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PhD THESIS

**RESEARCH ON DIGITAL MATERIALS
AND TECHNIQUES FOR THE ASSESSMENT
AND MINIMALLY INVASIVE TREATMENT OF
DENTAL WEAR**

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A B S T R A C T

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Introduction

The present thesis aims to explore the materials and digital techniques for the assessment and oral rehabilitation of tooth wear. In the digital era, novel techniques, like intraoral scanning can help the clinician to objective asses and to compare the tooth wear.

The main direction of my studies was focused on materials for the minimal invasive restoration of dental wear, like ceramic, nanoceramic and composite resin. It is well known that ceramics have overall superior mechanical and aesthetic properties, but resin-composite materials offer significant advantages related to their machinability and intra-oral repairability.

The current digital revolution fully favours digital dentistry, by introducing new materials methods and treatment concepts. With the advance of CAD/CAM (computer-assisted-design/computer-assisted-manufacturing) technologies, and the introduction of novel aesthetic materials, dental profession is undergoing a significant transformation. Technology development has led to major changes in operational methods and workflow .

Tooth wear and minimally invasive treatment options with CAD/CAM materials represent for me a challenging subject, that generates the core of this PhD thesis.

Tooth wear can be described as a physiological process that increases with age, producing changes in the appearance and anatomy of the teeth, as well as in the appearance of the lower third of the face.

It has been concluded that dental wear is in fact a multifactorial disease with a complex etiology with interconnected factors, one or more being dominating. Finding the responsible one is crucial in every treatment plan.

The prediction whether the tooth will withstand the rate of wear progression marks the boundary between normal and abnormal in terms of

dental wear. The pathological condition occurs when the teeth are so worn that they cannot fulfil their function and their anatomical shape is lost.

The cases in which the pulp can be seen through the remaining dental substance, especially in the case of the central maxillary incisors, indicate advanced tooth erosion.

Dentists should use proper diagnostic tools and indices to identify and monitor tooth wear, while adequate treatment is still possible. Tooth wear could be diagnosed based on visual examination of lesion characteristics, which can also be accompanied by clinical photography, documentation and diagnostic model. However, visual examination is subjective. Multiple methods are used to assess ultramicroscopic effects of beverages on teeth; these include surface hardness measurements, surface profilometry, iodide permeability tests, chemical analysis of dissolved minerals, microradiography, confocal scanning microscopy, quantitative light-induced fluorescence, atomic force microscopy, element analysis of solid samples, nanoindentation, ultrasonic measurements, and scanning electron microscopy (SEM).

Digital dentistry is becoming an indispensable tool in the dental office, increasing the number of intraoral scanners available on the market. Optical scanning is a part of this new technology that can offer multiple advantages like comfort for the patient, time efficiency, the reduced costs, the possibility of immediate control of the impression and 3D models that can be stored indefinitely.

The benefit of this last advantage needs to be fully explored regarding the evolution and control of erosion for the same patient in time. The most common way of measuring the accuracy of either conventional or digital impressions is by comparing a reference scan, usually obtained by scanning a physical model with a desktop or an industrial scanner, and the resulting STL file is then compared with the test scan groups.

The early diagnosis and monitorizing the progression of wear is very important in order to preserve as much dental tissue as possible.

The first study ***Intraoral scanning for early dental erosion assessment – an in vitro study*** aimed to evaluate if an intraoral scanner without specific software system can be use to diagnose early erosion based on multiple scans at different periods.

Studies regarding the detection of early erosive tooth wear using an intraoral scanner aided by specific software showed good performance for early detection and monitoring of tooth wear in vitro and has promising potential for in vivo application.

Even if it was indicated that the intraoral scanner utilized in this experiment (Planmeca, Planscan) was capable of detecting dental tissue loss and could be used to monitor early erosive tooth wear on patients, there are some limitations when considering clinical applicability. Using an intraoral scanner without dedicated software, that easily analyzes the scanned surfaces, takes additional time, requires further acquisition of third party metrology software and requires trained clinicians. In vitro conditions did not take into account the intraoral factors such as saliva, patient movement and other factors that could generate error or decrease the accuracy capabilities of the scanner. Further studies are recommended to evaluate the issue.

This study was published in the ***Romanian Journal of Oral Rehabilitation*** ISSN 2066-7000, ISSN-L 2066-7000, Volume 13, Number 1, January – March 2021, Iasi, Romania.

In the second study ***Compressive strength evaluation of thin occlusal veneers from different CAD/CAM materials, before and after acidic saliva exposure*** the three different CAD/CAM materials for chair side milling machines were considered: a nanoceramic resin (Cerasmart, GC Europe Dental Products, Tokyo, Japan), a lithium-disilicate-strengthened lithium aluminosilicate glass ceramic (Straumann Nice, Freiburg, Germany) and a composite resin (Tetric

CAD, Ivoclar Vivadent, Schaan, Liechtenstein). A complete description of the evaluated CAD/CAM material blocks.

Minimally invasive treatment approach has become an important alternative to traditional tooth preparation. Recent advances regarding the CAD/CAM materials and technology were made, offering new possibilities for the restorations of serious worn dentition where space is narrow. The development of new adhesive materials and techniques create the possibility to restore tooth wear with thin occlusal veneers, milled from different CAD/CAM blocks. To take full advantage of the benefits of these materials, new research regarding mechanical strength is useful. Knowledge regarding the mechanical properties of a restorative material has a great significance to researchers and clinicians because the extensive fracture of these materials has been reported as the major cause of failure.

The CAD/CAM restorative materials allows a precise reproduction of the tooth preparation design (veneers, full contour and partial restorations even fixed restorations with 3 elements), becoming more popular due to the numerous advantages, namely: lower costs, time-saving, stable quality of materials and improved physical, chemical, and mechanical properties.

The newest composites as well as ceramic hybrid materials allows milling surface even at a thin thickness in order to conserve the remaining substance of tooth. Occlusal veneers (table tops) from composite resin blocks have higher fatigue resistance than reinforced ceramics. The occlusal veneers are extra-coronal restorations, used to protect tooth structure, which require simple treatments modalities, based on anatomical considerations and interocclusal clearance. In addition, the occlusal veneers are easy to manufacture and highly useful in advanced erosion and attrition. Minimal tooth preparation is recommended to remove the superficial aprismatic enamel that gives low bonding strength to the composite resin. It also requires careful preparation to avoid exposing the dentine which would result in lower bonding strength. Enamel

thickness is assumed to range from 0.4 to 0.7 mm. Most of the researchers recommend 0.5 mm thickness for porcelain laminate veneer.

CAD/CAM composite materials, combine the essential properties of strength and elasticity to reduce the tooth preparation and produce a better marginal fit. Recent studies reported that resin-based ceramic materials possess good mechanical features, with surface properties quite analogues to natural teeth. Between the advantages of hybrid ceramic materials are both chairside fabrication without subsequent steps as well as esthetics and mechanical properties similar with those of lithium disilicate. Moreover, another important advantage for dental restorations is the full digital workflow, from intraoral scanning, to the digital design and milling of various CAD/CAM materials.

The mechanical strength of a restorative material largely depends on its composition, but endogenous and/or exogenous factors (i.e. acidic beverages, gastric acid, water sorption, cariogenic biofilm or salivary enzymes) may also affect the mechanical strength, by material degradation. Endogenous acids degrade both dental structure and restoration, due to the low pH value. Gastric juice is an endogenous acid with a pH ranging from 1.0 – 3.0, being highly present in the oral environment especially at patients with gastroesophageal reflux or other related disorder. For this type of patients, dental rehabilitation must be taken much more seriously and can be done by direct or indirect restoration depending on the severity of the disorder.

The purpose of this second study was the assessment of the compressive strength results of occlusal veneers milled from three type of CAD/CAM materials, with an ultrathin thickness of 0.5 mm and the degree of surface damage, before and after exposure for 1 month to acidic artificial saliva. The research hypothesis is that the use of 0.5 mm ultrathin occlusal veneers will be as resistant as thicker occlusal veneers of 0.7-1 mm when applying a higher compressive force as normal masticatory forces. In addition, we suppose that the immersion of the entire tooth-veneer complex in acidic artificial saliva, as well

as thermal cycling study contributes to the deterioration of its structure. In this sense, we want to determine the value of the maximum compression force, which can be applied to the whole complex and the degree of damage of the occlusal veneers with ultrathin dimension (0.5 mm).

The outcomes of the present study can be regarded as valuable observations for practitioners when they need to choose the most suitable materials in terms of mechanical properties, for the restoration of dental wear.

The failure degree of restorations surface damage, before and after immersion in acidic artificial saliva, was assessed according to the following classification:

First failure degree (I)—the appearance of extensive cracks at the surface of restorations;

Second failure degree (II)—the restorations were fractured;

Third failure degree (III)—both restorations and tooth structure were fractured;

Fourth failure degree (IV)—the appearance of longitudinal and profound fractures of the restorations as well as tooth structure fractures.

The SEM analysis showed that the most common degree of surface damage of the occlusal veneers in Cerasmart and Straumann Nice groups were third (III) and fourth (IV) failure degree, meaning both restorations and tooth structure were fractured; as well as the appearance of longitudinal and profound fractures of the restorations and tooth structure fractures. As regarding the Tetric CAD restorative material, the most common degrees of surface damage were first (I), second (II) and third (III) failure degrees, meaning the appearance of the extensive cracks and fractures, involving both the restoration as well as the tooth structure.

The three selected materials encompass the requirements for resistance and elasticity even in a thin layer of 0.5 mm. Moreover, we assumed that

immersing the entire tooth-veneer complex in acidic artificial saliva followed by performing the thermocycling study, contributes to the deterioration of its structure. That is why we wanted to determine the value of the maximum compression force that can be applied to the entire complex and the degree of damage of the occlusal veneers with ultrathin dimensions (0.5 mm), both for the specimens immersed in acidic artificial saliva or subjected to thermocycling, as well as for the specimens immersed in acidic artificial saliva and then subjected to thermocycling. The assumption that acidic artificial saliva would not affect any type of restorative materials considered, was rejected, because all three restorative materials suffered changes regarding their compressive strength. In order to test the significant differences between failure types within each group, the mean load of each type of failure was calculated and statistically analyzed, before and after exposure to acidic artificial saliva.

First of all, it was analyzed the specimens which comprises only the human molars covered with occlusal veneers from CAD/CAM restorative materials that were subjected to thermocycling, without being exposed to acidic artificial saliva. The outcomes from the static load tests, after thermo-cycling study, exhibited a mean failure load of 2131 N for the nanoceramic resin veneers (Cerasmart), 1919 N for the glass ceramic and 1418 N for the composite resin (Tetric CAD). Our results are higher than the failure loads, or comparable with those described in the literature for similar restorations.

Second, it was analyzed the specimens covered with occlusal veneers from CAD/CAM restorative materials which have been exposed to acidic artificial saliva followed by the thermal-cycle test. After statistical analyses, the null hypothesis was rejected and the results revealed that both the exposure to acidic artificial saliva and thermal cycling process, significantly affected the compressive strength mean values regarding the type of the CAD/CAM restorative material used. The most resistant CAD/CAM restorative material is Cerasmart (mean value – 1333 N), followed by Straumann Nice (mean value – 1313 N) and Tetric CAD, with a mean value of 1135 N.

Third, it was analyzed the specimens covered with occlusal veneers from CAD/CAM restorative materials which have been exposed only to acidic artificial saliva. Once again the null hypothesis was rejected showing that the results show statistical relevance. The most resistant out of the 3 tested materials is Cerasmart with a mean of 1591 N followed by Straumann Nice (1517 N) and Tetric CAD (1325 N) being the least resistant.

According to the results obtained, one can affirm that, the exposure to acidic artificial saliva led to a higher degradation of the CAD/CAM restorative material than thermocycling process. By performing both processes (exposure to acidic saliva and thermocycling), the degradation of the CAD/CAM restorative material is much deeper, highlighted also by the SEM analysis, which shows the degradation of the entire tooth-veneer complex, from the surface to the depth. We believe that the acidic artificial saliva has corroded the entire tooth-veneer complex and the thermocycling process has weakened him, which is why the crack lines no longer radiated in all directions at the surface of the occlusal veneers, but radiated toward the tooth. However, all the considered CAD/CAM restorations at 0.5 mm thickness demonstrated compressive strength values which exceeded both the maximum chewing force (up to 900 N), and parafunctional masticatory forces (780 – 1120 N) in individuals, even after 1 month in acidic artificial saliva. The results obtained in the present study could be owed to the adhesive cementation which makes a locked contact between the CAD/CAM restorative material, luting agent and dentinal substrate. A close contact between all three parameters can dissipate the applied force through the entire tooth, periodontal ligament even through the alveolar bone.

The present research study showed that all three types of CAD/CAM restorative materials (nanoceramic, glass ceramic and resin composite), with 0.5 mm thin thickness, and a correct cementation protocol, are suitable alternative for patients with tooth wear. The investigated 0.5 mm thickness occlusal veneers from CAD/CAM restorative materials showed a higher compressive load, compared to those immersed in acidic artificial saliva and/or submitted to thermal

cycling process, values which exceeded both normal and parafunctional bite forces, including the specimens immersed in acidic artificial saliva.

This study was published in *Odontology*, **SpringerLink** in 12 September 2022, <https://doi.org/10.1007/s10266-022-00741-5>, IF 2,885

The third study ***Full Mouth Rehabilitation of Tooth Wear using Digital and Conventional Technologies*** contains a clinical report illustrated with suggestive photos which aimed to corroborate both traditional and modern digital dentistry to obtain a desirable functional and esthetic tooth wear treatment.

A 50-years old female patient with the major complaints being esthetics and function, which presents worn teeth on both arches, maxillary and mandibular was the subject of this case report.

The vertical dimension of occlusion (VDO) has been significantly reduced by ongoing wear, and patient's esthetics have been compromised as well, so normalizing the lost occlusal function and recreating the esthetics are both required.

Because posterior teeth on the maxillary arch were missing and the patient refuses implant supported fixed dental prostheses, a hybrid alternative on natural teeth was selected. The fixed partial dental prostheses on frontal teeth with special attachments and a removable partial denture to restore the posterior edentulous area and reestablish the lost vertical dimension was fabricated.

For the mandibular arch, the treatment plan was first a provisional restoration, to test the new VDO acceptance, using a free-hand direct technique and the splint guide. The period of adaptation with the new VDO before placing the final restorations was three months duration.

After the adaptation period, a minimally invasive therapy was the chosen as final rehabilitation method. For this purpose, the teeth were minimally prepared for all ceramic restorations.

The present case report revealed the advantages of utilizing digital technologies combined with conventional methods for minimally invasive tooth wear treatment and oral rehabilitation. Advances in chairside CAD/CAM technologies and materials provide predictable and successful treatment outcome.

This case report was published in **ResClinMed.eu** Volume V, issue IV, October-December, 2021

The fourth study ***In vitro biological activity of three types of CAD/CAM dental materials, on human fibroblasts and keratinocytes*** aims to investigate in depth the biological activity of three types of restorative materials which were previously prepared to receive computer aided design/computer-aided manufacturing (CAD/CAM) occlusal veneers. The restorative materials were extensively investigated in the previous study, from the point of view of compressive strength.

Regarding the biological activity, it was evaluated the cytotoxicity of restorative materials. The cytotoxicity was assessed using the MTT proliferation test (3-[4,5-dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide), which is based on the conversion of MTT – an indicator of cell viability, into formazan crystals by living cells, which determines mitochondrial activity. Another indicator used to express the cytotoxicity is the LDH assay (lactate dehydrogenase) – an indicator of cell death, also known as LDH release assay, used to assess the level of plasma membrane damage in a cell population.

Another parameter which was evaluated in the present research study, is nitric oxide production (NO). It is well known that NO is produced by cellular organelles, including mitochondria, peroxisomes, and chloroplasts, playing a significantly role in the antioxidant and reactive oxygen species responses.

It can be observed that the fibroblasts adhere to the occlusal veneers, which shows that the restorative materials are biocompatible and represent support for the attachment and dispersion of cells. This aspect indicates a

possible positive reaction of the gum in contact with the restorative material. But, the fibroblasts do not react in the same way to the three tested restorative materials. CS and SN determine a weaker adhesion with fewer cytoplasmic extensions than TC. But with all that, it keeps its fusiform, morphologically normal appearance.

Due to the constant evolution of technologies and equipment, it is necessary to continue the research related to this innovative field of dental materials and techniques. The ultimate goal is to increase clinical efficiency in order to obtain aesthetic, functional and longlived prosthetic restorations.

This last study has been published in Medicina as part of the Special Issue New Concepts for Dental Treatments and Evaluations and is available online: <https://www.mdpi.com/1648-9144/59/1/104>, Medicina 2023, 59, 104. <https://doi.org/10.3390/medicina59010104> **IF=2,948**