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PhD THESIS

THE ENHANCEMENT OF ADHESION IN ALL-CERAMIC PROSTHODONTIC RESTORATIONS

A B S T R A C T

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ABSTRACT

The current technological advancements have greatly enhanced the field of digital dentistry, providing new materials, procedures, and treatment options. With the progress of CAD/CAM technology and the introduction of innovative aesthetic materials, the dental industry is going through a significant transformation. These technological developments have had a profound impact on clinical procedures and workflow.

The latest advances in ceramic material production offer fascinating choices for selecting materials and manufacturing processes. However, to ensure that these restorations function as intended, it is essential to have a deep comprehension of the material dynamics in connection to the restoration's design and intended use.

Advanced treatments in dentistry that aim to preserve dental tissue are known as "minimally invasive". Recent scientific developments have led to significant advancements in dental ceramics and processing technologies, particularly through the use of new microstructures and CAD-CAM methods. While multi-layered restorations offer better visual aesthetics, they are more susceptible to chipping and fractures. As a result, there has been a shift towards monolithic restorations in creating all-ceramic dental prostheses. Clinicians have adapted their practices to accommodate this trend.

For a strong and reliable bond between composite resin and prosthetic restoration, it is necessary to etch both the restoration and tooth surface properly. By using hydrofluoric acid etching on glass-matrix ceramic restorations, the surface becomes modified and allows for effective micro-retentions that make it easier to bond using composite resin-luting materials.

The concepts of adhesive dentistry have reorganized clinical strategies for tooth abutment preparing, ensuring durability, achieving aesthetics, and repairing tooth structure. However, dental professionals may feel overwhelmed by the wide variety of ceramic components available. Poor guidance on their appropriate use can lead to inferior clinical assessments and failures. To avoid this, professionals must be familiar with the different types of ceramic materials, their properties, and the composition of modern materials. This knowledge will help them select the most appropriate ceramic and their cementation process for each unique clinical situation.

The subject of this doctoral thesis focuses on ways in which adhesion techniques for all-ceramic prosthodontic restorations may be made more effective. One of the goals is to improve the development of evidence-based protocols for dental practitioners and professionals. These guidelines will contribute to the quality of patient care, treatment outcomes, and the sustained success of all-ceramic restorations, which will assist in encouraging the incorporation of scientific advancements into clinical practice.

This thesis study aims to determine the effects of surface morphological variations created by hydrofluoric acid on bond strength and roughness. The doctoral thesis focuses on the core topic of the effectiveness of minimally invasive treatment options, specifically by strengthening the cementation technique of CAD/CAM materials. This issue represents a significant challenge in the field of adhesive dentistry.

In the context of all-ceramic restorations, the main objective of the first research of this doctoral thesis ***“The influence of the cementation protocol for CAD/CAM all-ceramic restorations. A literature update.”*** is to investigate the slight relationships between materials, clinical procedures, and adhesive methods. The purpose of this study is to provide an extensive understanding of the processes involved in selecting, preparing, and cementing materials in order to achieve optimal outcomes. This literature review aims to provide updated information on the appropriate application of ceramic materials in various clinical settings, by evaluating the qualities, characteristics, and classifications of these materials.

Aspects of various surface treatment methods for all-ceramic restorations are included in the outline of this literature update, which also offers practical therapeutic advice.

English-language literature provided the results of the search. The study included papers published from 2003 to 2018 in the PubMed database, focusing on clinical surface treatments for all-ceramic restorations.

The current amount of literature indicates that there is no universally applicable material available. The dental substrate demonstrates optimal outcomes when subjected to etching and priming on enamel. Additionally, the application of

9.5% hydrofluoric acid on the ceramic surface creates appropriate porosity structures.

The optimization of clinical performance in all-ceramic prosthodontic restorations is contingent upon the use of precise surface treatments to achieve aesthetic, functional, and durable outcomes.

The currently available amount of research demonstrates that clinical circumstances need the use of various all-ceramic materials along with adhesive cementation methods, highlighting the absence of a universally applicable material. A comprehensive selection of 23 research articles that approached the specified criteria for surface treatments were selected. Additionally, an extensive assessment was conducted on five clinical trials that are closely associated with the subject material.

In conclusion, when it comes to the dental substrate, optimal outcomes were seen for all types of cement when using enamel etching and priming.

The use of a 23% acidulated phosphate fluoride etchant on the ceramic material does not provide adequate results in terms of achieving the necessary mechanical interlocking. In contrast, the application of a 9.5% hydrofluoric acid produces substantially greater etching patterns and porous structures, hence exhibiting a higher level of roughness.

Acidulated phosphate fluoride is characterized by a reduced concentration of hydrofluoric acid, which therefore results in a more superficial effect on the ceramic material.

In general, the use of hydrofluoric acid etching contributes to greater results of bond strength.

Successful optimization of clinical results for all-ceramic restorative materials is contingent upon the use of appropriate surface treatments. The use of hydrofluoric acid etching combined with silanization has been shown to provide superior bond strength in comparison to other etching methods. In instances when traditional adhesive and self-adhesive cements are used, it is recommended to apply etching and priming in order to enhance the bond strength.

The effective use of all-ceramic materials is predicated upon the clinician's ability in selecting the appropriate material and using the suitable cementation or bonding procedure to attain aesthetic, functional, and durable outcomes.

This study was published in **Medicine in Evolution**, Volume XXV, No. 1, 2019, Romania.

The purpose of the second study, in vitro research, is to examine the advancements made in using all-ceramic restorations, specifically leucite-reinforced ceramics. These glass-ceramics are often preferred for restoring the teeth in the frontal area because of their superior aesthetic qualities, compatibility, and versatility. To ensure strong bonding of ceramic restorations with a glass phase, it is important to acid etch them first. This will create an optimal surface structure that enhances the adherence of resin cement. The effectiveness of the acid treatment depends on factors such as the type of ceramic material used, the concentration of conditioner used, and the duration of the etching process. Glass ceramics are disposed to brittleness and fragility, and they have limited flexural strength. Thus, it is recommended to use definitive adhesive cementation with composite resin to improve the restoration's resistance to fractures. It is meaningful to evaluate the unique properties of leucite-reinforced ceramics and determine how they can be used with various treatment options to ensure successful adhesive prosthodontic outcomes.

Studies have demonstrated that adhesive cementation can enhance the effectiveness of restorations and boost their resistance to fractures. The research will investigate how surface treatments, such as hydrofluoric acid etching and primer application, can improve the surface roughness and bond strength between the resin cement and the glass ceramic.

The purpose of this study ***“The influence of hydrofluoric acid temperature and application technique on ceramic surface texture and shear bond strength of an adhesive cement”*** was to assess the effects of heated hydrofluoric acid (HF) pretreatment and application technique on the surface morphology and roughness of leucite-reinforced glass-ceramic materials (IPS Empress CAD, Ivoclar Vivadent). This evaluation is essential for gaining a new understanding of the adhesive cementation process.

The ceramic blocks were divided into five groups based on random assignment, with a total of 10 blocks (n=10). The groups were differentiated based on the surface treatments applied to each block.

- Group 1, referred to as the NT (control group), did not receive any surface treatment.
- Group 2, known as DH, underwent a dynamic application of preheated HF-gel for 60 seconds. This involved continuous movements of a micro brush on the ceramic surface.
- Group 3, assigned as SH, received a static application of preheated HF-gel for 60 seconds without brushing.
- Group 4, referred to as DNH, underwent a dynamic application of nonheated HF-gel (at room temperature) for 60 seconds. This involved active movements with a micro brush on the surface.
- Group 5, known as SNH, received a static application of nonheated HF-gel (at room temperature) for 60 seconds without brushing, using a micro brush.

Following the HF treatment, a 20-second air-water spray rinse was conducted on all specimens, which were then air-dried for a duration of 10 seconds.

To perform a visual examination, scanning electron microscopy (SEM) was used to capture micrographs of the ceramic surfaces. The SEM images were obtained at magnifications of x1000 and x5000. The intent of this analysis was to examine any changes in the morphology of the surfaces and to evaluate any effects on the ceramic area resulting from the treatments applied to the specimens. The analysis of each ceramic block was performed at the center of the specimen. In contrast to the porous surface seen in all the examined etched groups, the NT group revealed a pattern of lower retentiveness. The investigation indicated that all of the hydrofluoric acid (HF) treatments resulted in notable porosities on the surface of the ceramic material. As a result, the surface morphology of each CAD/CAM block underwent considerable changes subsequent to the application of surface treatments. The changes in surface roughness were easily discernible on scanning electron microscopy (SEM) micrographs.

The ceramic surface micro retentions are influenced by the ceramic conditioning process, as shown by the findings of microscopic analysis.

The measurement of surface roughness was conducted using a contact profilometer, namely the Surftest SJ-201 (Mitutoyo, Kanagawa, Japan). Following surface modifications, two perpendicular measurements were made starting from the center of each sample (with a cutoff length of 0.25 mm) along specific orientations. The study reported the Ra values, which reflect the average roughness values of the highest and lowest points assessed from a reference plane, for the surfaces that underwent treatment.

The values were expressed in micrometers (μm) and the mean of the data was documented. This analysis proved that different ceramic surface patterns are determined by the temperature and application technique of hydrofluoric acid.

To conclude, based on the significance level of $p < 0.05$ and regarding the output of the correlation analysis, it can be inferred that there is a linear correlation between roughness and SBS.

All specimens were treated with a silane coupling agent (Clearfil Ceramic Primer Plus; Kuraray Noritake Dental Inc., Tokyo, Japan) using an applicator brush, in accordance with the manufacturer's instructions.

Further, the second part of this study included translucent cylinders created by systematically cutting a polyvinyl tube with an inner diameter of 3 mm and a height of 5 mm, with parallel ends. Each specimen required one cylinder to bond adhesive cement on the conditioned surfaces. The polyvinyl cylindrical mold was carefully filled with cement (Panavia V5, Kuraray Noritake Dental Inc., Tokyo, Japan) through the opening of the polyvinyl tube and placed across the surface of the treated specimen. Afterward, cylinders of adhesive cement were bonded to the treated surfaces and cured using an LED curing device for 20 seconds from opposite sides, with a power intensity of 1000 mW/cm^2 . Due to the tube's thickness of 1 mm, the LED curing device had to be in contact with the tube to activate it. The polyvinyl tubes were then removed once the adhesive had completely set.

The Zwick/Roell ProLine Z005 universal testing device (ZwickRoell, Ulm, Germany) was used to conduct the shear bond strength (SBS) tests. The SBS values between the ceramic material and resin cement were tested for failure using universal testing equipment set at a crosshead speed of 0.5 mm/min at ambient temperature.

The SBS values were found to have a correlation with the micro-retentive surface roughness of the ceramic material. The bond strength between ceramic material and resin cement can be improved through static surface treatment techniques. The temperature of the hydrofluoric acid used (whether heated or not) and the application mode (static or dynamic) are two factors that have a statistically significant effect on the SBS. While the technique of application does not have a significant impact, the temperature of the hydrofluoric acid does. The interaction between these two factors does not have a significant effect on the results in terms of SBS shear strength. The mean SBS values for the NT, DH, and SH treatments do not vary statistically significantly from one another. Compared to the control group of NT, the surface preparations of the DNH and SNH groups resulted in average SBS values that indicated improvements of 56.32% and 74.88%, respectively. The impact of these two parameters can also be noticed in the increase in SBS values for DNH and SNH conditioning in comparison to the DH group, with increases of 65% and 84.59% respectively. The surface conditioning of the SH and DNH groups does not display statistically significant differences in SBS shear strength evidence. However, when comparing the SNH group to the SH group, there is a notable improvement of 35.73% in SBS. No significant difference was observed in the shear strengths between the DNH and SNH groups, which were distinguished only by how HF was applied.

This study concluded that regarding the two factors that have a significant impact on shear bond strength, specifically the temperature has a greater influence. When compared to the control group, the SBS values are improved by all four types of ceramic treatment.

Through the use of digital microscopy, an examination of the fractured surfaces of the specimens was conducted, resulting in the classification of failure mechanisms into three distinct categories: adhesive, cohesive, and mixed failure. The most frequent cause of failure was determined to be the mixed type. The cohesive failure only appeared in the ceramic material, whereas there was no cohesive fracture in the adhesive cement.

This study was published in the Special Issue **From Conventional towards Modern Biomaterials in Dentistry**, *Materials* **2023**, *16*(12), 4303; <https://doi.org/10.3390/ma16124303>. IF = 3,4.

With its success in restoring crowns, fixed partial dentures, and implants in cosmetic areas, all-ceramic restorations have grown in popularity. Zirconia ceramic has become widely used as a preferred alternative to metal frameworks in the context of tooth- and implant-supported restorations. This replacement has been attributed to the adaptability of zirconia ceramic to a wide range of treatment choices, along with its superior adhesion quality in prosthodontic restorations.

Despite the limited number of research investigating the use of adhesive cementation procedures by dentists, new literature indicates that the appropriate use of adhesives may lead to notable enhancements in the context of all-ceramic restorations. In order to minimize the significant clinical failure rate, it is essential for the prosthodontist to prioritize attention to the preparation design and the anticipated thickness of the restoration.

In order to achieve a strong resistance against masticatory stresses and ensure long-term durability, it is necessary to perform systematic decontamination pretreatment and surface conditioning on those involved surfaces prior to the application of adhesive cement.

The decision to use an appropriate cement is of equal significance to the application of the correct surface treatment, considering the diverse resistance values and distinct characteristics and properties demonstrated by ceramic materials.

Before adhesive cementation, the dental abutment undergoes a series of sequential processes. In the initial stages, the process of preparation involves implementing procedures to prevent the contamination of surfaces with blood, saliva, or residual cement. After rinsing the dental surface, phosphoric acid applied to the enamel will create micromechanical retention. A primer will increase chemical retention.

The objective of the study ***“Assessment of Different Techniques for Adhesive Cementation of All-Ceramic Systems”*** was to assess the current practices of dentists in terms of optimal conditioning techniques for ceramic surfaces. This was accomplished by the administration of an online questionnaire, which

involved a comprehensive review of relevant literature and manufacturers' instructions. The ultimate goal was to facilitate ongoing professional growth to improve clinical performance within the dental profession.

The application of all-ceramic cementation procedures, adhesives, and the surface conditioning of prosthodontic restorations among dentists in Timiș County, Romania, was evaluated via an anonymous questionnaire. The research selected dentists as participants, who were chosen based on their years of professional experience. The dentists were divided into two groups: group 1, consisting of individuals with 1 to 6 years of experience, and group 2, consisting of those with 6 to 9 or more years of experience. Consequently, the criteria for exclusion included those with a professional career of less than one year and those currently enrolled as dental students.

The study was divided into two distinct sections, namely a protocol referring to the cementation of oxide ceramics, specifically zirconia, and a protocol concerning the cementation of silicate ceramics, including feldspar, leucite, and lithium disilicate.

Targeting 300 dentists with various degrees of work experience, the questionnaire was distributed online for the entire period between May 2021 and April 2022 using the Google Forms platform. A total of 101 doctors, representing 33% of the survey, successfully responded to the questionnaire.

The protocols included a series of seven multiple-choice questions for each step of cementing ceramic restorations, aiming to gain insights into the practises used by practitioners. These questions focused on many aspects, including the specific kind of ceramic and cement utilised, the procedures adopted for surface conditioning, and the approach used for isolation throughout the cementation process. The questions related to the established techniques used in cementing all-ceramic dental restorations, as well as the standard processes applied when necessary or suitable. The layout of the questionnaire corresponded to the working technique and addressed problems encountered in the adhesion process of ceramic restorations.

The methodical steps of the questionnaire were developed from the existing literature and included functional approaches, used materials, and methodologies used in conducting a study on the cementation of all-ceramic restorations.

After being arranged in a Microsoft Excel database, the data was statistically analyzed. Regarding the number of years of work experience, the Mantel-Haenszel

chi-square test or the Fisher exact test was utilized to compare the cementation protocols of all-ceramic restorations between the two groups. Statistical significance indicated a probability level of $p < 0.05$.

This research highlights potential mistakes that may occur during the cementation technique, even among dentists who have received recent training and possess knowledge about contemporary conditioning methods. This study underscores the significance of continuous professional development in the profession of dentistry for practitioners at all levels of experience.

It may be observed that a significant proportion, around 50%, of the participants lacked knowledge regarding the specific kind of ceramic material they used. Conversely, the group with greater experience mostly identified the usage of zirconia or ceramic fused to zirconia restorations. Furthermore, independent of the dentist's degree of professional experience, both groups noted the need for cleaning oxide ceramic restorations subsequent to the try-in clinical procedure. Nevertheless, the use of conventional cement for the cementation of oxide ceramic restorations is considered a beneficial alternative among dentists with more years of experience in the field of dentistry. Moreover, it can be seen that the group with fewer years of experience consistently uses a rubber dam throughout the process of cementation, whilst the group with a greater level of experience tends to use it selectively.

The findings of this research, while acknowledging its limits, demonstrate the need for ongoing professional development via additional training, guidance, and control in order to enhance knowledge and ensure the implementation of adhesive systems, surface preparation techniques, and ceramic conditioning methods. Clinicians have the assignment of maintaining comprehensive information regarding the dental materials used in their practice as well as the office equipment utilized. The success of a prosthodontic restoration over a long period of time is influenced by the knowledge and skills and effectiveness of the dentist, as well as their ability to stay informed of advancements in contemporary techniques and technologies. Additional research is required to examine the workflow of a larger number of participants of clinicians and their training, in order to provide more evidence supporting the need for continuing medical education in the field of dentistry.

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This thesis will delve into the difficulties and factors to consider when achieving durable clinical outcomes in adhesive prosthodontics. It will also analyze the selection of materials and techniques used for cementation. The thesis will emphasize the need for maintaining bond integrity and prolonging the life of restorations, by outlining restoration isolation, preventing contamination, and following appropriate cleaning protocols. To have a complete comprehension of the adhesive cementation process, it is essential to understand how the surface morphology of ceramic materials reacts to specific pretreatment applications.

Through an in-depth analysis of the most recent research, clinical procedures, and treatment results, this doctoral thesis provides valuable insights into the field of adhesive prosthodontics. Continuing research in the innovative field of modern materials and digital techniques used in prosthetic treatment is necessary due to the constant evolution of technologies and equipment. By promoting the integration of scientific advancements into dental practice, the ultimate goal is to establish evidence-based protocols for dental professionals. This will help enhance patient care, improve treatment outcomes, and encourage the continued success of all-ceramic restorations.