“VICTOR BABEȘ” UNIVERSITY OF MEDICINE AND PHARMACY FROM TIMISOARA

FACULTY OF DENTISTRY

Department I

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PHD THESIS

DENTAL CERAMIC EVALUATIONS UNDER DIFFERENT THERMAL CONDITIONS

A B S T R A C T

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A B S T R A C T

TABLE OF CONTENTS

One of the primary challenges in the fabrication of dental prosthetic constructs, particularly metal-ceramic restorations, is maintaining the integrity and quality of ceramic materials under varying thermal conditions. Defects such as cracks and chipping, which can compromise the functionality and aesthetics of dental restorations, often stem from issues like decalibration in ceramic ovens. Over time, typically two to three years, the displayed temperature of these ovens can deviate from the actual internal temperature, necessitating adjustments. Experienced dental technicians often rely on subjective assessments of translucency and texture in porcelain samples to gauge and correct oven temperatures, a process that is both visual and subjective.

The choice of the research topic, "Evaluation of Dental Ceramics Under Different Thermal Conditions," is driven by the critical need to enhance the quality and durability of metal-ceramic dental prostheses. Dental ceramics are favored for their superior aesthetic and mechanical properties; however, their inherent brittleness and sensitivity to thermal variations can lead to fractures and clinical failures. This study seeks to explore innovative methods for monitoring and controlling temperature during the sintering process to optimize the performance and longevity of dental restorations.

The importance of this topic is underscored by recent advances in imaging technologies and the growing demand for durable, aesthetically pleasing dental restorations. The use of Optical Coherence Tomography (OCT) in non-invasive monitoring of the sintering process presents a unique opportunity to improve the quality of dental ceramics. The research is relevant both nationally and internationally, aligning with global efforts to advance dental material sciences and improve clinical outcomes. The objectives of this doctoral research include developing a non-invasive method for temperature monitoring using OCT, evaluating the impact of temperature variations on dental ceramics, and optimizing sintering conditions to minimize defects. This research not only aims to validate OCT as a standard tool in dental laboratories but also seeks to contribute significantly to the field of restorative dentistry.

The PhD thesis is divided into two main sections: a comprehensive general part and a specialized part. The general part provides a foundational overview, including historical context, classification of materials, and non-invasive analysis techniques for dental ceramics. It sets the stage by discussing the evolution and current state of dental materials, particularly focusing on the development and application of ceramics in prosthodontics.

The specialized part delves deeper into specific research contributions and experimental studies. This part includes detailed methodologies, results, and discussions on the evaluation of dental ceramics under various thermal conditions, using advanced imaging technologies like Optical Coherence Tomography. It explores innovative approaches to enhancing the durability and quality of dental restorations, providing valuable insights and recommendations for clinical practice and future research in the field.

The general part of the thesis is structured into four chapters, each focusing on a specific aspect of dental ceramics and their application in prosthodontics.

Chapter 1 provides a historical overview of dental ceramics, tracing their development from early uses to modern applications. It covers the introduction and evolution of porcelain materials in dentistry, the development of porcelain-fused-to-metal restorations, the progression towards advanced ceramic materials like zirconia and lithium disilicate, highlighting their increased strength and aesthetic properties.

Chapter 2 a detailed classification of the various types of ceramics used in dental restorations is presented. Key topics include the feldspathic ceramics, known for their excellent aesthetic properties, primarily used in veneers and anterior restorations. Leucite-reinforced ceramics, enhanced with leucite crystals for improved strength, suitable for crowns and small bridges. Lithium disilicate ceramics, renowned for their combination of strength and aesthetic appeal, often used in crowns and veneers. Zirconia-based ceramics, high-strength ceramics suitable for both anterior and posterior restorations, available in various translucency levels. Hybrid ceramics, combining ceramics with polymers, these materials offer flexibility and cost-effectiveness for various dental applications.

Chapter 3 explores the techniques used to analyze and ensure the quality of dental ceramics without damaging them. Key methodologies include: Spectroscopy, Radiography and Computed Tomography, Laser Scanning and Confocal Microscopy and Optical Coherence Tomography.

Chapter 4 discusses future trends and advancements in the field of dental ceramics. The integration of CAD/CAM systems and 3D printing in the production of dental restorations, allows for precise customization and improved material efficiency. The development of new ceramic materials, such as zirconia-reinforced lithium disilicate, have the potential to improve the durability and aesthetic quality of dental restorations.

Each chapter provides a thorough exploration of the respective topics, building a comprehensive understanding of the role and evolution of dental ceramics in modern prosthodontics. This foundation is crucial for the specialized studies and experiments presented in the special part of the thesis.

The **special part** of this PhD thesis consisted of 5 distinct studies, described from chapter 5 to 9. The personal contributions and general conclusions of these studies are described below, as followed:

In **Chapter 5**, titled Investigation of firing temperature variation in ovens for ceramic fused-to-metal dental prostheses using swept source optical coherence tomography, **the first study** was described. One of the primary techniques used in the fabrication of dental ceramics is sintering, a process involving the heating of the ceramic material to promote densification through viscous flow once the firing temperature is achieved. For restorations to be acceptable, the alloy and ceramic must be compatible in terms of chemical, thermal, mechanical, and aesthetic properties. This compatibility includes ensuring that the ceramic's fusing temperature does not distort the metal substructure. When ovens used for firing ceramic layers in metal-ceramic dental prostheses are decalibrated, it can lead to stress and cracks in the veneering material, ultimately resulting in restoration failure. In this study, 25 metal-ceramic prostheses were fabricated and divided into five groups, each sintered at different temperatures: one group at the manufacturer-recommended temperature, two groups at lower temperatures, and two groups at higher temperatures. The ceramic used was Unica Wegold, a single-layer ceramic. The study employed swept source optical coherence tomography, to evaluate the modifications induced by firing at temperatures different from those recommended.

It has demonstrated the effectiveness of optical coherence tomography for non-invasive monitoring of temperature variations within ceramic ovens used in the production of metal-ceramic dental prostheses. By using OCT, dental technicians can evaluate the ceramic layer at a specific depth, approximately 0.375 mm, using C-scan (en-face) images. A 43% variation in material reflectivity was found to be a critical threshold, indicating the need for immediate recalibration of the oven temperature to prevent thermal stress and material defects.

Differences in granulation and reflectivity allowed for the extraction of practical guidelines to quickly evaluate the current calibration of the ceramic oven using only the prostheses currently produced. OCT imaging enables the rapid identification of oven decalibration, thereby preventing the production of dental prostheses with defects. This method showed that enhances the reliability and quality of metal-ceramic dental restorations by ensuring precise temperature control during the sintering process.

The **second study,** in **chapter 6**, studying the assessment of dental ceramic sintered at different temperatures, the research underscored the critical impact of temperature fluctuations within the dental ceramic oven on the quality of metal-ceramic restorations. This study aimed to investigate the modifications that may occur due to deviations in sintering temperature for metal-ceramic crowns. For this in vitro study, 15 metal-ceramic crowns were created for tooth 2.1 and divided into five groups. Each group featured ceramic veneering sintered at different temperatures to optimize various properties: Group 1 was sintered at 910 ºC according to the manufacturer's recommendation, Group 2 at 940 ºC (+30 ºC), Group 3 at 960 ºC (+50 ºC), Group 4 at 880 ºC (-30 ºC), and Group 5 at 860 ºC (-50 ºC). The maxillary cast was scanned using the EXOCAD scanner to produce metal frameworks from a Cr-Co alloy (SCHEFTNER CoCr - 30 microns). The Ips InLine One ceramic, shade A3 developed by Ivoclar, was applied in two layers, each layer sintered at the same respective temperature. After sintering, the shade of each group was measured with the Vita Easy Shade spectrophotometer and compared using the Vitapan Classical shade guide.

The results showed that deviations in sintering temperatures can alter the ceramic's density and mechanical properties and lead to color shifts. These changes occur due to alterations in the ceramic material's microstructure, impacting its optical properties and consequently its perceived color.

This study highlights the crucial impact of sintering temperature variations on the quality and integrity of metal-ceramic dental restorations. The findings underscore the need for further innovation and research in thermal management within dental ceramics processing to achieve restorations that are not only aesthetically pleasing but also functionally reliable and compatible with the natural dentition. Advanced imaging techniques, such as OCT, play a vital role in ensuring precise temperature control and maintaining the high quality of dental prostheses.

The third study, in **chapter 7**, aimed to evaluate the efficacy of optical coherence tomography in non-invasively monitoring temperature variations during ceramic sintering for dental prosthetics, emphasizing the importance of precise temperature control for optimal material properties and structural integrity. The study utilized OCT to examine 17 metal-ceramic restorations at various sintering temperatures (standard, 80°C below, and 50°C above the standard) and Unica Wegold single-layer ceramic was used. The method involved generating 61 cross-sectional images per prosthesis to identify defects and structural changes.

The results showed that OCT revealed significant insights into the impact of temperature deviations on ceramic microstructure. At standard temperatures, the grain sizes were uniform, while elevated temperatures showed areas of reduced retention. These findings highlight the potential of OCT in quality control.

OCT offers a rapid, accurate, and non-destructive means to assess sintering temperatures and detect defects in dental ceramics, facilitating improvements in the fabrication process of dental prosthetics. The study advocates for the integration of OCT into routine dental laboratory practices to enhance the quality and reliability of prostheses.

The fourth study, in **chapter 8**, aimed to evaluate the interface of metal-ceramic prostheses produced using two different manufacturing technologies. For the manufacturing of the samples, the NeWay Open Technology Scanner was utilized. The metallic framework was designed on the virtual cast using the EXOCAD software for Selective Laser Sintering (SLS). Patterns for the casting technology were milled in wax using the Zenotec Select Hybrid system. The veneering of the Co-Cr metallic frameworks was carried out using IPS d-SIGN ceramic (Ivoclar). The samples were then sectioned and examined under an optical microscope.

The results showed that optical microscopy revealed inclusions and dehiscence at the metal-ceramic interface of pour-melted frameworks. The interface of ceramic and sintered frameworks also showed dehiscence and spherical inclusions in the veneering ceramic.

The study concluded that errors leading to the detachment of the veneered ceramic are reduced in the case of SLS due to better adherence of the ceramic to SLS metallic infrastructures. This highlights the superior performance of SLS technology in producing more reliable metal-ceramic prostheses with fewer defects at the interface.

The fifth study, in **chapter 9** aimed to assess the technical steps involved in creating metal-ceramic restorations using IPS InLine ceramic (Ivoclar), a multi- layered ceramic. The study utilized advanced imaging techniques and precise manufacturing protocols to fabricate metal-ceramic restorations.

The findings indicated that precise temperature control during the sintering process is crucial for achieving optimal material properties and structural integrity. OCT imaging provided detailed insights into the ceramic's microstructure, revealing uniform granulation at standard temperatures and structural inconsistencies at elevated temperatures.

The study demonstrated that the quality and reliability of metal-ceramic restorations using IPS InLine ceramic (Ivoclar) can be significantly enhanced through meticulous temperature control and advanced imaging techniques. Integrating OCT into routine dental laboratory practices can improve the fabrication process, ensuring high-quality, durable restorations that meet aesthetic and functional requirements.

The final conclusions, succinctly encapsulate the key issues addressed in the thesis, accurately reflecting the outcomes of the research and fully meeting the stated objectives. The findings from the conducted studies pave the way for new directions and topics for future research, offering significant potential for further investigations.

The conclusions, along with the elements of originality and perspectives drawn from the personal contributions in this doctoral thesis, have direct applicability in the dental laboratory. They are beneficial not only to practitioners but, more importantly, to patients, as they offer the potential for improving the quality of treatments provided.