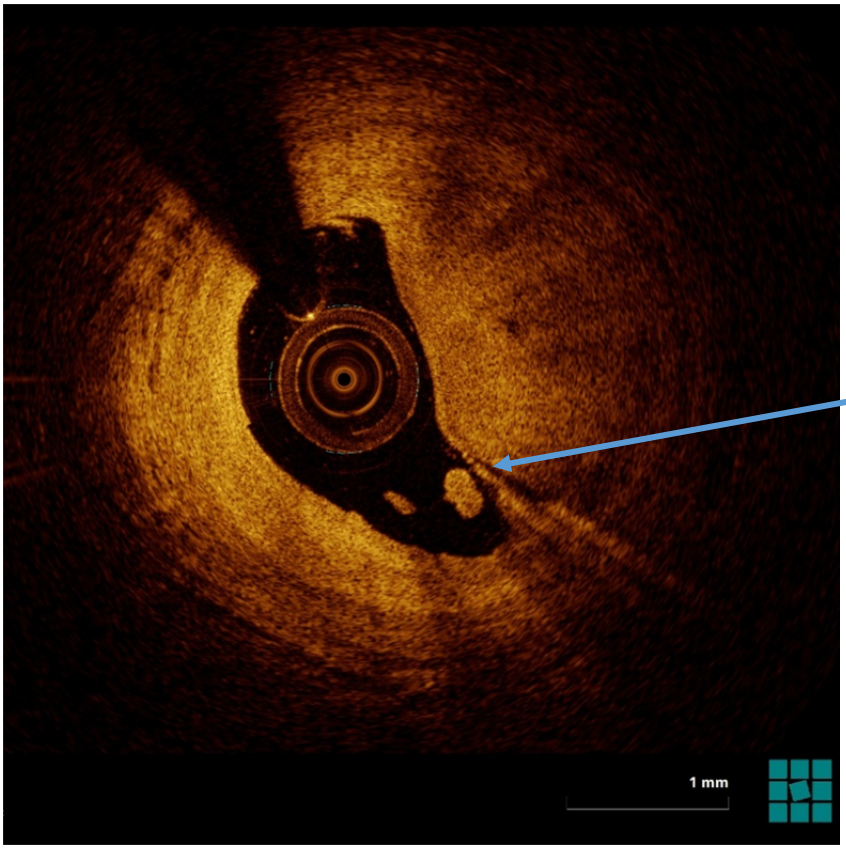


Figure. H

White Thrombus

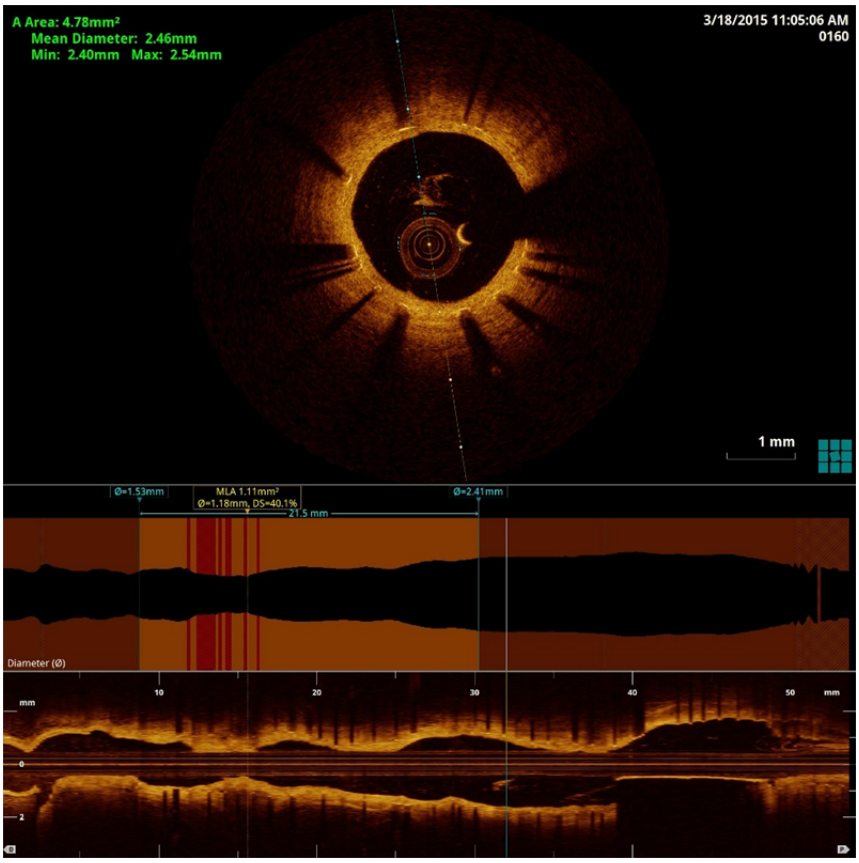


Figure. I

Mild Neointimal Hyperplasia (NIH)

All stent struts are covered (Endothelialized)

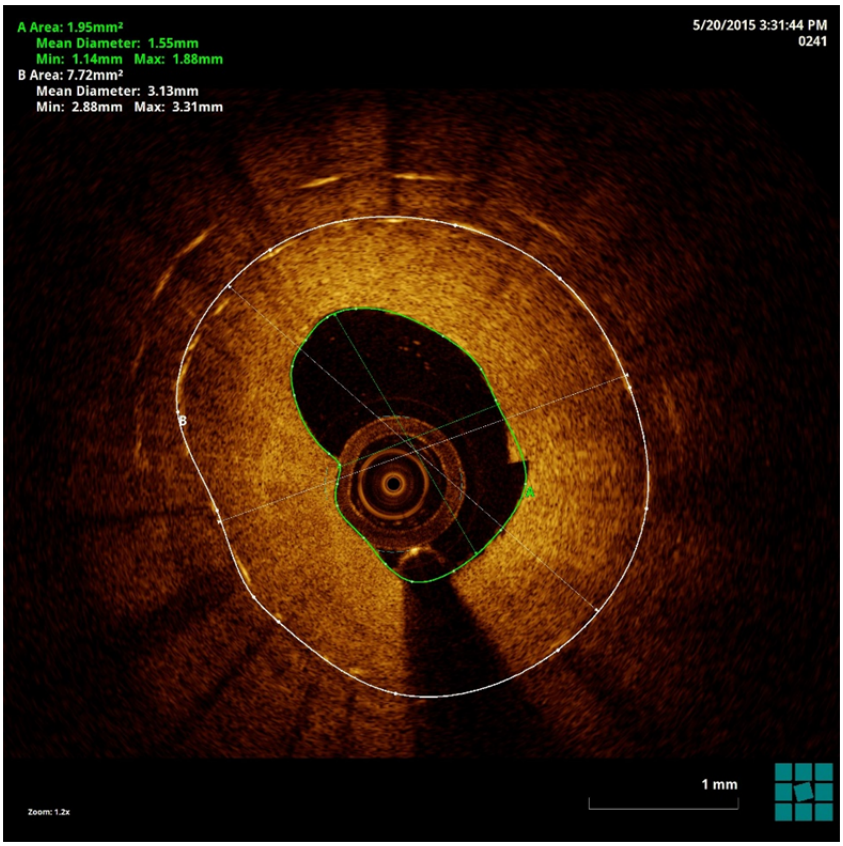


Figure. J

Homogeneous Neointimal Hyperplasia (NIH)

Neointimal Tissue area (NIT)
= 7.72-1.95
= 5.77 mm^2

Percent burden of NIT
= 5.77/7.72 X100 = 75%

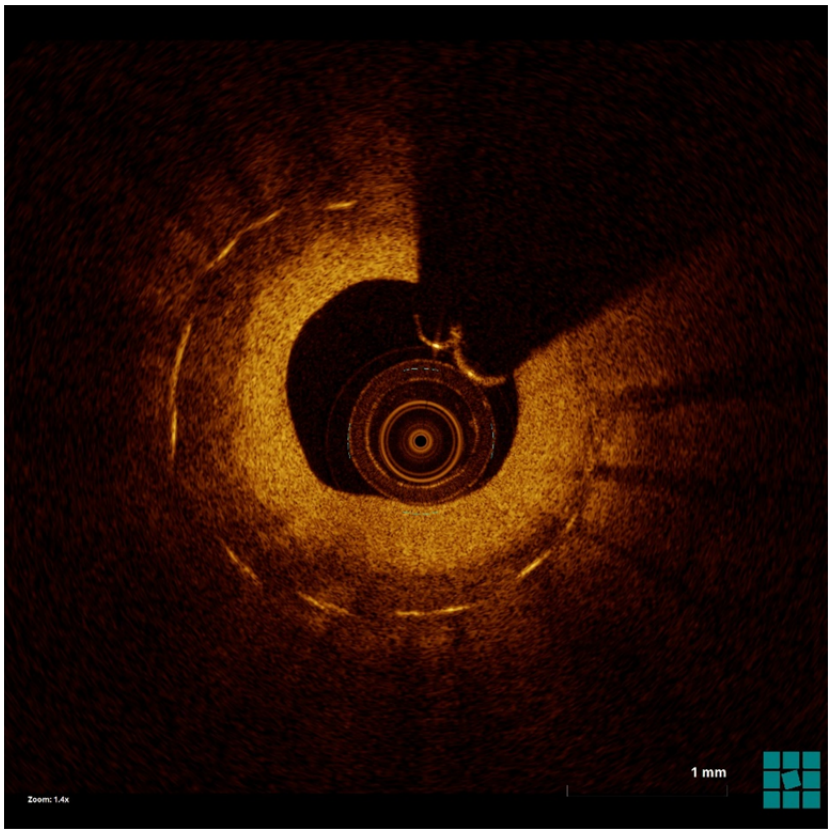


Figure. K

Layered Neointimal Hyperplasia (NIH)

Adluminal layer: High backscattering
Abluminal layer: Low backscattering

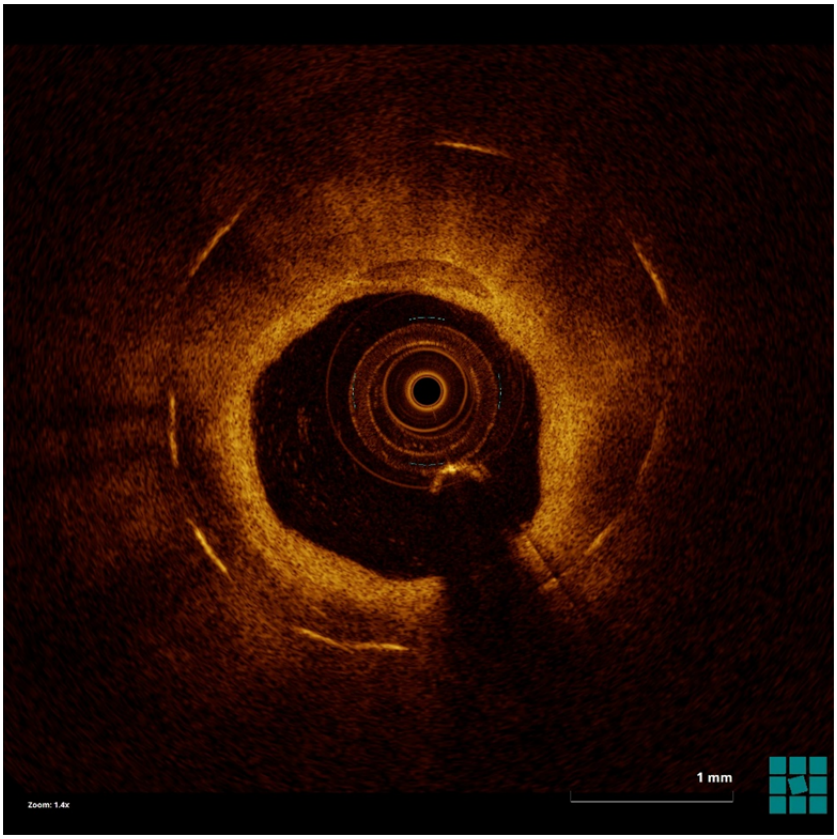


Figure. L

Heterogeneous Neointimal Hyperplasia (NIH)

Fibro-fatty tissue with calcification

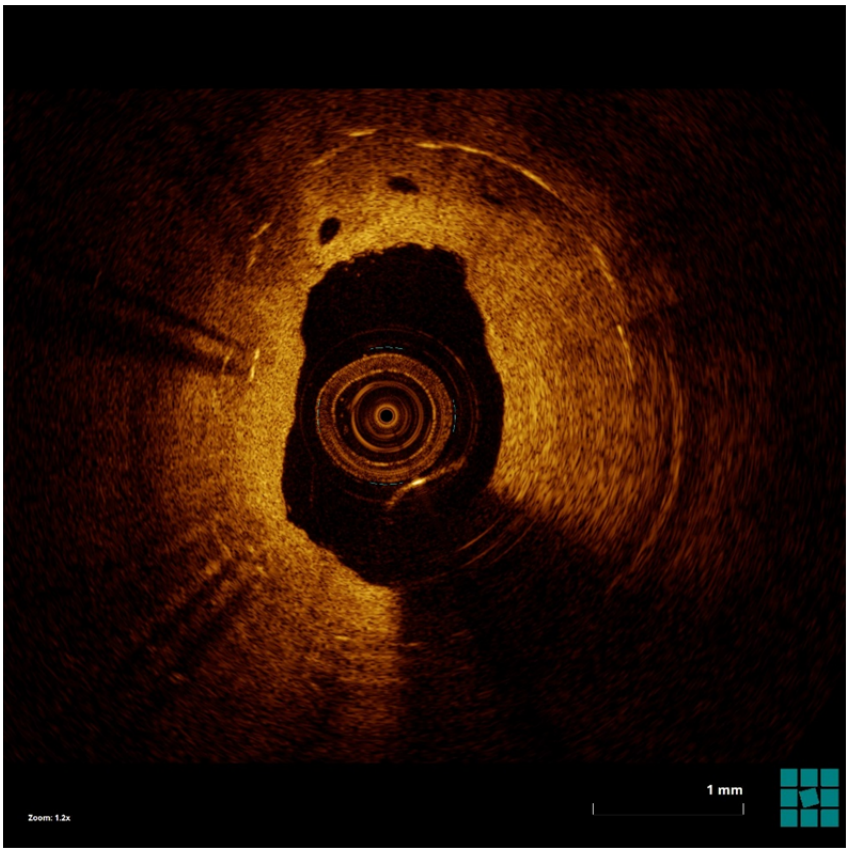


Figure. M

Micro-vessels in Neointimal tissue

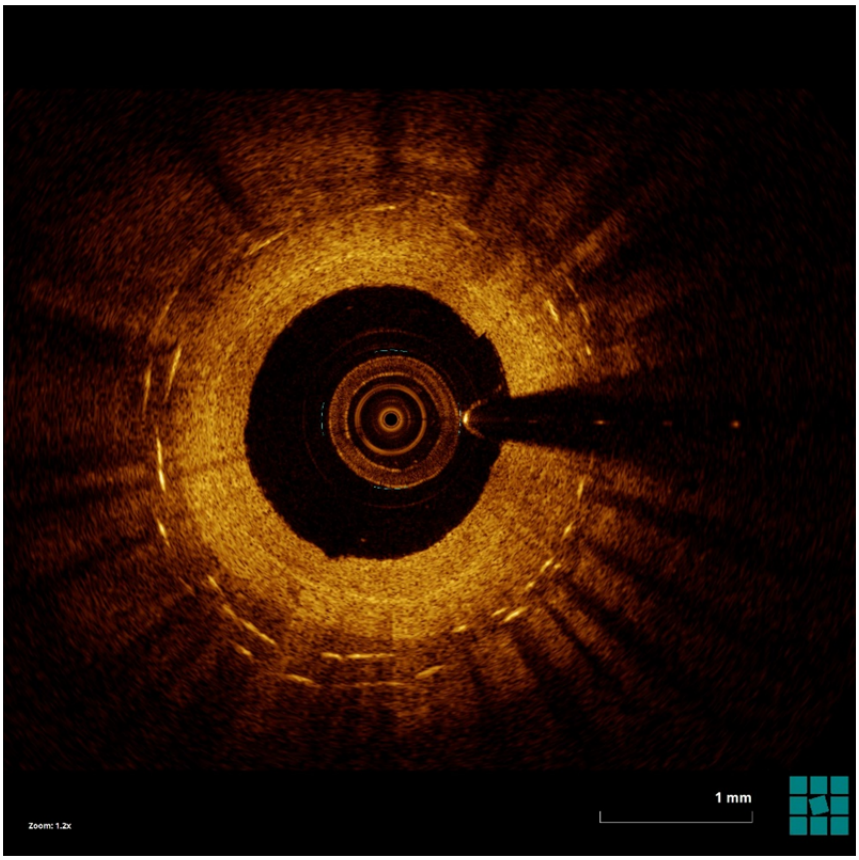


Figure. N

High Backscattering Neointimal Tissue

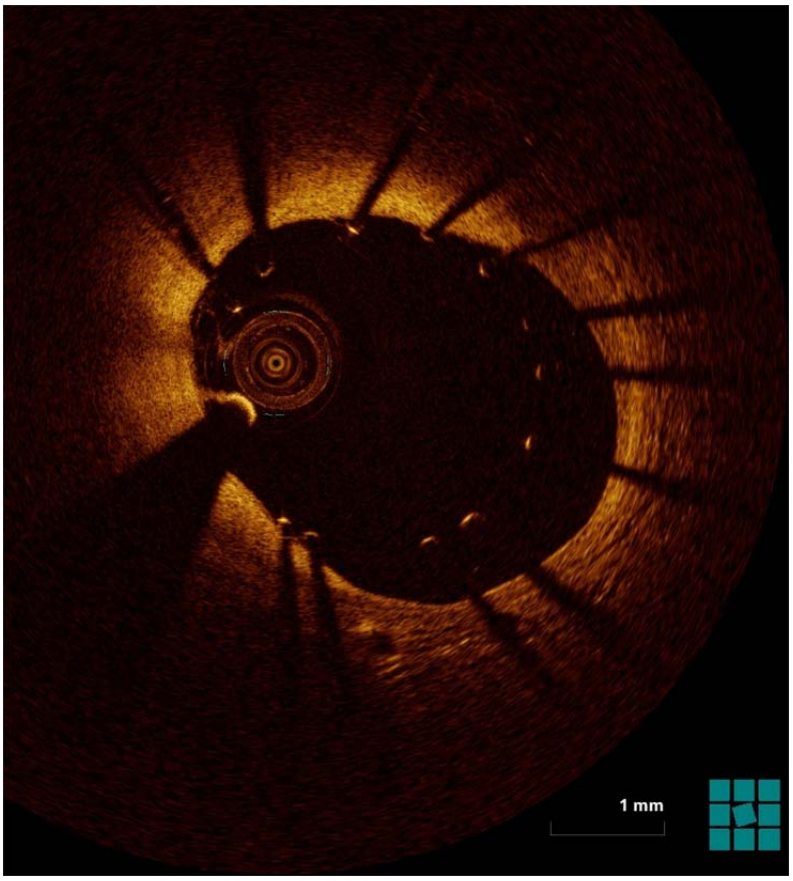


Figure. O

Malapposition of Stent struts

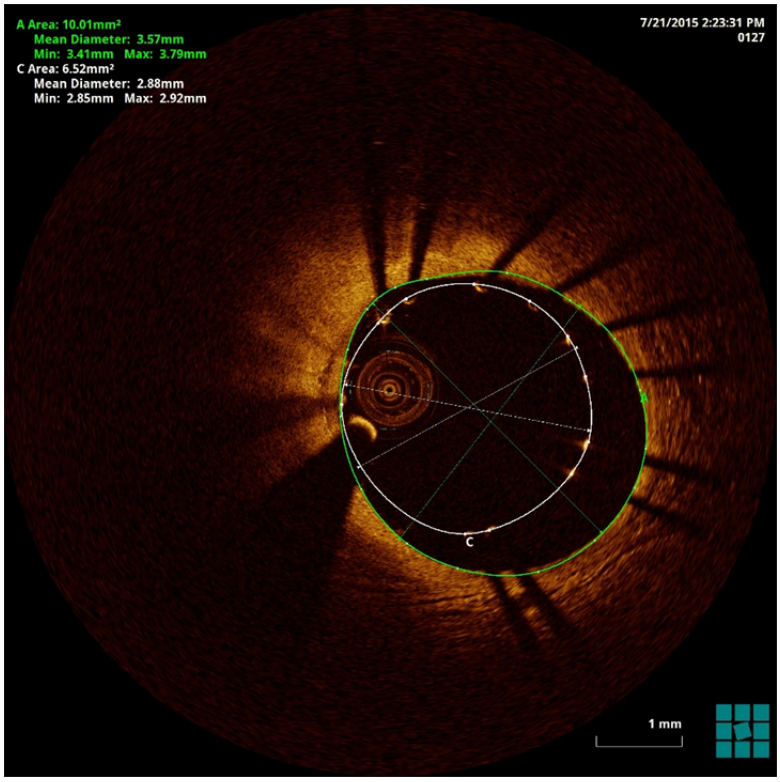


Figure. P

Malapposition of Stent struts

Malapposition area
= 10.01-6.52
= 3.49 mm^2

Percent Malapposition area = 3.49/10.01 X100 = 35%

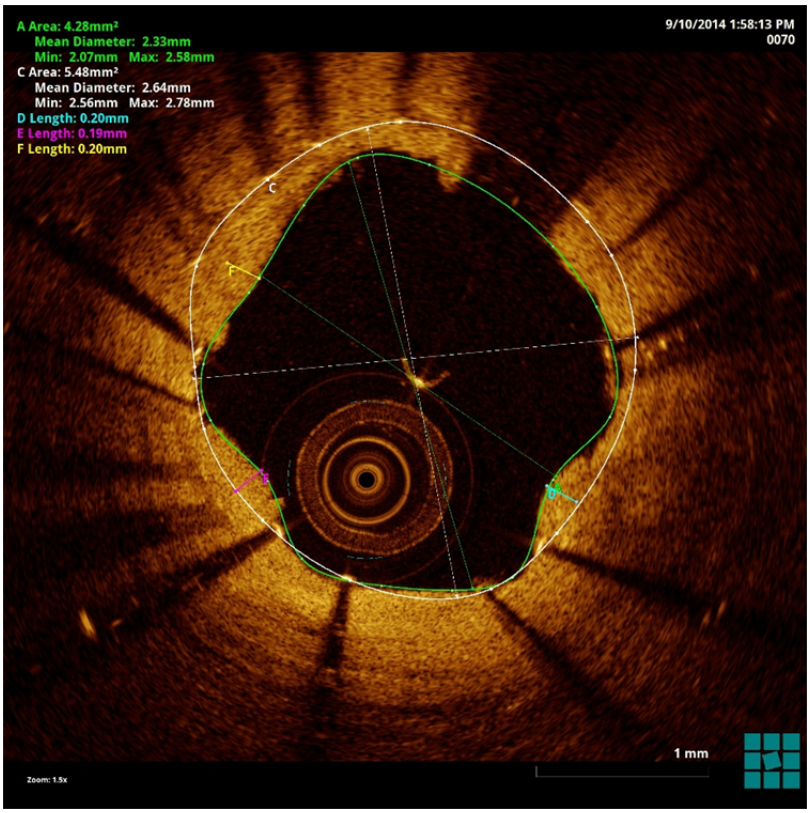


Figure. Q

Tissue prolapse

Tissue prolapse area
= 5.48-4.28
= 1.20 mm^2

Percent Tissue prolapse area
= 1.20/5.48 X100
= 22%

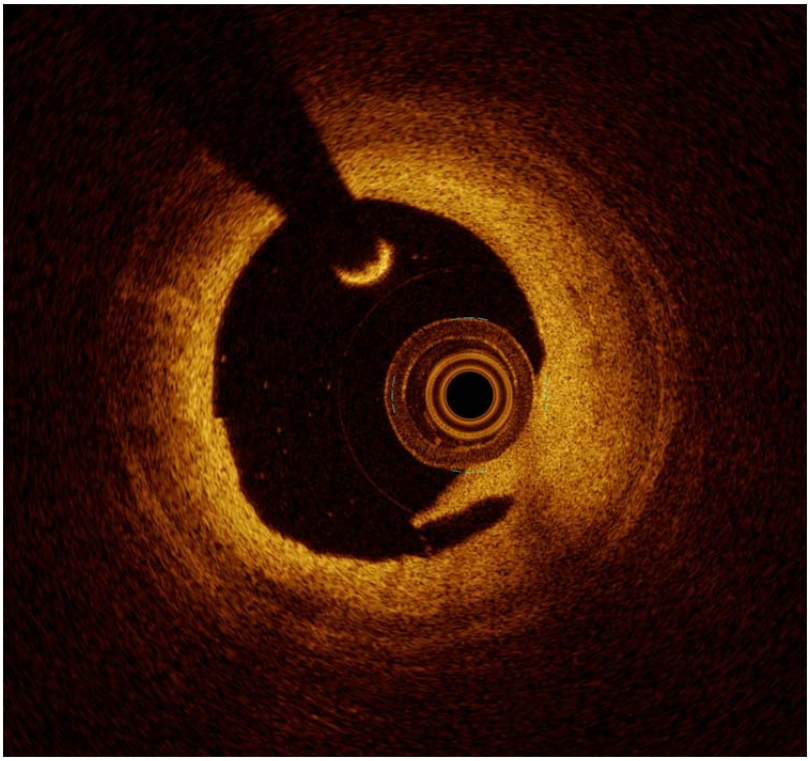


Figure. R

Edge Dissection

Dissection depth involving intima only

Edge dissection Arc of ≈35°

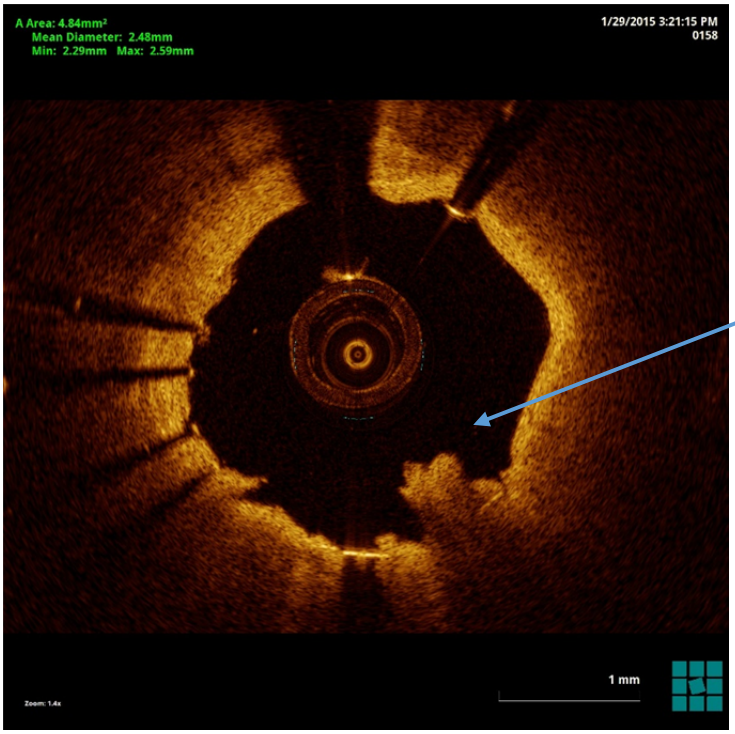


Figure. S

Red Thrombus

****Note: "All the Optical coherence tomography images shown here are taken from my Thesis patient's OCT DICOM data".**

DISCUSSION

Prevalence of ischemic heart disease is increasing very dramatically. Chronic stable angina is a large group among this patients. Our study predominantly represents male patient with age of more than 50 years presented to us with chronic stable angina. Prevalence of risk factors like hypertension, diabetes, dyslipidaemia and smoking was very high. Many of the patient underwent coronary angiography to look for coronary stenotic lesion. Patient will traditionally underwent angiography guided percutaneous coronary intervention (PCI). Limitations of angiography is well documented especially for assessment of plaque characteristic, exact vessel wall dimension, assessing complex lesion, assessing instent restenotic lesions, detection of underexpansion, malapposition, tissue prolapse, edge dissection and instent thrombus. OCT has resolution of 10-20 μm which is very high compared to conventional angiography & 10 time higher compared to IVUS. Previous studies have demonstrated that OCT can be safely performed in CAD patients to assess coronary lesion and to guide PCI.[11] Most of the published study on utilization of OCT for plaque assessment and PCI optimization has been performed in western part of world including European and north American countries. Very limited published data is available from India regarding use of OCT for guiding

PCI.[16] Our study is a retrospective study in which patient underwent angiographic assessment of coronary lesion followed by OCT evaluation of coronary lesion. It is seen that OCT evaluation gives better idea about lesion length and better in identifying relatively disease free reference segment which can be used as landing zone for stent edges. Previous studies have demonstrated that implantation of stent edge in lipid rich plaque is associated with high risk of stent edge restenosis with higher MACE events and by avoiding landing of a stent edge within a TCFA or calcified plaque reduces the rate of edge dissection.[45,46,47,48,49,50] In our study population which contains Indian patient, we detected fibro-fatty plaque as the most common plaque type and all plaque are lipid rich with diffuse involvement of coronary vessel, and because of diffuse nature of disease EEM (external elastic lamina) visibility at reference segment was very poor and only few patients were having optimal visibility of EEM to decide upon stent sizing according to it. Prevalence of thin cap fibroatheroma (TCFA) & spotty calcification was very common and was seen in almost two third of the patients suggestive of very high prevalence of vulnerable plaque. Previous studies have demonstrated that TCFA, spotty calcification with lipid rich plaque is associated with more MACE events and so are characteristic features suggestive of plaque vulnerability.[51,52,53,54,55,56,57,58] Previous studies have shown that OCT is a better modality for assessment of Instent

restenosis (ISR) lesions especially to identify mechanism of stent failure.[59] Previous studies have demonstrated that stent underexpansion is one of the risk factor for stent restenosis and stent malapposition is associated with higher prevalence of uncovered stent struts on follow-up and uncovered stent struts are likely to be associated with risk of stent thrombosis.[60,61,62,63] In our study we have one third of the patients with ISR lesions, who underwent OCT guided PCI. It was noticed that underexpanded stent was seen in most of the patient with ISR lesions. Neointimal tissue proliferation was diffuse in nature involving intra stent segment as well as extending outside the stent with involvement of reference segments. NIH tissue structure was showing mainly three types with Layered structure as most common followed by heterogeneous and homogeneous tissue. Previous studies have demonstrated that heterogeneity of tissue structure is because of different component of tissue like lipids, proteoglycans rich tissue, calcium, thrombus, features suggestive of neoatheroslerosis.[17] Nearly two third of ISR lesion were showing microvessel in NIH tissue suggestive of neovascularization of ISR plaque which is one of the feature demonstrated to be associated with plaque vulnerability in previous studies.[17,41,42] Previous studies have demonstrated that MACE had occurred more frequently in stents with heterogeneous neointima compared to non-heterogeneous

neointima.[43] Homogeneous neointima is associated with greater subsequent regrowth of NIH tissue at follow-up OCT.[44]

Drug eluting stent were used in all patients with everolimus, sirolimus and zotarolimus mainly. Stent length and diameter were selected based on OCT & angiography parameters. Suboptimal stent deployment in form of stent underexpansion, stent malapposition, tissue prolapse, Edge dissection and thrombus was detected more commonly by OCT imaging in compared to conventional angiography. ILUMIEN I study shown that optical coherence tomography detected suboptimal stent deployment parameters like malapposition, under-expansion, edge dissection and prompted further stent optimization based on OCT in 25% of patients using additional in-stent post-dilatation (81%) or placement of additional stents (12%).[13] ILUMIEN II study shown that due to higher detection of suboptimal stent deployment parameters by the use of OCT in comparison to IVUS, leading to additional intervention in form of additional stent implantation.[14] CLI-OPCI I study has shown that OCT evaluation leads to more detection of suboptimal stent deployment parameters like Stent malapposition in 30%, Stent underexpansion in 12%, Edge dissection in 14% leading to additional intervention in 35% of patients (additional stenting in 13% & additional stenting in 22%).[11] CLI-OPCI II study have shown that post-PCI OCT parameters in particular, in-stent minimum lumen

area <4.5 mm^2, dissection >200 μm at the distal stent edge and reference lumen area <4.5 mm^2 at either distal or proximal stent edges are independent predictors of MACE.[12] ILUMIEN III study has also shown that higher resolution of Optical coherence tomography confers greater sensitivity for detection of post-PCI dissection, malapposition, tissue prolapse, thrombus and underexpansion in comparison to conventional angiography leading to more additional intervention inform of additional balloon post-dilatation or additional stenting for optimization of stent deployment.[15] In our study post-PCI OCT evaluation detected Edge dissection in 22%, Stent underexpansion in 82%, Malapposition in 39% and Tissue prolapse in 53% patients whereas Conventional angiography detected same things in 8%, 16%, 0% and 4% respectively. In our study additional interventional was performed in 72% patients including additional balloon post-dilatation in 68% and additional stent implantation in 4% patients for optimization of PCI end results. Post PCI troponin T was performed and it was negative in 68% of patients. Eight (32%) patients were having marginally elevated troponins without symptoms or ECG changes and troponin values were below the 5 times of upper limit of normal, so overall Periprocedural MI rate was zero. All patient were prescribed aspirin, thienopyridine, Statins, beta-blockers on discharge, so all patient were given optimal medical therapy on discharge

and Dual antiplatelet therapy (DAPT) was continued for at least 12 months post-PCI in all patients.

ILUMIEN III study has shown the MACE event rate of 3% at 30 days which includes MI in 1%, stent thrombosis in 1%, ischemia driven target lesion revascularisation in 1%. No death were observed at 30 days follow-up.[15] Clinical outcome data available at 30 days only, no long term follow-up data.[15] CLI-OPCI I study has shown that OCT guided PCI had lower 1-year risk of cardiac death (1.2% vs 4.5%, p=0.010), cardiac death or MI (6.6% vs 13%, p=0.006), Composite of cardiac death, MI or repeat revascularisation (9.6% vs 14.8%, p=0.044) in comparison to angiography only guided PCI.[11] CLI-OPCI II study has shown that suboptimal stent deployment is associated with significantly higher MACE events at 1-year of follow-up (59.2% vs 26.9%, p<0.001) in comparison to patients with optimal stent deployment and it is an independent predictor of worse outcome (HR=3.53, p<0.001).[12] In our study we have follow-up data of 92% of study population with mean follow-up duration of 18.9 months which ranges from 7 to 32 months. On follow-up evaluation 12 patients were having mild symptoms which responded to optimization of medical therapy. MACE events including Death from any cause, Cardiac death, Any MI, Target vessel MI, Target lesion MI, Stent thrombosis, Target lesion revascularisation and CV strokes were studied on follow-up visits. On mean

follow-up of 18.9 months (median follow-up duration of 19 months) zero MACE were recorded. Small sample size and OCT guided optimization of PCI may be the reason for not getting any MACE recorded on follow-up. Large scale, multi-centre, randomized controlled trials with long term follow-up will be required to prove superiority of OCT guided PCI over angiography only guided PCI in terms of reducing major adverse cardiac events.

LIMITATIONS

1. Retrospective observational study
2. Non randomized
3. Single centre
4. Small number of patients
5. Statistically not powered enough for demonstrating clinical outcome difference
6. No head to head comparison between conventional angiography guided PCI vs OCT guided PCI
7. All patient had not undergone pre-PCI OCT evaluation
8. Repeat OCT evaluation was not performed after additional intervention
9. Only chronic stable angina patients were included in our study
10. Long term clinical follow-up is not available

CONCLUSIONS

1. OCT helps in assessing coronary plaque composition
2. Assessment of coronary vessel dimension and acute vessel wall effects during PCI can be performed more accurately by OCT
3. OCT is more sensitive and accurate for detection of stent malapposition, stent underexpansion, tissue prolapse and edge dissection compared to conventional angiography only.
4. OCT evaluation of In-stent restenosis lesions helps in identifying mechanism of stent failure especially stent underexpansion
5. Post PCI OCT evaluation helped in identifying suboptimal stent deployment leading to additional intervention for optimizing stent deployment
6. Optical coherence tomography (OCT) helps in assessing stenotic lesion characteristics during PCI and in optimization of PCI result
7. OCT guidance during PCI may have helped in improving short term clinical outcome
8. Large randomized trials will be required to prove superiority of OCT guided PCI over conventional angiography only guided PCI in terms of reducing major adverse cardiac events.

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ABBREVIATIONS

ACS	-	Acute coronary syndrome
ACE-I	-	Angiotensin converting enzyme inhibitor
ARB	-	Angiotensin receptor blocker
Atm	-	Atmosphere
ARC	-	Academic Research Consortium
BMI	-	Body mass index
BB	-	Beta blocker
BMS	-	Bare metal stent
BVS	-	Bio vascular scaffold
CVD	-	Cardiovascular diseases
CAD	-	Coronary Artery disease
CT Ratio	-	Cardiothoracic ratio
CSA	-	Chronic stable angina
CABG	-	Coronary artery bypass grafting
CKD	-	Chronic kidney disease
CCB	-	Calcium channel blocker
CTO	-	Chronic total occlusion

DALYs	-	Disability adjusted life years
DES	-	Drug eluting stent
DEB	-	Drug eluting balloon
DICOM	-	Digital Imaging and Communications in Medicine
DS	-	Diameter stenosis
EES	-	Everolimus eluting stent
ECG	-	Electrocardiography
EEM	-	External elastic membrane
FD-OCT	-	Frequency-domain OCT
FFR	-	Fractional flow reserve
HR	-	Hazard ratio
IHD	-	Ischemic heart disease-
ISR	-	In-stent restenosis
IMH	-	Intramural hematoma
IVUS	-	Intravascular ultrasonography
LAD	-	Left anterior descending artery
LCX	-	Left circumflex coronary artery
LVEF	-	Left ventricular ejection fraction
MLA	-	Minimal lumen area

MACE	-	Major adverse cardiac events
MI	-	Myocardial infarction
MR	-	Mitral regurgitation
MSA	-	Minimal stent area
NYHA	-	New York Heart Association
NSTEMI	-	Non ST elevation myocardial infarction
OCT	-	Optical coherence tomography
OPD	-	Outpatient department
PCI	-	Percutaneous coronary intervention
PAH	-	Pulmonary artery hypertension
QCA	-	Quantitative coronary angiography
RWMA	-	Regional wall motion abnormalities
RCA	-	Right coronary artery
SIHD	-	Stable ischemic heart disease
SD	-	Standard deviation
ST	-	Stent thrombosis
STEMI	-	ST elevation myocardial infarction
SCAD	-	Spontaneous coronary artery dissection

SYNTAX	-	Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery
TLR	-	Target Lesion Revascularization
TVR	-	Target vessel Revascularization
TIMI	-	Thrombolysis in MI
TCFA	-	Thin cap fibroatheroma
TD-OCT	-	Time-domain OCT
UA	-	Unstable angina
3D	-	Three dimensional

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

Institutional Ethics Committee
(IEC Regn No. ECR/189/Inst/KL/2013)

SCT/IEC/1003/DECEMBER-2016 03.07.2017

Dr. Hiren Tulsibhai Kevadiya
Resident
Department of Cardiology
SCTIMST, Thiruvananthapuram

Dear Dr. Hiren Tulsibhai Kevadiya,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "ANALYSIS OF INTRACORONARY OPTICAL COHERENCE TOMOGRAPHY (OCT) PARAMETERS DURING PERCUTANEOUS CORONARY INTERVENTION (PCI) IN STABLE ISCHEMIC HEART DISEASES" (IEC/1003) on 17th December, 2016.

The following documents were reviewed:

Original submission

1. *Covering letter addressed to the Chairman, IEC, SCTIMST, dated 23.11.2016 with check list*
2. *Forwarding letter from HOD, Department of Cardiology, dated 23.11.2016*
3. *TAC Approval Letter*
4. *IEC Application Form*
5. *Project Proposal*
6. *Proforma*
7. *Patient Information Sheet and Informed Consent Form in English and Malayalam*
8. *CV of Principal Investigator and Co- Investigators*

Revised submission

1. *Covering letter addressed to the Chairperson, IEC, SCTIMST, dated 19.06.2017 with check list*
2. *Forwarding letter from HOD, Department of Cardiology, dated 19.06.2017*
3. *TAC Approval Letter*
4. *IEC Application Form*
5. *Project Proposal*
6. *Proforma*
7. *Patient Information Sheet and Informed Consent Form in English and Malayalam*
8. *The Telephonic script in English and Malayalam*
9. *CV of Principal Investigator and Co- Investigators*

The following members of the Ethics Committee were present at the meeting held on 17th December, 2016 at G. Parthasarathi Board Room, AMCHSS, SCTIMST

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Justice Gopinathan. P.S	BSc. LLB	Male	Legal Expert (Chairperson)	No
2.	Dr. Harikrishna Varma PR	PhD	Male	Biomedical Scientist	Yes
3.	Dr. Meenu Hariharan	DM	Female	Clinician (Gastro-Enterologist)	No
4.	Dr. Rema M. N	MD	Female	Pharmacologist	No
5.	Dr. R V G Menon	PhD	Male	Lay Person	No
6.	Smt. Sathi Nair	MA	Female	Lay Person	No
7.	Dr. K R S Krishnan	ME, PhD	Male	Biomedical Scientist/Engineer	No
8.	Dr. Kala Kesavan. P	MD	Female	Pharmacologist	No
9.	Dr. Christina George	MD	Female	Psychiatrist	No
10.	Dr. P. Manickam	PhD	Male	Scientist - Epidemiologist	No
11.	Dr. Mala Ramanathan	MSc, PhD, MA	Female	Ethicist/Social Scientist (Member Secretary)	Yes

IEC Decision

The IEC approved the conduct of the study in the present form.

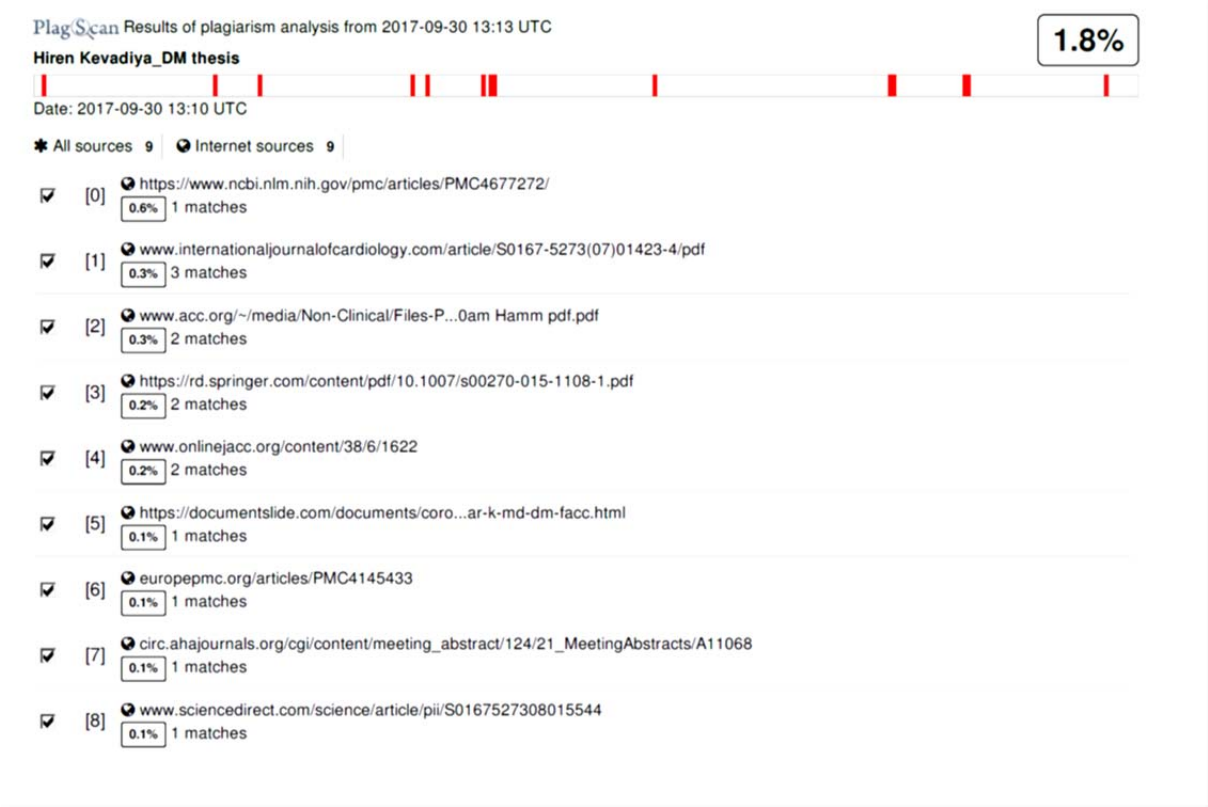
Remarks:
The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,

Mala Ramanathan
Member Secretary, IEC

Plagiarism Certificate



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