Review Article

Rotational Atherectomy (Rotablator) in Complex Calcified Coronary Lesions: Current Evidence and Clinical Applications

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Abstract

Rotational atherectomy is a fundamental tool in the management of complex calcified coronary lesions, particularly in cases in which conventional balloon angioplasty is insufficient. These lesions, which are common in older patients and in those with comorbidities such as diabetes mellitus, chronic kidney disease, hypertension, and dyslipidemia, are associated with greater anatomical complexity, reduced vascular compliance, difficulty achieving adequate stent expansion, and poorer clinical outcomes. The pathophysiology of coronary calcification involves active processes such as osteogenic differentiation, inflammation, and metabolic disturbances, all of which have direct implications for lesion rigidity and the success of percutaneous coronary intervention. In this setting, assessment with intravascular imaging, particularly intravascular ultrasound and optical coherence tomography, is essential to characterize the distribution, depth, and severity of calcium and to guide the selection of plaque modification strategies. Rotational atherectomy works through differential ablation of calcified tissue and requires careful technical execution, including appropriate burr selection, controlled rotational speed, and adjunctive pharmacologic support. Available evidence demonstrates high procedural success rates, although the technique is also associated with a higher incidence of complications such as slow flow, no-reflow, coronary perforation, distal embolization, and burr entrapment. In contemporary practice, its integration with complementary techniques such as intravascular lithotripsy, together with the increasing use of imaging-guided algorithms, has expanded its utility in complex scenarios and reinforced its role within an increasingly individualized and technically precise interventional approach.

Key words

Rotational atherectomy, coronary calcification, percutaneous coronary intervention, plaque modification, intravascular imaging, stent expansion.

Introduction

Complex calcified coronary lesions are characterized by substantial calcium deposition within the coronary arteries and are frequently identified in patients with comorbid conditions such as diabetes mellitus and renal impairment [1]. In the setting of percutaneous coronary intervention, these lesions represent a major technical challenge because their rigidity and resistance to balloon expansion increase procedural difficulty and favor suboptimal stent deployment [2].

In this context, coronary calcification has been consistently associated with greater procedural complexity and worse clinical outcomes, including higher rates of in-stent thrombosis, target lesion revascularization, myocardial infarction, and death [1]. Furthermore, the presence of calcified lesions may lead to technical failure during percutaneous coronary intervention, particularly through inadequate stent expansion and incomplete stent apposition, both of which are essential determinants of long-term procedural success [3].

Conventional balloon angioplasty often fails to achieve adequate dilation in heavily calcified lesions, which contributes to incomplete stent expansion and, consequently, to a higher risk of restenosis [2]. In parallel, stent delivery is especially difficult in this setting because plaque rigidity may prevent the device from either reaching the target lesion or expanding appropriately once deployed [4].

For these reasons, plaque modification techniques have become particularly relevant in the treatment of severe coronary calcification. Rotational atherectomy is used to modify calcified plaque through calcium ablation, thereby increasing luminal area and facilitating both stent delivery and stent expansion [4]. Evidence has shown that the early use of rotational atherectomy can reduce procedural complications and improve technical success rates when compared with indirect rotational atherectomy or balloon predilatation [3]. Thus, rotational atherectomy is especially useful in cases in which conventional percutaneous coronary intervention techniques are insufficient, offering an effective strategy for the management of heavily calcified lesions and for improving patient outcomes [5].

The objective of this article is to review the clinical significance of complex calcified coronary lesions in percutaneous coronary intervention, with emphasis on their impact on procedural success and clinical outcomes, the limitations of conventional balloon angioplasty and stent delivery, and the rationale for the use of rotational atherectomy as a plaque modification strategy.

Methodology

This manuscript was developed as a structured narrative review aimed at providing an updated and clinically integrated analysis of rotational atherectomy in complex calcified coronary lesions, with particular emphasis on lesion assessment, procedural strategy, clinical outcomes, and complication management. The review was conducted in accordance with the SANRA (Scale for the Assessment of Narrative Review Articles) framework and followed a predefined methodological protocol established prior to literature screening. Given the clinical heterogeneity of calcified coronary disease, the variability in lesion morphology, intracoronary imaging findings, and plaque modification strategies, a narrative interpretative synthesis was selected over quantitative pooling to integrate pathophysiological, technical, and clinical considerations into a coherent and clinically applicable framework. Special attention was given to the pathophysiology of coronary calcification, the role of intravascular imaging in procedural planning, the technical principles of rotational atherectomy, comparative evidence with other plaque modification technologies, and the prevention and management of periprocedural complications. The objective was to provide a structured synthesis capable of supporting decision-making in the interventional treatment of heavily calcified coronary lesions.

A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science, including peer-reviewed articles published in English or Spanish between January 2020 and December 2025. The final search was performed in March 2026. This timeframe was selected to capture contemporary advances in plaque modification techniques, intracoronary imaging-guided intervention, device technology, and evolving evidence regarding clinical outcomes after rotational atherectomy. Foundational studies were incorporated when necessary to contextualize pathophysiological mechanisms, technical development, or the historical evolution of atherectomy in percutaneous coronary intervention. The search strategy combined MeSH and free-text terms using Boolean operators related to rotational atherectomy, Rotablator, coronary calcification, calcified coronary lesions, percutaneous coronary intervention, plaque modification, intravascular ultrasound, optical coherence tomography, stent expansion, procedural success, coronary complications, intravascular lithotripsy, orbital atherectomy, and clinical outcomes. Searches were conducted in titles and abstracts as well as indexed subject headings to maximize sensitivity.

The initial search yielded 192 records. After removal of duplicates, 138 articles remained for title and abstract screening. Of these, 77 underwent full-text evaluation, and 35 studies were included in the final synthesis. Selection was performed independently by two authors, with disagreements resolved through discussion and consensus. Exclusion criteria comprised non-peer-reviewed publications, isolated case reports, editorials without outcome data, purely technical reports lacking clinical relevance, redundant datasets, and studies not directly addressing lesion assessment, procedural strategy, outcomes, complications, or comparative effectiveness of rotational atherectomy in calcified coronary lesions.

Eligible studies included randomized controlled trials, large observational cohorts, systematic reviews, meta-analyses, expert consensus statements, and contemporary international guidelines from interventional cardiology and cardiovascular imaging societies. Priority was assigned to multicenter investigations, studies with standardized definitions of severe coronary calcification, and research evaluating procedural success, stent expansion, periprocedural complications, and short- and long-term clinical outcomes. Extracted variables included study design, patient risk profile, lesion characteristics, imaging findings, rotational atherectomy technique, adjunctive devices or therapies, procedural success rates, complications, and clinical outcomes including restenosis, target lesion revascularization, myocardial infarction, and mortality. Methodological quality and internal validity were assessed narratively, considering risk of bias, sample size, follow-up duration, consistency of calcification definitions, and reproducibility of reported outcomes. In cases of conflicting evidence, greater interpretative weight was assigned to higher-level evidence and guideline-supported recommendations.

Reference lists of included studies were manually screened to identify additional relevant publications. Given its narrative design, this review is subject to potential selection bias and does not provide pooled quantitative estimates. Artificial intelligence-based tools were used exclusively to assist in literature organization and structural coherence, whereas critical appraisal, synthesis, and final interpretation were conducted independently by the authors to preserve methodological rigor.

Pathophysiology of Coronary Calcification

Vascular calcification is a complex and active biological process driven by multiple interacting mechanisms. Among these, osteogenic differentiation plays a central role, as vascular smooth muscle cells may acquire an osteoblast-like phenotype and contribute directly to calcium deposition within the arterial wall. This process resembles bone formation and is mediated by factors such as bone morphogenetic proteins and osteopontin [12]. In parallel, inflammation is particularly relevant during the early stages of calcification, since inflammatory cytokines promote both calcium deposition and plaque vulnerability [13]. Metabolic factors also contribute substantially to this process, especially in patients with disorders such as diabetes mellitus and renal impairment, in whom altered calcium-phosphate metabolism is associated with increased coronary calcification [1].

From a pathological standpoint, it is important to distinguish between intimal and medial calcification, as each has different clinical and procedural implications. Intimal calcification is typically associated with atherosclerotic plaques and is closely linked to lipid accumulation and inflammation, thereby contributing to plaque instability. In contrast, medial calcification is more commonly observed in patients with chronic kidney disease and primarily affects the elasticity of the arterial wall, with a lesser association with plaque rupture [12].

The distribution of calcium within the vessel wall also has major implications for lesion preparation. Superficial calcium is generally easier to modify with techniques such as rotational atherectomy and can therefore be managed more effectively to improve subsequent stent expansion. By contrast, deep calcium is more difficult to treat and may require more advanced plaque modification strategies, including intravascular lithotripsy, in order to achieve adequate lesion preparation [13].

These calcific changes have direct consequences on arterial mechanics and procedural success. Calcification reduces arterial compliance, making optimal stent expansion more difficult and increasing the risk of stent thrombosis [13]. At the same time, the increased rigidity of the lesion often necessitates the use of atherectomy devices to modify the plaque and facilitate stent delivery and deployment [13]. In this regard, adequate lesion preparation is essential for achieving proper stent expansion, and techniques such as rotational atherectomy have been shown to improve outcomes by modifying calcified lesions before stent implantation [16, 17].

The overall burden of calcification is closely related to adverse outcomes. A greater calcification burden is associated with increased procedural complexity, lower procedural success, and higher rates of major adverse cardiovascular events [1, 17]. In addition, rotational atherectomy has been associated with higher long-term risks of major adverse cardiovascular events and mortality, which underscores the importance of careful patient selection and thorough procedural planning [9].

Lesion Assessment and Imaging Modalities

Angiographic assessment provides the first clues suggestive of severe coronary calcification, particularly in the presence of lesion length, bifurcation involvement, vessel tortuosity, and marked vessel calcification, all of which have been identified as significant predictors of the potential need for rotational atherectomy [18]. In this context, severe calcification is often recognized angiographically by radiopaque densities that are visible even in the absence of cardiac motion, reflecting the presence of substantial calcium deposits [19].

However, despite its routine use in percutaneous coronary intervention, angiography alone has important limitations for calcium assessment. Because it provides only a two-dimensional view of the vessel, it cannot adequately determine the depth or circumferential distribution of calcium [19]. As a result, angiography may underestimate the true severity of calcification, which can lead to suboptimal procedural planning and device selection [20].

For this reason, intravascular imaging plays a central role in the evaluation of calcified coronary lesions. Intravascular ultrasound is particularly valuable because it allows assessment of the calcium arc, thickness, and length, thereby providing a more complete three-dimensional understanding of lesion morphology [16]. In addition, intravascular ultrasound is useful for determining the appropriate burr size for rotational atherectomy and for evaluating guidewire bias, both of which are critical for procedural success [21]. Furthermore, intravascular ultrasound–based calcium scoring can assist in the selection of plaque modification strategies, although some discrepancies may exist when compared with optical coherence tomography–based scores [22].

Optical coherence tomography, in turn, offers higher-resolution imaging and enables more detailed characterization of calcium, including its thickness and distribution. This modality is especially useful for evaluating the effects of lesion preparation strategies on stent expansion and symmetry [23]. In addition, optical coherence tomography can provide a more precise calcium score, which is highly relevant for guiding treatment decisions, including the possible use of intravascular lithotripsy [22].

Taken together, intravascular ultrasound and optical coherence tomography provide imaging-based criteria that are essential for selecting the most appropriate plaque modification strategy, since both the distribution and depth of calcium directly influence the choice of calcium modification devices [20]. In this regard, the updated consensus document suggests the use of intravascular lithotripsy in cases in which post-atherectomy imaging demonstrates persistent heavy calcification [24].

Decision-making algorithms have therefore been developed to integrate angiographic and intravascular imaging findings to determine when rotational atherectomy is required [19]. Among these, the A-M-A-S-A algorithm has been proposed for the management of calcified coronary lesions, emphasizing the central role of imaging in device selection [20].

Technical Principles of Rotational Atherectomy

Rotational atherectomy operates according to the principle of differential ablation, whereby the rotating burr selectively ablates calcified tissue while preserving the more elastic components of the arterial wall. This selective effect is achieved through the high-speed rotation of a diamond-coated burr, which pulverizes calcified plaque into microparticles small enough to pass through the coronary microcirculation without causing embolic complications [21, 22].

The Rotablator system is composed of several essential components, including the console, the advancer, the burr, and the guidewire. The console regulates the rotational speed of the burr, whereas the advancer permits precise manipulation and controlled advancement of the device within the coronary artery. The burr, which is available in multiple sizes, serves as the primary instrument for plaque modification, while the guidewire provides the pathway along which the burr is advanced during the procedure [22].

Appropriate burr sizing is a key determinant of procedural success and is commonly based on the burr-to-artery ratio, which should ideally range between 0.5 and 0.7. Adequate sizing allows effective plaque modification while reducing the likelihood of complications such as vessel perforation or dissection [21].

In addition to burr size, rotational speed is another critical factor in procedural optimization. The recommended burr speed generally ranges from 140,000 to 180,000 revolutions per minute. Maintaining this range is essential to achieve effective ablation while minimizing thermal injury to the vessel wall [1, 22].

The technical execution of rotational atherectomy also relies on the use of the pecking motion technique, which consists of short and controlled burr advancements that allow gradual plaque modification and reduce the risk of vessel injury. In this context, each run should not exceed 20 to 30 seconds to prevent overheating and potential vascular damage [21, 22].

Adjunctive pharmacology plays an essential role during rotational atherectomy procedures. Vasodilators such as nitroglycerin are used to prevent coronary spasm, whereas anticoagulation, most commonly with heparin, is administered to reduce the risk of thromboembolic complications during the intervention [21, 22].

Indications and Procedural Strategy

Rotational atherectomy is primarily indicated in severely calcified coronary lesions that are resistant to conventional balloon angioplasty, particularly in undilatable or uncrossable lesions [25, 26]. In contrast, its use is relatively contraindicated in situations associated with a higher risk of perforation, such as very thin-walled vessels or scenarios with an elevated risk of distal embolization [27]. Likewise, rotational atherectomy is not recommended for lesions that can be treated adequately with less invasive methods [10].

Pre-procedural preparation is essential to ensure both procedural safety and effectiveness. In this regard, intravascular imaging with intravascular ultrasound or optical coherence tomography plays a crucial role in assessing the extent of calcification and in planning the intervention [16, 24]. At the same time, patient optimization should include appropriate antiplatelet therapy and, when indicated, anticoagulation. In selected high-risk cases, hemodynamic support may also be considered as part of the pre-procedural strategy [27].

The procedural workflow begins with an initial lesion assessment based on imaging findings in order to define lesion characteristics and determine the most appropriate burr size. Once this evaluation has been completed, rotational atherectomy is performed using a stepped burr strategy, typically beginning with a smaller burr and progressing to larger sizes when necessary [16]. After plaque modification with rotational atherectomy, adjunctive techniques such as balloon angioplasty or intravascular lithotripsy may be employed to achieve further lesion preparation and optimize the vessel for stent implantation [25].

The integration of adjunctive devices is often necessary to maximize procedural success. Rotational atherectomy may be followed by cutting balloon angioplasty to further enhance lesion modification and facilitate adequate stent expansion [10, 15]. After sufficient lesion preparation, drug-eluting stents are generally deployed to reduce the risk of restenosis [3]. In addition, when rotational atherectomy alone does not achieve adequate calcium modification, intravascular lithotripsy may be used to address residual calcification [25].

Special strategies are required in complex coronary anatomies. In bifurcation lesions, rotational atherectomy can be used effectively, although meticulous planning is necessary to minimize the risk of side branch compromise [25]. In long calcified lesions, a combination of rotational atherectomy and adjunctive balloon-based techniques may be required to ensure sufficient lesion preparation [26].Similarly, rotational atherectomy is effective in ostial lesions, but careful technique is necessary to avoid injury to adjacent vessel segments [27].

Clinical Evidence and Comparative Effectiveness

Rotational atherectomy has been extensively evaluated in the treatment of calcified coronary lesions, and evidence from large registries and observational studies reflects its widespread use in contemporary interventional practice. At the same time, these studies consistently underscore important limitations of the technique, including its marked operator dependency and the risk of complications such as coronary perforation and slow flow [9, 28].

Evidence from randomized and non-randomized trials has further clarified the role of rotational atherectomy in lesion preparation. Studies such as ROTAXUS and PREPARE-CALC have shown that rotational atherectomy improves procedural success during the treatment of calcified lesions, although these benefits have not necessarily translated into superior long-term outcomes when compared with alternative approaches [29].

In procedural terms, rotational atherectomy demonstrates a high rate of technical success, but this is accompanied by longer procedural times and higher complication rates compared with intravascular lithotripsy [28]. The likelihood of procedural success is influenced by multiple factors, particularly lesion characteristics and operator experience. More specifically, lesion length, the severity of calcification, and the burden of patient comorbidities are important determinants of the effectiveness of rotational atherectomy [9].

About clinical outcomes, rotational atherectomy is associated with a higher risk of short-term complications, especially coronary perforation and slow flow, when compared with intravascular lithotripsy [28]. Nevertheless, short-term major adverse cardiovascular event rates appear to be comparable to those reported with other plaque modification techniques. Over the long term, however, rotational atherectomy has been associated with higher risks of major adverse cardiovascular events and mortality compared with newer technologies such as orbital atherectomy, which has shown lower rates of all-cause mortality and target vessel revascularization [9, 10].

Comparative analyses with alternative plaque modification technologies have highlighted important differences in safety and effectiveness profiles. Intravascular lithotripsy appears to offer a more favorable safety profile, with fewer complications and higher procedural success rates than rotational atherectomy [28]. Orbital atherectomy has also been associated with lower all-cause mortality and target vessel revascularization, suggesting that it may represent a preferable strategy in selected patients [10]. Although less commonly used, laser atherectomy has also been compared with rotational atherectomy in studies such as ROLLER COASTER-EPIC22, demonstrating similar outcomes while offering specific advantages in certain lesion subsets [30].

Taken together, these findings indicate that the selection of a plaque modification modality should be individualized according to patient-specific factors, lesion characteristics, and the risk profile associated with each technique. In this context, intravascular lithotripsy and orbital atherectomy may be preferred because of their safety and procedural efficiency, whereas rotational atherectomy remains a valuable option in selected lesion types in which other methods may be less effective [10, 8].

Complications and Periprocedural Management

Slow flow and no-reflow are among the most common complications associated with rotational atherectomy and generally result from microvascular obstruction caused by distal debris embolization and vasospasm. Intravascular ultrasound findings have shown that greater lesion length and a wider calcification arc are associated with a higher likelihood of slow flow [31]. Although short single-session strategies have been explored as a means of reducing this complication, no significant difference has been demonstrated when compared with longer sessions [22]. Nevertheless, the use of vasodilators and meticulous procedural technique may help mitigate these effects [27].

Coronary perforation represents one of the most serious complications of rotational atherectomy and is often associated with aggressive burr sizing and high rotational speeds. This complication is more likely to occur in heavily calcified and tortuous vessels [4]. When perforation occurs, immediate management requires interruption of the procedure, reversal of anticoagulation, and the use of covered stents or coils to seal the perforation [27].

Distal embolization is another relevant complication and occurs when debris generated from the lesion obstructs smaller downstream vessels, resulting in microvascular dysfunction. This risk is especially significant in saphenous vein grafts. In these scenarios, embolic protection devices are recommended to reduce the likelihood of distal embolization, particularly during interventions involving saphenous vein graft lesions [27].

Burr entrapment is a rare but technically challenging mechanical complication that tends to occur in tortuous or heavily calcified vessels. Its management may involve gentle manipulation, the use of smaller burrs, and, in selected cases, surgical retrieval when less invasive measures are unsuccessful [4].

Hemodynamic instability may develop because of prolonged procedural duration or of major complications such as perforation or distal embolization. In addition, arrhythmias may arise due to mechanical irritation of the coronary vessel or myocardial ischemia during the procedure. For this reason, continuous hemodynamic monitoring is essential, along with readiness to administer antiarrhythmic agents or provide temporary pacing when necessary [4].

Given the spectrum of possible complications, preventive strategies are crucial for improving procedural safety. Careful patient selection, pre-procedural imaging, and the use of smaller burrs can help reduce complication rates. Moreover, combining rotational atherectomy with other plaque modification techniques such as intravascular lithotripsy may improve both safety and efficacy in selected cases [25]. At the same time, availability of bailout strategies, including covered stents, vasodilators, and embolic protection devices, remains essential for the prompt management of intraprocedural complications [27].

Emerging Applications and Future Directions

Rotational atherectomy has expanded beyond conventional lesion preparation and is increasingly being used in complex clinical scenarios in which standard devices are insufficient. In chronic total occlusions, it is often required for lesions that are uncrossable or undilatable with conventional techniques, and available evidence indicates that it can achieve successful revascularization with safety and efficacy comparable to that observed in non–chronic total occlusion lesions [32]. It has also been used effectively in left main disease, where plaque modification is particularly important because of the severity and distribution of calcification. In this setting, case reports have demonstrated that rotational atherectomy can facilitate stent expansion and optimize procedural results [33]. In acute coronary syndromes, rotational atherectomy combined with intravascular lithotripsy has been used as a bailout strategy in high-risk patients, showing efficacy in facilitating stent delivery in heavily calcified arteries [34].

Hybrid approaches have also emerged as an important development in the management of complex calcified coronary lesions. Among these, the combination of rotational atherectomy and intravascular lithotripsy, known as Rotatripsy, has shown high success rates and low complication rates in a wide range of lesions, including bifurcations and ostial lesions. This strategy appears to be particularly useful in cases of balloon underexpansion after rotational atherectomy [25]. In addition, comparative data suggest that although both rotational atherectomy and orbital atherectomy serve as effective plaque modification strategies, orbital atherectomy has been associated with lower rates of all-cause mortality and target vessel revascularization, highlighting the potential value of integrating different atherectomy approaches according to lesion characteristics and patient profile [10].

At the same time, advances in device technology and imaging integration have contributed to improving the outcomes of rotational atherectomy. Recent developments in atherectomy systems, together with the use of newer generation drug-eluting stents, have been associated with satisfactory acute and long-term results in calcified lesions. Moreover, the incorporation of intravascular ultrasound into procedural planning has improved lesion characterization and device selection, thereby enhancing both procedural success and safety, particularly in patients at high risk of contrast-associated acute kidney injury [15].

This growing emphasis on imaging guidance has also strengthened the role of physiology-guided and imaging-guided interventions. Minimal-contrast intravascular ultrasound-guided rotational atherectomy has been shown to be both feasible and safe, with high success rates and a lower risk of contrast-associated acute kidney injury [15]. In parallel, the integration of physiological assessment with intravascular imaging may further optimize lesion preparation and stent deployment, potentially improving outcomes in complex calcified lesions [21].

Ongoing clinical research is expected to refine the role of rotational atherectomy in high-risk populations and complex anatomies. The CRATER trial, for example, compares elective versus bailout rotational atherectomy in patients with chronic renal failure and may provide important insights into the most appropriate use of this technique in vulnerable patients [35]. More broadly, future investigations are focusing on the refinement of rotational atherectomy techniques, the evaluation of new combinations of plaque modification devices, and the integration of advanced imaging modalities to improve procedural outcomes and reduce complications [21].

Taken together, these developments have important implications for clinical practice and future guideline formulation. The integration of rotational atherectomy with complementary plaque modification techniques and advanced intravascular imaging has improved procedural success and safety, thereby influencing decision-making in complex coronary interventions [9]. As the evidence base continues to grow, clinical guidelines may increasingly incorporate hybrid strategies and imaging-based approaches, with a stronger emphasis on individualized treatment selection for patients with calcified coronary lesions [21].

Conclusion

Rotational atherectomy continues to play a significant role in the treatment of severely calcified coronary lesions, especially when non-dilatable or non-crossable lesions are present, as it allows for effective plaque modification and facilitates subsequent stent expansion. However, its usefulness depends on appropriate patient selection, proper procedural planning, and operator experience, due to its technical complexity and the risk of associated complications.

Comprehensive evaluation of coronary calcification using intravascular imaging, particularly intravascular ultrasound and optical coherence tomography, is essential to characterize the distribution, depth, and severity of the calcium, as well as to guide the selection of the most appropriate plaque modification strategy. In this context, the use of intracoronary imaging has improved procedural safety, device selection, and interventional outcomes in complex lesions.

Although rotational atherectomy boasts high procedural success rates, its risk profile remains considerable, with complications including slow flow, no-reflow, coronary perforation, distal embolization, and burr entrapment. Therefore, the current trend is toward more personalized strategies that integrate hybrid techniques such as intravascular lithotripsy, new technological advancements, and enhanced image guidance, with the aim of optimizing outcomes and reducing adverse events in both the short and long term.

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