Summary

Cleaning of historical artifacts has always represented a critical treatment in conservation practice, requiring a delicate balance between effective removal of unwanted materials and preservation of the original surface. Traditionally, this process has relied heavily on the conservator's experience and judgment, with limited tools for objective monitoring during the cleaning procedure itself.

Conventional chemical-physical analyses provide valuable preliminary insights on material distribution and film formation on artefact surfaces, supporting informed cleaning decisions. However, these characterizations are primarily performed ex-situ, i.e. before and after treatments, creating a significant analytical gap during the cleaning process. Conservators typically perform cleaning under microscopic observation or with magnifying tools, but this approach remains inherently subjective and lacks quantitative measurement capabilities regarding the progressive removal of altering and potentially harmful materials.

A scientific literature review offered in the first chapters of this Ph.D. research, highlight recent trends focusing on scientific research supporting conservation processes both with material engineering and with analytical techniques development. Among them Optical Coherence Tomography (OCT) raised interest in the scientific community in the last two decades.

OCT technology, originally developed for medical diagnostics, provides cross-sectional imaging of sub-surface structures with micrometer resolution, making it ideally suited for cultural heritage applications where minimally invasive techniques are essential.

The research methodology combined OCT measurements with complementary spectroscopic techniques, with reference to fluorescence spectroscopy, to quantitatively measure the thickness of overlapped layers to be removed throughout the cleaning process. This dual approach enabled comprehensive assessment of coating distribution and homogeneity, suitable for real case studies.

Moreover, the OCT system's ability to visualize sub-surface structural changes at interfaces between different material layers further expanded its application potential, leading to validation efforts for OCT as a non-invasive methodology for sub-surface roughness profile measurements, a critical parameter in evaluating cleaning efficacy and potential surface alterations.

Notably, the research included a successful first attempt to qualitatively measure the spatial distribution of siloxanes in treated painted layers, providing insights into the material's behaviour at the microscale. This achievement opens promising perspectives for monitoring the penetration and spatial diffusion of consolidants in painted layers, an interesting complementary outcome that significantly expands the application scope of OCT monitoring in conservation treatments beyond cleaning procedures.

The metrological framework developed during this research established protocols for accurate assessment of intervention materials and procedures on original matter, providing conservators with quantifiable data to support cleaning decisions. Parameters evaluated included layer thickness reduction rates, surface topography changes, interface clarity between layers, and structural integrity of underlying materials, all monitored in real-time.

Experimental validation was carried out through a systematic approach involving laboratory-prepared mock-ups with controlled layer compositions, complementing manual measurements with AI based algorithms, which guaranteed an increase of the dataset acquired and limited the time-consuming manual measurements. A first tentative application on a complex real case study presenting varied conservation challenges was performed.

Results demonstrated significant correlations between OCT-derived measurements and traditional assessment methods, while offering the distinct advantage of possible continuous monitoring throughout the treatment process.

The obtained results permit to hypothesize the application on hundreds real cases presenting similar stratigraphy and related problems. As well, this should be considered a good starting point for the removal of the studied material from other substrates (differently reactive to solvents or to the aqueous medium).

The method could also be tested on more recent painted surfaces, especially if varnished. Moreover, with regards to the developing of a methodology to map a resin layer underneath another different composition coating, this preliminary study could suggest possible advances in imaging analysis.

The integration with spectroscopic techniques appears to be, as a future perspective, a key feature to measure, jointly with the specific aspects studied with OCT techniques, highlighting also the chemical features of the inspected materials.

The research outcomes report both the considerable potential and current limitations of the proposed analytical approach: even if OCT monitoring successfully provided quantitative data for cleaning optimization with transparent and semi-transparent coatings, challenges remained with highly opaque materials and complex surface geometries. Future work will focus on expanding the technique's applicability through advanced signal processing algorithms and integration with complementary imaging modalities.

All considered, this research represents an important step toward more objective, data-driven conservation practices that enhance both the quality and documentation of cleaning interventions for historical artifacts.