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**FACULTY OF DENTAL MEDICINE**

**Department III**

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# PHD THESIS

## Computational and experimental approaches in the structural analysis of dental materials: Applications in endodontics, prosthetic and periodontology

## A B S T R A C T

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# T A B L E O F C O N T E N T S

# A B S T R A C T

The multi-faceted study in focus presents comprehensive analyses of numerous aspects in dental science, with a spotlight on endodontic treatments, diagnostic imaging, and dental prosthetics. Conducted through a series of rigorous experiments, simulations, and comparative reviews, the research effectively establishes a rich framework to guide the evaluation and application of various dental procedures and technologies.

**The first study** investigating the efficacy of nanoparticle-based irrigation solutions in endodontic procedures, particularly in root canal treatment. The study employs Optical Coherence Tomography (OCT) scans to analyze root canal morphology and the presence of nanoparticles in the apical segment of root canals after irrigation. The primary goal is to improve the efficacy of endodontic disinfection by utilizing nanoparticle-based solutions, specifically NanoCare Plus and NanoCare Gold, both of which contain silver and gold nanoparticles in varying concentrations.

The study comprises 12 root canals, each analyzed using approximately 100 OCT images. The regions of interest (ROI) were chosen based on root canal morphology, and the pixel values were analyzed using ImageJ software. The greyscale pixel values (ranging from 0 to 255) were connected to the light absorption rates, thereby indicating the radiological density of tissues. Statistical analyses were performed using Student's t-test to identify statistically significant differences between the groups.

The results:Irrigants with Nanoparticles: The OCT scans showed that nanoparticle-based solutions, when used as irrigants, increased the grey-scale values of root canals. This indicates a higher light absorption rate and suggests that the nanoparticles effectively adhere to the root canal walls.

Significant Differences: A statistically significant difference was found in the greyscale levels between the control group (Group 1) and the groups using nanoparticle-based irrigants (Groups 2 & 3), both showing $P < 0.00001$.

Shape and Contour: Interestingly, the study also reported an almost circular shape of the root canal contours after rotary instrumentation with nickel-titanium instruments.

Inconclusive Results: However, there was no statistically significant difference between the two groups using nanoparticle irrigants (Groups 2 and 3) concerning greyscale levels ($P > 0.05$).

The study concludes that nanoparticle-based solutions can significantly improve the efficacy of endodontic irrigation procedures. These particles were even observed in the apical segment of root canals, which is traditionally difficult to clean effectively. These findings open the door for an optimized and more effective disinfection process in root canal treatments.

However, there are limitations, including the resolution limitations of the OCT system used in the study, which could not clearly differentiate between the dental tubules and nanoparticles. Future research could involve improved imaging techniques and specific bacterial culture tests to assess the antimicrobial efficacy of these nanoparticles.

Overall, the study points toward a promising direction in the field of endodontics, combining nanotechnology and imaging sciences for better patient outcomes.

**Comparative Analysis of Endodontic Files**

The research initiates its discourse by critically comparing the performances of three widely-used endodontic files—Reciproc Blue, WaveOne Gold, and ProTaper Gold—in shaping simulated root canals. The experiment was structured to measure two pivotal metrics: canal transportation and centering ability.

Findings:

Reciproc Blue: Demonstrated a more pronounced canal transportation in mesial and buccal directions, highlighting a certain level of aggressiveness in shaping. This could be concerning when maintaining the original canal anatomy is crucial.

WaveOne Gold: Exhibited diminished centering ability, specifically in the mesio-distal direction. Such characteristics may increase the risk of perforations or weakening of the surrounding root structure.

ProTaper Gold: Provided the most balanced performance, characterized by minimal canal transportation and commendable centering ability. It was also the least intrusive when it came to altering the canal curvature, indicating its potential for conserving anatomical features.

Methodology: Utilization of simulated root canals enabled the creation of a controlled environment, thereby ensuring higher validity in outcomes.

Implications: The data serves as an invaluable resource for dental practitioners to make informed choices on endodontic files, particularly when the focus is on minimally invasive treatments or when dealing with complex canal anatomies.

**Optical Coherence Tomography (OCT) and Micro-Computed Tomography (µCT) in Diagnostics**

Transitioning from procedural tools to diagnostic technologies, the study dives into the capabilities of Optical Coherence Tomography (OCT) and micro-Computed Tomography (µCT) in identifying root canal conditions.

Findings:

OCT: Highlighted for its superior and safer axial resolution, especially when the source spectrum is broadened. The technology is notably effective in identifying defects such as gaps in root canal fillings and inconsistencies at canal wall interfaces.

µCT: Endorsed for its role in substantiating OCT findings. The research implies that µCT could serve as a secondary diagnostic tool, working in tandem with OCT for a more holistic analysis.

Methodology: Advanced OCT and µCT imaging techniques were used for a detailed cross-sectional analysis of simulated root canal samples, increasing the accuracy and reliability of the results.

Implications: This section paves the way for integrating cutting-edge imaging technologies into routine dental diagnostics, potentially revolutionizing the standard of care in endodontics. It also underlines the need for post-endodontic treatment for comprehensive care.

**Monitoring Ceramic Furnace Temperatures**

Another noteworthy facet of the research involves the use of Multi-Spectral/Single-Spectral OCT (MS/SS-OCT) for real-time temperature monitoring inside ceramic furnaces, crucial in the crafting of dental prosthetics.

Findings: Significant variations in material reflectivity serve as early indicators for calibration needs. The study revealed that a 40% change in reflectivity compared to control samples should prompt immediate recalibration to avoid defects and fractures in ceramic layers.

Methodology: The furnace temperature and material reflectivity were continuously monitored using MS/SS-OCT, and the data were compared with preset control values.

Implications: The findings emphasize the indispensable role of rigorous temperature monitoring for the production of resilient and effective ceramic prosthetics, thereby influencing long-term treatment success.

**Effectiveness of PerioTabs in Managing Gingival Inflammation**

The study included a clinical trial aiming to gauge the efficacy of PerioTabs in alleviating gingival inflammation among patients with periodontal disease who were also fitted with Fixed Partial Dentures (FPDs).

Findings: A marked decrease in gingival inflammation was observed, coupled with increased patient satisfaction.

Methodology: The trial involved patients with pre-existing periodontal issues being treated with FPDs and was structured to include control and test groups to ensure accurate results.

Implications: The results indicate that PerioTabs can be an effective adjunct treatment in periodontal disease management, specifically for those also undergoing prosthetic treatments.

**Structural Models for Ceramic-Zirconia Restorations**

The research incorporates computational techniques like Finite Element Analysis (FEA) and CAD/CAM technology to evaluate the biomechanical behavior of ceramic-zirconia crowns.

Findings: The study concluded that the choice of the zirconia frame and the cladding material considerably impacts the biomechanical integrity of the crowns.

Methodology: Different combinations of zirconia frame models and cladding materials were simulated using CAD/CAM and assessed through FEA.

Implications: Dental practitioners can utilize these insights to customize treatments, ensuring both aesthetic and functional longevity of the prosthetics.

**Portable OCT Devices**

The study concludes by introducing portable OCT devices that have been successfully implemented in both otorhinolaryngological and dental contexts. The ultimate aim is to replace

certain applications of Scanning Electron Microscopy (SEM) with these more efficient OCT systems.

Findings: The portable OCT devices, based on 1D Grating Spectrometer (GS), have shown promise in various medical and dental applications.

Methodology: The technology was implemented in real-world clinical settings for validation.

Implications: The portable devices present an opportunity to expand the scope of OCT in diagnostic settings, increasing both its accessibility and utility.

Future Directions and Conclusion

The research provides a rich tapestry of insights and data, serving as a cornerstone for further exploration and application in dental science. Its detailed scrutiny of endodontic files, advancements in diagnostic imaging, and thorough evaluation of material sciences in dental prosthetics offers a holistic understanding of the current landscape. The study also sets the stage for future research endeavors by highlighting areas like control structure optimization for OCT devices and exploring non-destructive testing (NDT) possibilities.

In summary, this expansive research piece serves as a crucial guide and resource for ongoing and future studies, and holds significant potential to elevate the standard of dental healthcare. The study’s multi-dimensional approach not only advances our understanding of current technologies and methods but also serves as a catalyst for future innovations in the field.