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NON-INVASIVE METHODS OF PULPAL BLOOD FLOW ASSESMENT AFTER TOOTH PREPARATION FOR PROSTHETIC RESTORATIONS

ABSTRACT

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Introduction:

Currently, prosthetic restorative procedures are widely utilized therapeutic options, even among younger patients. Contemporary restorative prosthodontic practices emphasize conservative tooth preparation to preserve maximal dental structure, aiming to minimize any impact on the biological integrity of the teeth. The primary goal during prosthetic preparation of vital teeth is to maintain pulp vitality. However, the heat generated during this process poses a risk to the dental pulp, potentially leading to inflammation and tissue death. The degree of heat transferred to the tooth varies depending on factors such as the type of burs used, cutting parameters, applied pressure, cooling techniques, and rotary instrument settings. Elevated temperatures in the pulp chamber can result in pulpal alterations, potentially compromising pulp vitality. Thus, post-procedure vitality assessment is crucial for managing vital teeth. Dentin hypersensitivity commonly occurs after tooth preparation, manifesting as sharp, transient pain. Exposure of dentinal tubules during prosthetic preparation increases dentin permeability, leading to pulpal irritation. Although various treatments for dentinal hypersensitivity have been explored, a standardized protocol remains elusive. Enhancing understanding of pulpal health in the context of prosthetic treatment on vital teeth can significantly impact clinical practice and advance treatment options. The selection of this topic for the doctoral thesis stems from the need for improved knowledge about factors influencing dental pulp health in relation to prosthetic interventions. By investigating dental pulp temperature regulation and microcirculation assessment post-prosthetic preparation, we aimed to deepen comprehension of these factors and their impact on pulp health. Our research focused on refining the laser Doppler flowmetry (LDF) vitality assessment technique through the development of a more precise, efficient, and comfortable LDF probe holder, aiming to improve the predictability of laser Doppler measurements.

The first part of this thesis (the general part) reflects the current state of knowledge in the field.

Prosthodontics navigate nowadays through a landscape of historical significance and future prospects. While emphasizing functionality and aesthetics of the restorations combined with integrity preservation, modern practices heavily rely on digital technologies and minimally

invasive techniques facilitated by CAD/CAM systems. However, challenges persist, particularly in margin design for all-ceramic restorations and ensuring the durability and efficiency of diamond burs through proper sterilization. Enamel cutting, crucial yet invasive, underscores the necessity of understanding the dentin-pulp complex physiology to maintain pulp vitality during preparation. Moreover, the integration of Laser Doppler flowmetry (LDF) offers promising perspectives for non-invasive assessment of pulpal vitality, evaluating dynamic changes in blood flow to provide real-time insights into tissue health. LDF's objectivity and ability to provide continuous, real-time measurements contrast with traditional sensibility tests, offering superior accuracy and repeatability in evaluating vascular dynamics. Its non-invasive nature and ability to quantify blood flow dynamics before the onset of clinical symptomatology present notable advantages in dental diagnostics. Moreover, the monitorisation of intra-pulpal temperature rise during tooth preparation emerges as a critical concern, given its potential to cause irreversible pulp pathology. Studies highlight the threshold temperature rise to avoid such effects and emphasize the correlation between heat transfer, dentin thickness, and degenerative parameters post-preparation. Despite the significance of heat control in dental procedures, limited quantification exists, underscoring the need for further research in this area.

The second part of the thesis (personal contribution) includes four studies, aimed to delve into the previously stated knowledge gaps from the literature.

The first study, *Evaluation of the Pulp Chamber Temperature During Tooth Veneer Preparation Using Burs with Different Degrees of Wear—A Preliminary In Vitro Study*, is an in-vitro experiment aimed to evaluate whether the different degrees of wear of the diamond burs significantly influence the temperature changes in the pulp chamber during tangential veneer preparation. The sample comprised 30 intact permanent monoradicular teeth, randomly assigned to three study groups of 10 teeth each, out of which 5 had the pulp tissue preserved and 5 had thermo-conductive paste in the pulp chamber. For prosthetic preparation, new burs were used in the first group, burs at their fifth use in the second group, and burs at their eighth use for the third group. The pulp chamber temperature was evaluated at the start, after one minute, and after three minutes of preparation, using a k-type thermocouple. The results of the statistical analysis using three-way ANOVA and Tukey post hoc comparisons showed a highly significant effect of the time of measurement, while the pulp condition and the degree of wear

of the burs had no effect. In conclusion, the study revealed that different degrees of wear of conventional diamond burs do not produce statistically significant different changes in the pulp chamber temperature.

The second study, *Analysis of the Pulpal Blood Flow Microdynamics During Prosthetic Tooth Preparation Using Diamond Burs with Different Degrees of Wear*, continues the work from the first study, transitioning from an experimental in-vitro setting to in-vivo conditions. Moving from controlled laboratory conditions to real-world applications adds depth and relevance to our findings. The aim of this in vivo study was to evaluate whether the wear of diamond burs has an influence on the vascular microdynamics at the level of the dental pulp, during tangential preparation for zirconia crown. The study was performed with a split-mouth design and included 32 vital permanent monoradicular teeth (20 maxillary and 12 mandibular), from 6 subjects, aged between 20-50 years. The teeth were randomly assigned to two study groups of 16 teeth each. For prosthetic preparation, new burs were used in the first group, and burs at their fifth use were used in the second group. Four consecutive determinations of the pulpal blood flow by Laser Doppler flowmetry were taken for each tooth included in the study: before the preparation (control values), immediately after, at 24 h and at 7 days after the prosthetic preparation. A four-way ANOVA statistical analysis was applied to analyse the effect of four considered factors (bur wear degree, time of measurement, tooth number and tooth location) on the pulpal blood flow. A significant increase in pulpal blood flow compared to the baseline was recorded immediately after preparation ($p < 0.01$), at 24 hours ($p < 0.01$), and at 7 days ($p < 0.05$) in both groups, but more pronounced in the case of burs at the fifth use. The blood flow was significantly higher in upper jaw teeth, irrespective of the measurement time. In conclusion, the use of worn-out diamond burs was found to produce lasting modifications in the pulpal blood flow of teeth that undergo prosthetic crown preparation.

The third study, *Using Laser-Doppler Flowmetry to Evaluate the Therapeutic Response in Dentin Hypersensitivity*, was intended to investigate whether assessing dental pulp vascular micro-dynamics by laser-Doppler flowmetry (LDF) would be functional for therapeutic evaluation, in contrast to a verbal rating scale (VRS). A split-mouth single-blind randomized study was conducted on seven patients and a total of 36 teeth. Two dentin hypersensitivity (DH) therapeutic methods were employed: (i) fluoride gel; (ii) Nd:YAG radiation combined with fluoride gel. For each tooth, five consecutive LDF determinations of pulp blood flow were made (before and immediately after desensitizing treatment, then after 24

h, 7 days, and 1 month), and the VRS was applied each time. Spearman's correlation was applied for concurrent validation. Two-way (treatment and patient) repeated measures ANOVA full factorial was applied, followed by Tukey's post-hoc comparisons and Pillai's trace multivariate statistic. While VRS scores had moderate reliability, LDF could objectively estimate treatment effects. In conclusion, LDF proved to be an objective technique that can quantitatively assess DH evolution, and it is effective in reliably monitoring oral health and therapeutic interventions.

Lastly, **the fourth study**, *Digitally Designed and Manufactured Laser Doppler Probe Holder for Tooth Vitality Assessment – A Novel Technique*, was a pilot study with the purpose of developing a new method to facilitate laser Doppler tooth vitality assessment, using a digitally designed probe holder. Two probe holders, for upper and lower arch, were designed by scanning a casted model, followed by 3D printing of the probe holders. In order to test the probe holders, a straight optical probe from MoorLab instruments was used. The probe holder proved to be stable and could be used to obtain accurate signal acquisition in the given experimental conditions.

Conclusions:

This comprehensive doctoral study provides valuable insights into various aspects of dental pulp temperature regulation, pulpal blood flow, microcirculation assessment, treatment of dentinal hypersensitivity and probe holder design. Through meticulous experimentation and analysis, several conclusions have emerged, each shedding light on critical aspects of our research.

In the first study, *Evaluation of the Pulp Chamber Temperature During Tooth Veneer Preparation Using Burs with Different Degrees of Wear—A Preliminary In Vitro Study*, we examined the influence of conventional diamond burs with different degrees of wear on the temperature changes within the dental pulp chamber during prosthetic tooth preparation. Despite limitations such as small sample size and uncontrolled variables, our findings revealed that:

- the degree of bur wear did not significantly affect the temperature variations, underlining the reliability of conventional methods in dental practice;
- the prosthetic preparation of the frontal teeth, using conventional diamond burs with

different degrees of wear (first use, fifth use, and eighth use) under water cooling, produced similar but highly statistically significant decreases in temperature at the level of the teeth pulp chamber;

- the use of cooling water during tooth preparation with a high-speed handpiece is effective in preventing an intra-pulpal temperature increase;
- thermal imaging remains a valuable tool for non-invasive temperature monitoring and provides valuable insights into thermal dynamics during prosthetic tooth preparations;
- the integration of thermal imaging technology into dental research protocols offers valuable insights into the thermal dynamics associated with dental procedures;
- the observed cooling effect of handpiece cooling water highlights the need for further investigation into strategies to optimize temperature management during dental interventions, ultimately contributing to enhanced patient outcomes and treatment efficacy.

Building upon this foundation, the second study, *Analysis of the Pulpal Blood Flow Microdynamics During Prosthetic Tooth Preparation Using Diamond Burs with Different Degrees of Wear*, explored the impact of bur wear on pulpal blood flow, presenting intriguing results that question established beliefs. Despite the need for enhanced study design and variable control, our observations suggest that:

- burs with a certain degree of wear may induce a more pronounced increase in pulpal blood flow compared to new burs, emphasizing the complexity of dental prosthetic procedures;
- the micro dynamics of PBF exhibited a similar upward trend immediately after preparation, accentuated immediately post-grinding, with a downward trend after 7 days, maintaining a level higher than the baseline.

The third study, *Using Laser-Doppler Flowmetry to Evaluate the Therapeutic Response in Dentin Hypersensitivity*, investigated dental hypersensitivity treatment by utilizing Laser Doppler Flowmetry to objectively assess alterations in pulpal microcirculation. Our findings underscored the following aspects:

- the potential of LDF as a reliable instrument for assessing therapeutic efficacy,

offering a versatile approach beyond subjective pain scales in clinical settings;

- LDF reliably recorded the changes occurring in dental pulp microcirculation at all assessment times of the study, even when the patient did not identify any change from a clinical point of view through VRS;
- this proof-of-concept study demonstrated that LDF is an objective instrument to evaluate and quantify the effects of DH treatment. LDF can capture the contribution of many concurrent factors and their interactions, in contrast to the subjective one-dimensional pain scales used in current practice.

Lastly, the fourth study, *Digitally Designed and Manufactured Laser Doppler Probe Holder for Tooth Vitality Assessment – A Novel Technique*, focused on optimizing probe holder design for precise and efficient measurement of dental parameters. Our digitally designed holders exhibited superior stability, customization options, and ease of disinfection compared to traditional counterparts, paving the way for enhanced diagnostic accuracy and procedural efficiency in prosthodontic practice:

- the digitally designed and 3D printed probe holders are more stable, fit perfectly and might also better isolate the testing surfaces, compared to a double silicone impression; however manufacturing is more time consuming, implies more steps and additional equipment is needed;
- the digitally designed holder offers a better fit and isolation, so that the signals that come from the gingiva or the neighbouring teeth are not interfering with the signal acquisition;
- the manufactured holders are light weight and permit individualizations, so they can be more helpful for determinations at the level of the prepared teeth for different prosthetic restorations;
- the positioning of the optical probe within the holder is digitally pre-determined, this way after fitting the holder in place the possibility of positioning errors is reduced;
- the holder can also be disinfected more easily compared to the condensation silicone holders.

In summary, the clinical and experimental research carried out within this doctoral study has made a substantial contribution to the field of dental research, overcoming limitations, exploring novel areas, and offering innovative solutions. Moving forward, the insights from these studies lay a strong groundwork for future research, clinical practice, and progress in dental science.