UNIVERSITY OF MEDICINE AND PHARMACY
"VICTOR BABEȘ" TIMIȘOARA
FACULTY OF DENTAL MEDICINE
1ST DEPARTMENT DENTAL MEDICINE

STAN V.I. ADRIAN TUDOR

SUMMARY
PhD THESIS

INNOVATIVE IMAGISTIC METHODS IN THE EVALUATINON OF DENTAL TREATMENTS

Scientific Coordinator
PROF.UNIV.DR. MIHAI ROMÎNU

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SPECIFIC PART

The motivation for choosing the research topic is the constant need to develop the current state of non-invasive imaging techniques of dental treatments and, why not, to implement new ones with new material&method and protocol, to be used in the field of odontotherapy.

The aim of this manuscript is to address the essential issues of dental composite restorations. Why do some direct dental restorative materials fail clinically? What tests may be appropriate to predict clinical performance? Does ex vivo evaluation correlate with clinical performance? What clinical steps or methods can be taken for predictable restorations?

Despite the notable efforts of manufacturers and researchers, the ability of dental restorative materials to have a predictable clinical performance has not significantly advanced. Certain correlations between specific properties and clinical performance have been identified over the years and have been used to guide clinicians in the selection and judicious use of materials, but the science in this regard remains largely empirical.

Current research and development efforts are aimed at changing the composition of resins and filler particles to produce materials with low light-curing shrinkage and, more importantly, reducing the stress caused by light-curing shrinkage. This effort comes as a direct reply to the very sensitive and somewhat complex layering techniques required for these composite materials, and the fact that the occurrence of marginal leakage and secondary caries has consistently been the main clinical reason for replacing dental composite restorations, fracture being he second most important reason. Although some have suggested that the replacement of restorations is primarily caused by fracture in the first five years after placement and caused by secondary caries after the first five years, other studies disproven this conclusion.

There are currently thousands of published studies evaluating the clinical performance of dental composites. Undoubtedly, other clinical studies have been performed, but have not been documented in the

literature. Despite this investment of time, energy and money to study these materials, no exact and ideal chemical composition has yet been identified for the restorative material to possess the necessary properties or characteristics to ensure its long-term clinical success. Thus, new materials are subjected to several ways of testing and evaluation to know their physical characteristics, predominantly compared to other products already on the market, for which there is a test of time in relation to their clinical success. In this regard, the development of dental composites is based only to some extent on engineering design principles and, as such, many questions arise when launching a new material, questions that are answered by clinical evaluation, which often delays product acceptance by practitioners or allows immediate use with some degree of discomfort and uncertainty.

To address the problem of predictability of clinical outcomes through laboratory research, it is necessary to clearly understand the actual clinical performance through controlled evaluations or studies. This, in itself, is a significant problem because clinical data, even those from controlled studies, are usually affected by high variability.

Clinical studies show growing evidence for the long-term successful performance (> 10 years) of dental composite in small to moderate restored cavities. A 22-year study of two light-curable hybrid composites placed with a dam in class I and II cavities showed overall success rates of 75% and 64%, respectively. The main reasons for failure in these studies were dental wear, secondary caries and fracture. Other clinical studies suggest that dental composites can be expected to be predictable in the restoration of small to moderate cavities and relatively suitable for large restorations. However, performance appears to be better in premolars than in molars.

One question that needs to be addressed is the multitude of factors that affect the clinical performance of composite restorations. Three main

factors can be considered as the most notable. First, mechanical properties as well as wear resistance play a significant role. These properties depend very much on the chemical composition of the material, as designed by the manufacturer, but are also greatly influenced by the polymerization reaction and sensitive working technique, both of which are controlled by the dentist. While it is true that there are no specific design criteria, few would deny that there is a minimum threshold for every mechanical property in the composites, below which failure would be highly likely. The best evidence in this regard is that certain materials, such as glass ionomer cement (CIS) and zinc oxide eugenol cement (ZOE), can usually only be used as temporary restorations, yielding in situations of excessive occlusal stress at the level of the posterior permanent teeth. Second, the dimensional characteristics that determine marginal adaptation are of critical importance, as evidenced by the fact that the main reason for replacing composite restorations is secondary caries. These characteristics also include the volumetric contraction of the material during polymerization and a subsequent volumetric increase that may occur due to the absorption of water from the oral environment. These properties depend very much on the chemical composition of the material. Finally, the design of the prepared cavity plays a key role in long-term success, including the geometry, quantity, and quality of the remaining hard dental structure, the location of the tooth on the dental arch, and the relationship with antagonistic and adjacent teeth.

There are a variety of methods for evaluating the properties of materials available for marginal integrity composite assessment and there are standardized test methods. Recent studies of the methods and their correlation with clinical performance have concluded that laboratory research alone cannot be used to predict the clinical success of a composite. However, there are cases reported in the literature in which the clinical performance of a dental restoration could be predicted by relatively

simple and reproducible ex vivo tests. Most ex vivo studies on marginal percolation, evaluated with dyes, or marginal adaptation, evaluated using microscopic techniques, show that most materials or layering methods result in imperfect adaptation or sealing. It was concluded that there is no precise correlation between the results obtained from ex vivo marginal percolation tests and the clinical results. Similarly, a recent 10-year longitudinal study of hybrid composite / CIS, which included class I and II cavities, showed that almost half of the restorations had marginal defects and, over time, what these imperfections have increased. Thus, future studies are needed to establish the exact nature of the relationship between ex vivo marginal adaptation analysis and the clinical performance of restorative material.

The main scientific objectives of this research are:

1. Evaluation of the tooth-restoration interface, adhesive layer and surface structure / texture of different types of dental composite resins using confocal laser scanning microscopy (CLSM)

2. Assessment of the marginal and internal adaptation, as well as the volumetric dimension of the shortcomings at the interface level, of the restorations in the DRC using micro-computed tomography (μ-CT)

3. Evaluation of the marginal integrity of the sealed cavities with dental composites and Biodentine using time-domain optical coherence tomography (OCT).

The first study evaluated the interface between resin composites and the hard dental structure, the quality and thickness of the adhesive layer and the surface structure / texture of the composite resin, using confocal microscopy with laser scanning. The considered structures were measured, evaluated and the differences between the different materials

were discussed through the imagistic reconstruction. The microscopy study was possible due to the acquisition in 2011 by the University of Medicine and Pharmacy "Victor Babeș" from Timisoara, in collaboration with the University of Szeged, Hungary, within the cross-border project HURO / 0802 / 011_AF, acronym HU-RO-CARDIO -POL, of an Olympus Fluoview FV1000 confocal microscope.

The second study evaluated the marginal and internal adaptation after photopolymerization of various composite resins, using a non-destructive technique of micro-computed tomography with X-rays (micro-CT). The variables were the types of composite resins used and the different polymerization times. The μ-CT investigation was performed using the Nikon XTH 225ST device from Top Metrology (Dumbrăvița / RO) to reveal the adaptation defects or shortcomings of the restoration interface with the possibility of consecutive marginal percolation.

The third study analyzed the marginal adaptation of a bulk-fill composite material and Biodentine using optical coherence tomography in time-domain mode. This non-invasive imaging method allows a detailed quantitative and qualitative analysis of the studied dental interfaces because in current dental practice it is often difficult or even impossible to visually distinguish and control adhesion defects in adhesive restorations. OCT has been used successfully for a long time at the University of Medicine and Pharmacy "Victor Babeș" Timișoara, Faculty of Dentistry, Discipline of Propaedeutics and Dental Materials, following international collaborations with the University of Kent, Canterbury, UK. Since 2009, within the discipline there is the first national OCT system of time-domain type dedicated to applications in the field of dentistry, and since 2011 there is the first national OCT system of spectral-domain type dedicated to dental clinical applications.

The experimental protocols of the studies performed received the approval of the Commission for Ethics of Scientific Research (CECS) within the University of Medicine and Pharmacy "Victor Babeș" from Timișoara, opinion number 42-17 / 19.11.2019. Also, the materials and the experimental activity were financially supported, in part, by the doctoral grant won from the competition organized by UMFVBT, grant number 3811 / 03.10.2016.

The general conclusions of this thesis are the following:

1. CLSM provides robust and reliable information on penetration, distribution, marginal discrepancy and surface area of composite resin compared to conventional methods and can be used successfully to assess adhesion to the composite restoration interface.

2. In the restorations of the proximal cavity, especially those with apical edges located by JAC, the lack of marginal integrity is observed regardless of the bulk-fill composite used, and the SonicFill Bulk Fill composite obtained significantly lower values of lack of marginal adaptation to Filtek Bulk Fill.

3. When the marginal integrity along the four walls of the cavity was compared, the gingival wall showed more deficiencies than the rest of the cavity walls in all groups analyzed.

4. The surface roughness test procedure showed small differences between the two tested materials, both finished and unfinished.

5. It was found that the existence of polymerization shrinkage is closely related to the internal adaptation and the marginal adaptation of composite resin restorations.

6. Considerable discrepancies were detected between the different polymerization times and large variations were identified between the bulk-

fill dental composite and the hybrid resin, concluding that the bulk-fill type may be the more suitable option.

7. Micro-CT can detect non-destructively and in the smallest detail the marginal and internal adaptation around the restoration of the DRC in all three dimensions, unlike most of the other methods currently used.

8. The proposed method for evaluating internal adaptation using micro-CT imaging is already emerging and is becoming a gold standard for 3D evaluation of the adaptation of composite materials to dental tissue.

9. OCT imaging has the potential to non-destructively evaluate the interface adaptation of composite restorations and other restoration materials and to detect internal and marginal defects.

10. The bulk-fill composite obtained better results than Biodentine; however, overfilling a cavity will compromise the sealing of the adhesion interface regardless of the type of composite used.

11. Due to the major discrepancies between the marginal integrity of the composite material and Biodentine, to the detriment of the latter, it is not recommended to use the open-sandwich technique or any other technique that will leave a direct connection between Biodentine and the oral cavity.

12. 90% of the restorations had fractures and / or lack of marginal adaptation, considered niches for the early dissemination of new fracture lines or caries.

13. The diagnostic power of OCT was greater than that of visual inspection for marginal adaptation. In addition, with OCT, clear images were observed in section in the depth of the interface.

14. The present study demonstrated the ability of the OCT method in visualizing the morphology and integrity of dental restoration interfaces to be used for further development of OCT instruments in vivo.

Personal contributions:

1. Development of protocols dedicated to research in the field of dentistry using confocal laser scanning microscopy.

2. Finding a laser wavelength of the confocal microscope adapted to dental hard tissues, for a high quality imaging acquisition.

3. Demonstration that the use of Biodentine for the restoration of cervical root lesions / cavities (according to the manufacturer's instructions) is not recommended.