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INFLUENCE OF THE OPTICAL PROPERTIES OF NEW CAD/CAM CERAMIC MATERIALS ON THE AESTHETICS OF PROSTHETIC RESTORATIONS

ABSTRACT

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SUMMARY OF THE PhD THESIS

1. INTRODUCTION

Technology has advanced at astounding speed during the past ten years in many facets of life. Our lives are now dominated by digital technology, from smart homes and automobiles to mobile phones. Consequently, it should not come as a surprise that digital technology is being used more and more frequently in dentistry, from special instruments used for tooth color determination to CAD/CAM systems and intraoral scanners. This technological progression aims to standardize medical practice, by reducing subjectivism and the probability of errors throughout the clinical and laboratory stages. Additionally, the communication between the dental office and the laboratory is facilitated by these digital tools, which ultimately produces far superior outcomes. Moreover, patients are increasingly concerned with the aesthetics of their dental restorations and the aesthetics of their teeth. The desire to provide as natural-looking aesthetic restorations as possible drove to the development of both dental materials and digital technologies.

Recent dental materials development has featured nanocomposite resins, polymer-infiltrated ceramics, leucite reinforced glass-ceramics, lithium disilicate reinforced glass-ceramics, zirconium dioxides and zirconia reinforced lithium silicate.

With the evolution of all-ceramic systems, digital systems for communication, analysis and verification of shade have also developed. Intra-oral color measurement systems have been created mainly to meet the requirements of clinical dentistry, including information on the corresponding shade tabs, tooth translucency, and information related to color communication, replication, and verification. A new generation of portable colorimeters, spectrophotometers, and digital cameras for clinical use has been developed to improve the success of color matching, communication, reproduction and verification in clinical dentistry and ultimately to improve the efficacy of aesthetic restorative work in any practice.

2. CURRENT STATE OF KNOWLEDGE

Color, a complex and subjective psychophysical phenomenon, represents a response to the physical interaction of light energy with an object as well as the observer’s subjective perception. Understanding pigment colors is essential for dental work because all restorative materials have color. Aesthetic dentistry places a significant emphasis on the way colors interact with one another. It is vital to have knowledge of the primary, secondary and complementary colors in order to manage and adjust hues to achieve a predictable aesthetic restorative

result. To have a complete understanding of color, one must be able to comprehend its various dimensions, including hue, value, chroma; dimensions that are represented in the Munsell system.

Color is perceived by human observers because of the interaction between the spectrum of visible light that enters the eye and the three types of color receptors that are located in the retina of the eye; these color receptors then send signals to the brain via the optic nerve.

Visual color identification using shade guides is the most commonly used method for matching shades in clinical practice. Typically, a shade guide has a series of color tabs that are compared one by one to the tooth being restored under the same lighting conditions, until the tab with the most chromatic similarity to the genuine tooth is identified. Instrumental tooth color measurements are performed with the help of spectrophotometers, colorimeters, and imaging systems. These instruments for measuring color have been developed to meet the requirements of clinical dentistry, such as the ability to measure tooth translucency, correlating shade tabs, and data related to color reproduction, communication, and verification. The data recorded by instrumental means is converted into numerical values, to quantify the dimensions of color. Currently, CIEL*a*b* color notation system of the CIE-Commission Internationale de l'Eclairage and its associated color differences formulas are frequently used for color characterization, color measurement and evaluation in dentistry.

In 1976, Commission Internationale de l'Eclairage had the aim of promoting uniformity in the color measurement, consequently they recommended the use of 2 color specification system, CIELab and CIELUV with their associated corresponding formulas for color difference. Based on the CIELab formula, the CIEDE2000 formula was published by CIE in 2001. Differences in matter of color can be quantified using either the CIELab formula or the CIEDE2000 formula.

The mechanical characteristics and clinical performance of ceramic materials are determined by their unique microstructures, grain sizes, and grain distributions. To behave like real enamel, ceramics need to have a coefficient of friction, wear processes, and surface roughness that are all comparable to those of the substance.

Digital prosthetic restorations can be made using either the additive approach, in which materials are fused or stacked, or the subtractive method, in which materials are cut from a block or disk using mechanical cutting, thanks to digital technology.

The abbreviation CAD-CAM stands for computer-aided design (CAD) and computer-aided manufacturing (CAM), a technology that allows effective and rapid fabrication of restorations including inlays, onlays, veneers, crowns, fixed and partial dentures. The CAD/CAM method has several benefits, including the ability to automate the production process, the ability to create uniform and accurate restorations, to save production stages electronically, and to have a greater repeatability. In a CAD/CAM system, scanners collect digital data of tooth structure, the software is used to design virtual protheses and the

processing machines create the restoration from various materials. In comparison to more traditional approaches, CAD/CAM systems have enabled significant cost and time savings, as well as simplification of the production process.

However, CAD/CAM technology has several downsides, including the need for expensive equipment and the need for the dentist or technician to possess the proper skills to operate the system.

Ceramic restorative materials are separated into three categories: glass-matrix ceramics, polycrystalline ceramics, and resin-matrix ceramics. Within each group, the subcategories and their constituents are analysed, making it possible to include recently discovered substances into the established primary families. The distinction between ceramic materials is based on the phases existing in their chemical characteristics. Thus, an all-ceramic material is characterized based on whether a glass-matrix phase is present (glass-matrix ceramics) or missing (polycrystalline ceramics) or whether the material has an organic matrix densely packed with ceramic particles (resin-matrix ceramics).

The materials that can be milled with CAD/CAM technology include silicates based ceramics (feldspathic ceramics, leucite ceramics, lithium disilicate ceramics and lithium silicate ceramics reinforced with zirconia), oxide ceramics (magnesium oxide ceramics, aluminium oxide ceramics or zirconium oxide), hybrid ceramics, composite or acrylic resins, wax and metal alloys.

3. AIM OF THE THESIS

In order to provide prosthetic restorations with aesthetic and mechanical properties as similar as feasible to natural teeth, ceramic materials have undergone several alterations over time.

The first objective of my doctoral research was to examine the behaviour of CAD/CAM ceramic materials when immersed in liquids often consumed by patients, with the intent of observing the optical changes that occur and determining if the test materials exhibit superior optical stability.

After immersing all-ceramic materials in gastric acid, another study monitored the microstructural alterations, changes in the tested materials hardness, color changes, and translucency changes. Through this study, I sought to determine which of the evaluated materials demonstrates the highest performance in an acidic environment and can be used for the prosthetic rehabilitation of patients with gastroesophageal reflux.

Another in vitro examined the effect of the color of the selected resin cement and the color of the abutment on the final color of the hybrid ceramic.

One of my research projects aimed to validate the spectrophotometer's measurement accuracy by utilizing many light sources to conduct measurements.

The last study aimed to evaluate any discrepancies in the optical properties of zirconia lithium silicate prosthetic restorations obtained by heat pressing versus CAD/CAM milling.

4. PERSONAL CONTRIBUTIONS

The first study entitled **Color changes of different CAD/CAM ceramic blocks after immersion in usual beverages** aimed to investigate the color stability of various CAD/CAM ceramic blocks following exposure to a variety of extrinsic dyes, replicating the clinical state of all-ceramic restorations after use for more than two years.

The following types of CAD/CAM ceramic blocks were selected for this study: leucitic ceramics (IPS- Empress CAD HT, Ivoclar Vivadent), feldspathic ceramic (TriLuxe Forte, Vita, Zahnfabrik), and lithium disilicate ceramic (IPS e.Max CAD, Ivoclar Vivadent). 16 ceramic discs were produced from each material, for a total of 48 ceramic discs.

To producing an artificial stain, three different solutions were utilized: green tea, coffee, and red wine were used for the experimental group, while distilled water served as the control. After being submerged in solutions, the ceramic discs were placed in an incubator set to a temperature of 37 degrees Celsius. In order to replicate proper oral hygiene, the discs were washed and brushed with a toothbrush after every 72 hours and also, the solution was changed.

Before being submerged, the color was determined with a spectrophotometer (VITA Easyshade V). There was a re-evaluation of color constancy after 2 and 4 weeks using the same methodology.

The color stability of CAD/CAM ceramic blocks may be compromised by regular consumption of beverages, hence affecting the cosmetic quality of the restorations.

In the present investigation, it was observed that the feldspathic ceramic material demonstrated the most notable degree of impregnation, particularly following its immersion in a coffee solution.

All the CAD/CAM ceramic blocks underwent a color change subsequent to their immersion in red wine. The study was restricted to certain limitations, namely the relatively brief immersion period and the staining of both surfaces of the ceramic material. It is worth noting that this differs from the clinical scenario when the material typically experiences staining on just one surface.

This study was published in the ***Romanian Journal of Oral Rehabilitation*** ISSN 2066-7000, ISSN-L 2601-4661, Volume 13, No.1, January-March 2021, Iasi, Romania.

The second study, **Effects of simulated gastric acid exposure on surface topography, mechanical and optical features of commercial CAD/CAM ceramic blocks,** determines the effect of gastric acid on surface topography, hardness, color stability and translucency of 4 different CAD/CAM ceramics.

The monolithic materials tested in this in vitro study were feldspathic ceramic (Triluxe Forte, VITA, Zahnfabrik), nanoceramic resin (Cerasmart, GC Europe), hybrid ceramic (Enamic, VITA, Zahnfabrik), and leucite-reinforced

glass ceramic (Empress CAD, Ivoclar, Viva- dent). Specimens were individually submerged in simulated gastric acid solution for a period of 18 hours before being placed in an incubator and heated to 37º Celsius.

The investigated parameters were the optical parameters, the translucency parameters, the microhardness, the surface roughness and scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX) analysis.

The observation of the optical properties indicated that the feldspathic ceramic material known as Triluxe Forte was the only monolithic material that had a minor alteration of color following exposure to a simulated solution of gastric acid.

Regarding microhardness investigations, it was observed that the assessed CAD-CAM monolithic materials exhibited a noticeable reduction, except for Cerasmart, which demonstrated consistent attributes throughout the evaluation. Triluxe Forte exhibited the most significant alteration in microhardness among the monolithic materials.

Based on the data collected, it can be concluded that there are no statistically significant differences observed among the dental materials Cerasmart, Enamic, and Empress CAD. The Triluxe Forte material had statistically significant variations and displayed the greatest degree of alteration in surface roughness. This alteration has the potential to weaken the restoration by causing a nonuniform distribution of stress, ultimately resulting in fracture.

The current work conducted a morphological examination, which demonstrated that all monolithic materials underwent noticeable alterations in surface topography following exposure to simulated stomach acid.

Based on the findings of this in vitro investigation, it can be concluded that there exists a growing need for enhanced restorative materials to be produced. Furthermore, it is imperative that these materials have the capability to adapt to the specific needs of individuals suffering from diverse medical problems, like gastric reflux disease, bulimia, or continuous acute nausea episodes seen during pregnancy. The enhancement of materials exhibiting enhanced mechanical, optical, physicochemical, and surface topographical properties hold the potential to enhance the overall well-being of individuals requiring medical intervention. The findings of this study unequivocally demonstrated that Triluxe Forte, a CAD/CAM monolithic restorative material, experienced significant alterations following exposure to a simulated gastric acid solution. These changes included a decrease in hardness, an increase in roughness, a change in color, the emergence of pores and irregularities, and the observation of crater-like grooves. These observations indicate the degradation of the ceramic component or other embedded materials within the Triluxe Forte material. In contrast, empirical evidence has shown that the Cerasmart monolithic restorative material exhibited the lowest susceptibility to simulated stomach acid exposure.

The results of this study will provide valuable guidance to dentists in their decision-making process on the optimal material selection for patients with

concurrent medical issues. This study was published in **Applied Sciences 2021;11(18):8703.** https://doi.org/10.3390/app11188703, in 18 September 2021, **IF 2.679.**

The third study entitled **Resin cement and substrate color influence on color difference of hybrid CAD/CAM restorations,** evaluates the optical behaviour of hybrid CAD/CAM ceramic, depending on the chosen shade of resin cement and the underlying substrate.

The monolithic materials tested in this study, were nanoceramic resin (Cerasmart, GC Europe) and hybrid ceramic (Enamic, VITA, Zahnfabrik). The resin cement used was Variolink Esthetic LC with three different shades (light, neutral and warm). A quantity of cement was positioned and enclosed between two transparent glass surfaces, followed by the application of gentle pressure. Following that, the cement specimens were meticulously extracted from the interstitial space between the glass plates, obtaining cement films with a uniform thickness of 1 mm. Three composite resin foundation specimens (14x12x4 mm) were fabricated in a silicone mold by using the A1, A3 and A3.5 shade of Evetric composite. The specimens were sequentially layered as follows: first, the composite resin foundation was applied, followed by the cement and finally the ceramic block.

This study aimed to examine the influence of the substrate material and cement color on the alteration of color in CAD/CAM hybrid ceramics. To decrease the probability of human error, it is advisable to conduct color measurements utilizing measurement tools.

The choice of cement plays a crucial role in determining the extent to which crown retention is attained. In comparison to other types of cement now available in the market, adhesive cements have demonstrated greater results when used in combination with full ceramic restorations. The optical color of the final ceramic material is determined by two factors: the composite resin foundation beneath it and the shade of the cement used.

In the present investigation, the use of three hues of resin cement generated very imperceptible modifications to the ΔE coordinates of hybrid ceramic and nanoceramic discs.

The present study is subject to various constraints, among which is the observed correlation between the thickness of ceramics and their opacity, which tends to increase.

As the thickness of ceramic material grows, a significant portion of diffused reflection takes place within the restoration. The comparative analysis of the thickness parameters of the ceramic material was not conducted within the scope of this study.

Future in vitro and in vivo investigations should investigate the impact of ceramic thickness on several optical qualities, including translucency, chroma, and color.

This study was published in ***RESEARCH AND CLINICAL MEDICINE JOURNAL,*** *Volume V, Issue 4, 2021*

The fourth study, **Influence of different illuminants on spectrophotometric tooth color determination** aims to assess the precision of a spectrophotometer in determining tooth shade under various illuminants.

To provide precise and replicable lighting conditions, a novel device named Luxvid 19 was developed and fabricated in the Prosthodontic Clinic, Faculty of Dentistry Timisoara. The device is comprised of a parallel circuit configuration, whereby eight light sources are interconnected. The functioning of each light source can be autonomous or in cooperation with others, depending on the clinician's requirements. The readings were carried out in the presence of: natural light, which served as the control group (300 lux), halogen light (1800 lux), led with warm light (1940 lux), neon ambient light (3000 lux), led with cold light (21200 lux), halogen light with neon ambient light (23400 lux), chair light at full intensity (32500 lux), both warm and cold led simultaneously on (36000 lux) and all eight light sources of the device on (44000 lux).

The examination of the middle portion of a single central incisor on a selected patient was conducted utilizing both visual observation and instrumental techniques. The shade matching process was conducted on the central region of the tooth (main body color). The purpose of this action was to minimize the impact of the transparent incisal edge and to reduce the influence of the gingival color on the cervical measurement.

The aim of this study was to assess the potential impact of ambient light on the accuracy and reliability of the Vita Easyshade spectrophotometer, when employed for tooth color determination. The use of neutral daylight is advised for shade determination, however in clinical settings, it can be challenging to achieve consistent lighting conditions due to factors such as weather, time of day, and season.

This study provides evidence to support the idea that exposure to warm light at a brightness level of 1940lux can exert a statistically significant impact on instrumental color determination. In the context of determining tooth color, it was observed that the dental unit light at its maximum intensity (32500 lux) and natural light (300 lux) were identified as the most effective illuminants.

This study has been published in **Journal of Clinical and Medical Research**, Volumes 4, Issue 4, 2022, https://doi.org/10.37191/Mapsci-2582-4333-4(4)-117.

The fifth study, entitled **Optical properties of zirconia-reinforces lithium dilisicate veneers obtained with CAD/CAM milling and hot-pressing techniques: a comparative *in vitro* study,** had the aim to evaluate any discrepancies in the optical properties of ZLS prosthetic restorations obtained by different methods, namely heat pressing and CAD/CAM milling.

Two distinct categories of zirconia-reinforced lithium silicate veneers were created utilizing two independent manufacturing methodologies. Subsequently, the materials underwent testing to assess their respective degrees of translucency and opalescence. The production of zirconia-reinforced lithium silicate (Celtra, Dentsply) veneers included the use of two techniques: heat-

pressing (Celtra Press) and computer-aided design/computer-aided manufacturing (CAD/CAM) manufacturing blocks (Celtra Duo).

The assessment of color variations between hot-pressed and milled veneers was carried out by quantifying the parameters (translucency, contrast ratio and opalescence) against a white and a black background using a spectrophotometer. In relation to the contrast ratio, a modest variation was observed while assessing the glazed veneers, resulting in a decrease compared to the polished samples.

While the overall values of the opalescence parameter are very similar, it has been noted that there is a discrepancy in opacity between the groups of polished veneers. Specifically, ZLS veneers produced through the hot-pressing process exhibit greater opacity compared to ZLS ceramic veneers created by CAD/CAM milling, which display a lower level of opacity. There are variances in the optical qualities of dental restorations produced from the same type of dental material, but through the utilization of different processing procedures. The translucency and opalescence properties of zirconia-reinforced lithium silicate appear to be primarily influenced by the specific processing procedure employed. This study was published in **Medicine and Pharmacy Reports** [Internet]. 4Sep.2023 [cited 4Sep.2023];. Available from: https://medpharmareports.com/index.php/mpr/article/view/2654

5. CONCLUSIONS

Consuming significant amounts of liquids such as green tea, coffee, and red wine on a regular basis may potentially have an impact on the aesthetic appearance of dental restorations. Regarding the color stability of leucitic, feldspathic, and disilicate ceramics for a period of two weeks and, correspondingly, four weeks after immersion in a variety of commonly consumed beverages, it was concluded that the color constancy of CAD/CAM ceramic blocks may be compromised by commonly consumed beverages.

The impact of immersion in various substances on feldspathic ceramics was found to be most pronounced with coffee, followed by red wine and green tea, in descending order. Upon immersion in red wine, it was observed that each CAD/CAM ceramic disc exhibited noticeable alterations in color.

The study regarding the effects of simulated gastric acid exposure on the surface topography, mechanical properties, and optical characteristics of commercial CAD/CAM ceramic blocks, conducted to the conclusion that the manufacturing industry is experiencing an increasing need for enhanced restorative materials that can effectively respond to the specific needs of persons with medical diseases such as gastric reflux disease, bulimia, or prolonged acute nausea episodes during pregnancy. The development of materials exhibiting enhanced mechanical, optical, physicochemical, and surface topographical characteristics has the potential to improve the overall well-being of individuals afflicted with gastric reflux disease or bulimia. The feldspathic CAD-CAM monolithic restorative material Trilux Forte, experienced

notable changes when subjected to a simulated gastric acid solution, like decrease in hardness, an increase in roughness, a change in color, the emergence of pores and irregularities, and the visibility of crater-like grooves. The nanoceramic monolithic restorative material Cerasmart demonstrated the least susceptibility to simulated stomach acid exposure. The results of this study will provide valuable guidance for dentists in their decision-making process on the optimal material choice for patients with diverse medical conditions.

Regarding the evaluation of the optical behaviour of dental ceramics depending on the chosen shade of resin cement and the underlying substrate, it was observed that the optical hue of the ultimate ceramic restoration is influenced by both the underlying composite resin substrate and the shade of the cement. The color parameters had minimal modifications due to the alteration of the underlying composite's color. In the present study, the utilization of three different hues of resin cement yielded minimal changes in the ΔE coordinates of hybrid ceramic and nanoceramic discs, rendering them nearly imperceptible.

Following the analysis of the accuracy of the spectrophotometer in determining tooth color when subjected to the influence of a variety of lighting conditions, the following conclusions were reached: the spectrophotometer provided definitive confirmation of the presence of the color shift phenomenon, a widely observed occurrence in clinical settings. When employing LED warm light for color determination, the color coordinates experienced modification. The procedure of color matching should be conducted in lighting conditions that closely resemble those experienced in typical daily situations.

The comparative study regarding the optical properties of zirconia-reinforced lithium silicate veneers obtained with CAD/CAM milling and hot-pressing techniques lead to the conclusion that dental restorations produced through various processing methods display variations in their visual characteristics, although being constituted of identical dental materials. The attributes of translucency and opalescence seem to be predominantly impacted by the manufacturing process employed for zirconia-reinforced lithium silicate. The results of this study revealed that Celtra Press HT, in comparison to the other groups under examination, distinguishes itself by displaying translucence and opacity values that nearly resemble those found in natural teeth.

It is imperative to conduct comprehensive evaluations of CAD/CAM ceramic materials in diverse settings, encompassing both laboratory conditions and real-life scenarios, in order to deliver durable aesthetic restorations, that align with the specific requirements of each patient. This is particularly crucial given the continuous advancements in technology and the ongoing evolution of ceramic materials.