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„CAROL DAVILA" UNIVERSITY OF MEDICINE AND PHARMACY, BUCHAREST
DOCTORAL SCHOOL
DENTAL MEDICINE

APPLICATIONS OF 3D TECHNOLOGY IN ENDODONTICS

SUMMARY OF THE DOCTORAL THESIS

Doctoral supervisor:
PROF. UNIV. DR. PERLEA PAULA

PhD student:
ȘTEFĂNESCU COSMIN

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TABLE OF CONTENTS

LIST OF ARTICLES PUBLISHED WITHIN THE DOCTORAL RESEARCH

1. Perlea P, **Stefanescu C***, Al-Aloul OA, Ionita C, Petre AE. Digital Workflow for Producing Hybrid Posts and Cores. Healthcare (Basel). 2023 Mar 2;11(5):727. doi: 10.3390/healthcare11050727. PMID: 36900732; PMCID: PMC10001014[1].
(ISI- Factor de impact 2.8, Indexat PubMed)
Link: https://www.mdpi.com/2227-9032/11/5/727
Capitolul 7 (paginile 99-114)

2. Perlea P, **Stefanescu C***, Petre AE. Clinical Acceptance of Digitally Produced Zirconia and Metal Post and Cores, Based on the Impression Method. Clin Pract. 2024 Nov 20;14(6):2533-2541. doi: 10.3390/clinpract14060199. PMID: 39585027; PMCID: PMC11586991[2].
(Indexat PubMed)
Link: https://pubmed.ncbi.nlm.nih.gov/39585027/
Capitolul 5 (paginile 35-73)

INTRODUCTION

The topic of this doctoral research was proposed by analyzing the new trends in modern dentistry regarding the extensive use of treatments performed using digital technologies. In this way, clinicians can offer predictability and safety to patients by applying methods and technologies extensively studied and analyzed in the specialized literature. The subject is of high global interest, given the competition among manufacturers of digital technology, which have impressively advanced in research and development of CAD-CAM applications designed for both dental laboratories and, increasingly, dental clinics. The evolution has been so rapid that the vast majority of dental practitioners can now afford a CAD-CAM system for their practice, due to the price accessibility resulting from competition among major companies.

The first research direction analyzes the accuracy and precision of deep scanning of the preparation for this type of restoration. Five scanners will be used and a comparative analysis of the obtained digital impressions will be conducted. The choice of this doctoral thesis topic is motivated by the need for a rigorous assessment of the precision and accuracy of intraoral scanners in the fabrication of post and cores restorations, especially after endodontic treatments, where the fidelity of the digital impression is critical for proper adaptation of the restoration. Considering the rapid technological advancement and the lack of a generalized consensus on the performance of various intraoral scanners in this specific indication, the proposed research aims to provide clarity and objective evidence regarding the clinical efficiency of this technology. The topic aligns with the current trend of digitization in dentistry and contributes to optimizing the post-endodontic digital protocol.

The second research direction aims to perform a comparative analysis of restorations obtained in the dental laboratory following digital impressions versus conventional impressions.

The third research direction aims to develop a new fully digital technique for post and cores, without the use of conventional impression materials, consisting of a radicular part with the physical properties of dentin and a coronal part with the physical properties of zirconia.

II. PERSONAL CONTRIBUTIONS

CHAPTER 3 – WORKING HYPOTHESIS AND GENERAL OBJECTIVES

3.1. General Hypothesis

The general working hypothesis of this doctoral study was that 3D technology has major applicability in the field of endodontics, as opposed to other fields of dentistry where it has already left its mark for decades: fixed prosthodontics, removable and semi-removable prosthodontics, implantology, oral surgery, and orthodontics.

The increasing use of digital tools in dentistry has generated a growing demand among clinicians worldwide to understand and implement them. In the last decade, there has been an exponential increase in the number of specialized articles focusing on digital methods and technologies in all areas of dentistry.

Driven by the desire to contribute to this trend and the need to develop new digital methods, the general hypothesis of this doctoral research was formulated with the aim of developing new applications of 3D technology in endodontics and investigating the behavior of post and cores restorations, which are essential after endodontic treatment of teeth severely damaged by dental caries.

3.2. Objectives of the Study

The general objectives of this doctoral research focused on:

- Applying CAD-CAM technologies to address restorative needs following endodontic treatment;
- Analyzing the performance of intraoral scanning in the field of endodontics;
- Evaluating the digital workflow protocol for obtaining post and cores after endodontic treatment and comparing it with conventional methods;
- Developing a new fully digital technique for fabricating post and cores.

The specific objectives of this doctoral research aimed to:

- Perform a comparative evaluation of the accuracy and precision of five intraoral scanners in capturing digital impressions for post and cores
- Identify the impression method that enables the most accurate digitally fabricated post and cores restorations and compare the most commonly used materials for these post-endodontic restorations: metal vs zirconium oxide;

- Develop a novel digital method for fabricating a hybrid post and core restoration that presents, in its radicular portion, dentin-like properties within the prepared endodontic space, and in its coronal portion, enhanced strength to provide support and retention for a future crown.

CHAPTER 5 – SCANNING EFFICIENCY IN TERMS OF ACCURACY AND PRECISION FOR POST AND CORE RECONSTRUCTION AFTER ENDODONTIC TREATMENT

5.1 Introduction

Given the necessity of precision and accuracy in scanning preparations for post and cores, the existing literature provides data emphasizing the impact of scanning on capturing the surfaces within the prepared root canal. If the scan does not accurately reproduce the prepared surface, the post and core restoration will not fit properly. Therefore, an in vitro study was proposed to comparatively assess the accuracy and precision of scanning this type of preparation using five of the most commonly used intraoral scanners. The null hypothesis formulated was that the type of scanner used would have no impact on the accuracy and precision of scans for post and cores restorations.

5.2 Materials and Methods

The study was conducted between September 2024 and April 2025 in the Aspen Dental Laboratory, Bucharest, Romania.

A reference scan was performed using a high-precision laboratory scanner – Medit T710. Then, sequential scans were obtained using five intraoral scanners: 3Shape TRIOS 3 (Copenhagen, Denmark), 3Shape TRIOS 4 (Copenhagen, Denmark), Sirios Straumann (Basel, Switzerland), Medit i900 (Seoul, South Korea), and iTero Element 2 (Tempe, USA). The scanning protocol was identical for all 50 scans and executed by the same operator, following the manufacturers' guidelines.

In each of the five scanners' software, a new scan was initiated by selecting the appropriate button and entering a virtual name "Test". The tooth map was then selected for TRIOS 3 (Figure 5.6), TRIOS 4, Medit i900, iTero Element 2, and Straumann SIRIOS, to allow the scanner to proceed with the actual scanning process.

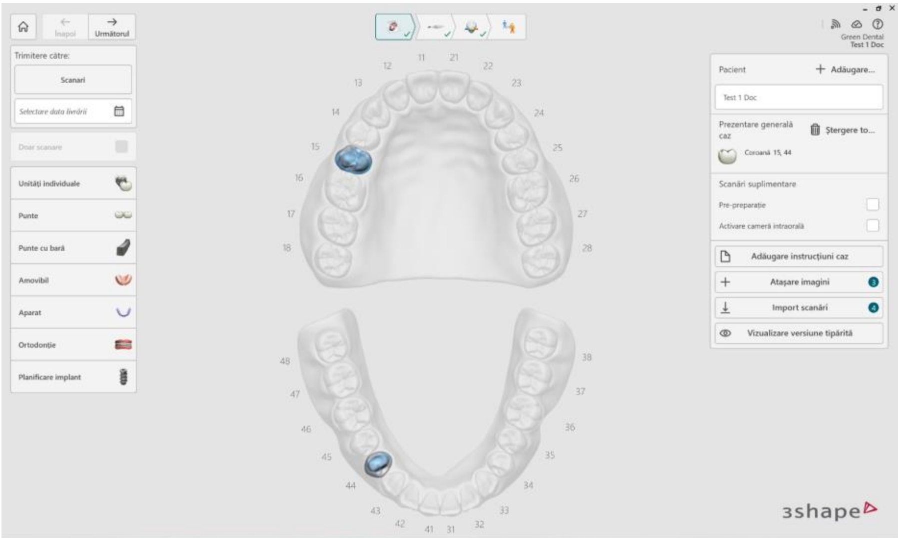

Figure 5.6. Tooth map for TRIOS 3 (screenshot, personal archive)

For accuracy analysis, each STL file was aligned with the reference STL file, resulting in ten datasets per group. For precision analysis, each STL file was aligned with every other scan from the same category, resulting in 45 datasets per group. For this purpose, the Geomagic Control X software from 3D Systems (Rock Hill, USA) was used (Figure 5.19).

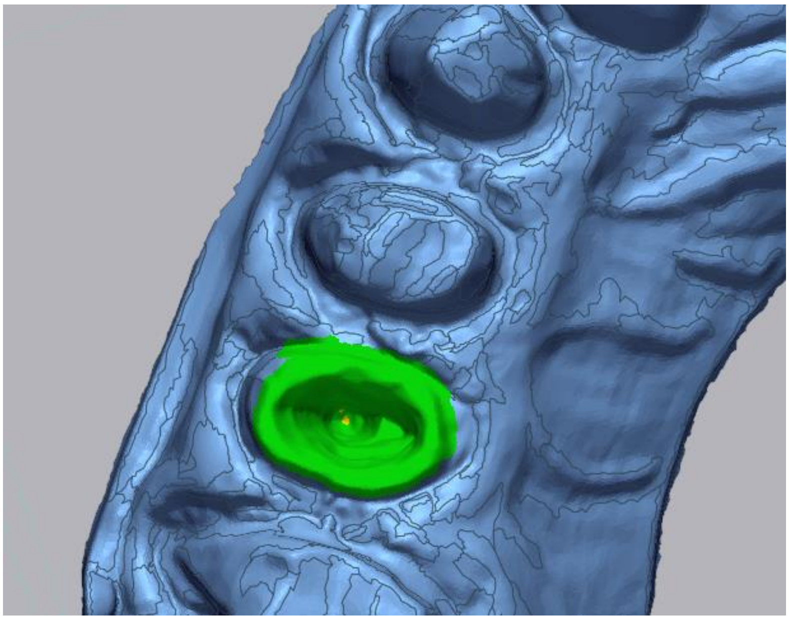

Figure 5.19. Prepared surface for post and core restoration placement (screenshot, personal archive)

5.3 Results

The normality of the results was assessed using the Shapiro-Wilk test, which indicated p-values > 0.05 for both accuracy and precision. Therefore, one-way ANOVA was used to test for possible differences in the root mean square deviations among the five study groups.

For the accuracy analysis, a p-value < 0.05 (1.17×10^{-10}) was obtained (Figure 5.20), indicating significant differences among the study groups. Similarly, the precision analysis also yielded a p-value < 0.05 (5.32×10^{-98}) (Figure 5.21), indicating significant differences among the groups.

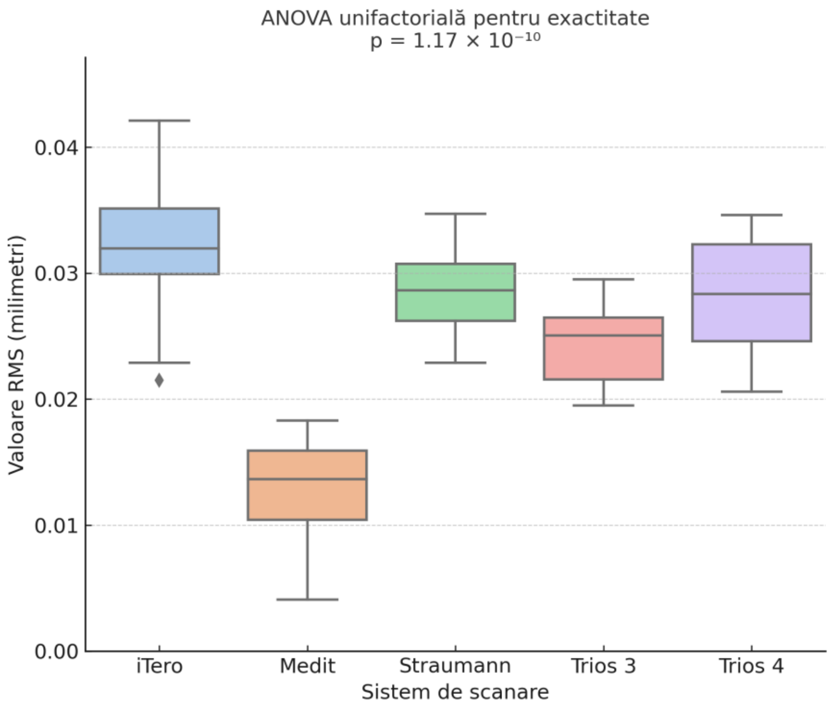

Figure 5.20. One-way ANOVA for accuracy

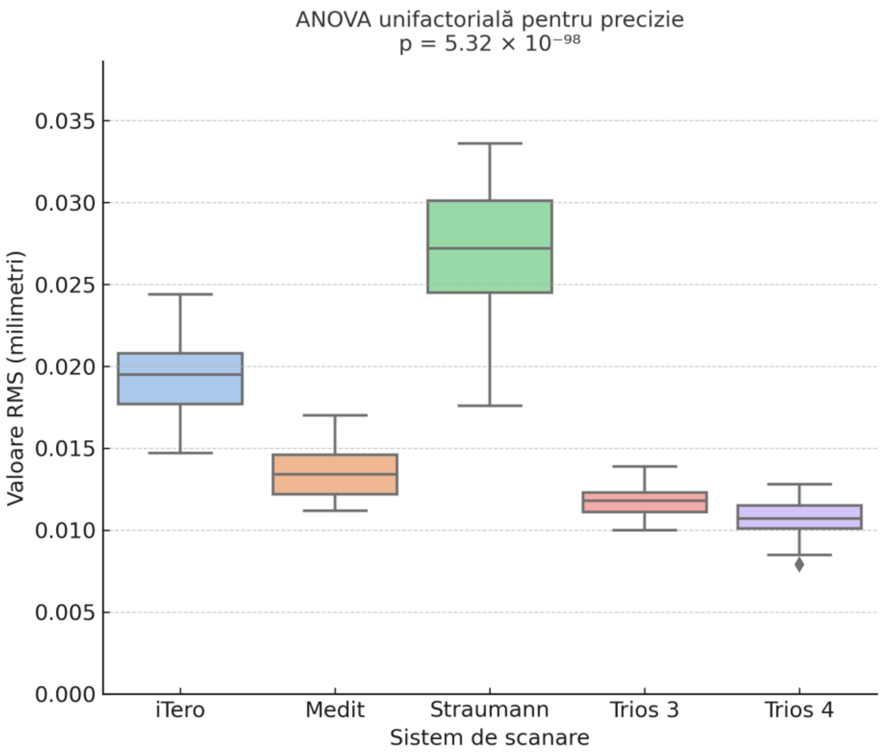

Figure 5.21. One-way ANOVA for precision

5.4 Discussion

These results are consistent with recent literature evaluating the performance of intraoral scanners in similar contexts. Studies by Taha et al.[3] and Emam et al.[4] reported that Medit scanners offered superior accuracy in capturing post spaces compared to TRIOS systems. Similarly, Dupagne et al.[5] showed that Medit i700 produced comparable or superior results to Omnicam and TrueDefinition when scanning post preparations.

5.5 Conclusions

In conclusion, the Medit i900, TRIOS 3, and TRIOS 4 demonstrated superior accuracy and precision in digitally scanning preparations for post and cores restorations. These findings support the use of new-generation intraoral scanners when capturing such impressions, providing high clinical potential in ensuring correct adaptation and long-term success of restorations.

The null hypothesis formulated at the beginning of the study was rejected for both the accuracy and precision analyses. The comparative evaluation revealed significant differences among the scanners tested.

CHAPTER 6 – ACCEPTABILITY OF DIGITALLY MADE POST AND CORE RECONSTRUCTIONS AFTER ENDODONTIC TREATMENT, ACCORDING TO THE IMPRESSION METHOD

6.1 Introduction

This study aims to determine how many of the posts received from the dental laboratory are accepted for cementation by clinicians and how many are rejected. This crucial criterion, referred to as clinical acceptability, reflects the percentage of post and cores deemed acceptable by dentists upon arrival from the dental lab, prior to cementation. Accordingly, a null hypothesis was formulated: there are no differences in the clinical acceptability of zirconia post and cores obtained via conventional versus digital impressions. Additionally, another null hypothesis was formulated: there are no differences in the clinical acceptability of metal post and cores obtained via conventional versus digital impressions.

6.2. Materials and Methods

The study was conducted by collecting data from the Aspen dental laboratory (Bucharest, Romania) for the calendar year 2023 (January–December).

From the Dent Estet dental clinic (98 Aviatorilor Blvd., Bucharest, Romania), a total of 577 impressions—both digital and conventional—were received and deemed clinically acceptable.

The same laboratory fabricated the post and cores based on both digital intra-canal impressions and conventional impressions using condensation silicone in two viscosities: putty and light body.

PROCEDURE for post and cores based on digital intra-canal impressions:

The digital impression recorded with an intraoral scanner (TRIOS 4, 3Shape, Denmark) was received and the integrity of the prepared root canal was checked on the scanner screen.

The STL dataset was used to design the post and core in CAD software (Exocad Rijeka, EXOCAD GmbH, Germany). The cement space parameter was set to 50 µm on the entire internal surface of the post and core.

3.a. After design completion, the STL files were sent to a 5-axis milling machine (CORiTEC® 250i Loader PRO, Imes Icore GmbH, Germany) for milling the zirconia disc (Luxen, Dentalmax, South Korea). The attachment pins were cut and finished. The post and cores were sintered in a furnace (AUSTROMAT Series 6, DEKEMA Dental-Keramiköfen GmbH, Germany) for 11 hours at a peak temperature of 1530°C.

3.b. Alternatively, STL files were sent to a 3D metal printer (MySint100, Sisma, Italy) using Cr-Co powder for laser sintering of metal post and cores. The attachment pins of printed posts were then cut and finished (Figure 6.1).

Figure 6.1. Post attachment pins on the 3D metal printer platform (personal archive)

PROCEDURE for post and cores based on conventional silicone impressions:

1. Impressions were taken using condensation silicone (Speedex, Coltene, Switzerland) in two viscosities. These were sent immediately to the lab.

2. The impressions were scanned using a lab scanner (Medit T510, Medit, South Korea). The STL files were used to design the post and cores in CAD software (Exocad Rijeka). Cement space was set to 50 µm throughout the internal surface.

3.a. After design completion, STL files were digitally ordered (Figure 6.2) and sent to a 5-axis milling machine (CORiTEC® 250i) for milling zirconia discs. Post-milling, the attachment pins were cut and finished. The post and cores were sintered in zirconia furnaces: AUSTROMAT Series 6 (DEKEMA) (Figure 6.3) and HTS – 2/M/ZIRKON-120m (MIHM-VOGT GmbH, Germany) (Figure 6.4) for 11 hours at 1530°C.

3.b. 3.b. Alternatively, STL files were sent to a 3D metal printer (MySint100) with Cr-Co powder. Printed posts were then cut and finished.

Figure 6.2. STL files digitally arranged in the zirconia disc (personal archive)

After laboratory procedures, clinicians evaluated each post and core both extraorally and intraorally. If the adaptation was unsatisfactory, no adjustments were made. The lab received a binary response for each post and core: accepted or rejected. All responses were compiled into a table (Annex 2), forming the study database for post and core acceptability throughout 2023. A total of 577 post and cores were examined and divided into four groups: Group 1 were Cr-Co post and cores from conventional impressions, Group 2 were Cr-Co post and cores from digital impressions, Group 3 were zirconia post and cores from conventional impressions and Group 4 were zirconia post and cores from digital impressions.

Differences in acceptance rates between zirconia and Cr-Co post and cores were analyzed using the Chi-squared test in Prism software (GraphPad, USA).

6.3 Results

A total of 577 post and cores were fabricated. Of these, 234 were Cr-Co and 343 were zirconia (Figures 6.5, 6.6).

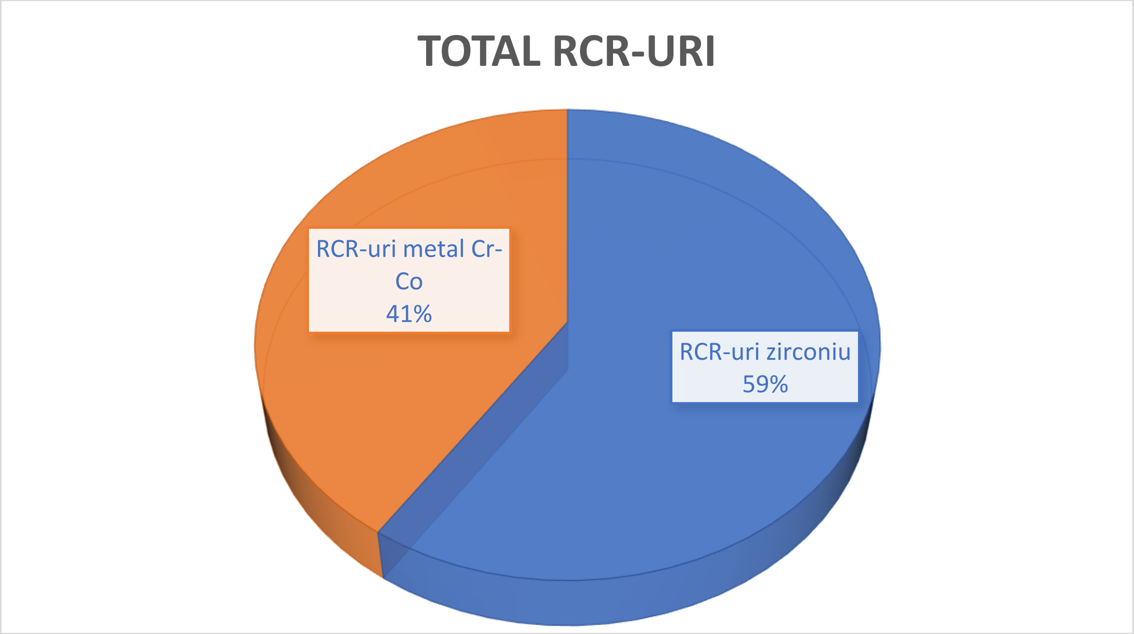

Figure 6.5. Cr-Co vs zirconia post and cores percentage

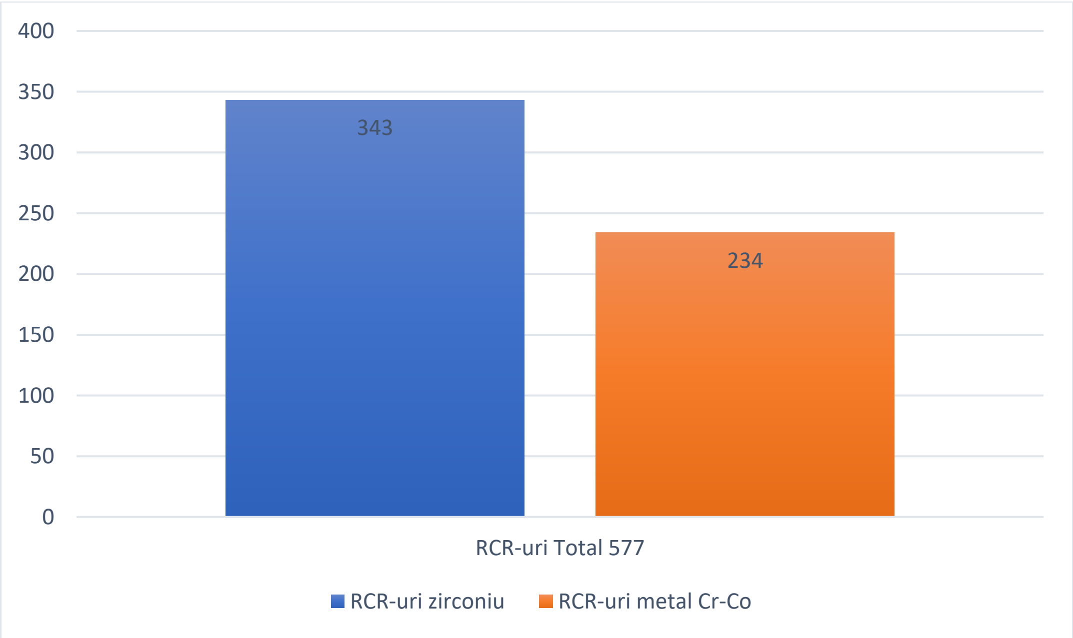

Figure 6.6. Cr-Co vs zirconia post and cores count

Clinical acceptability for Cr-Co post and cores was 95% for both conventional and digital impressions. The Chi-squared test yielded p = 0.98, indicating no significant statistical difference (Figure 6.23).

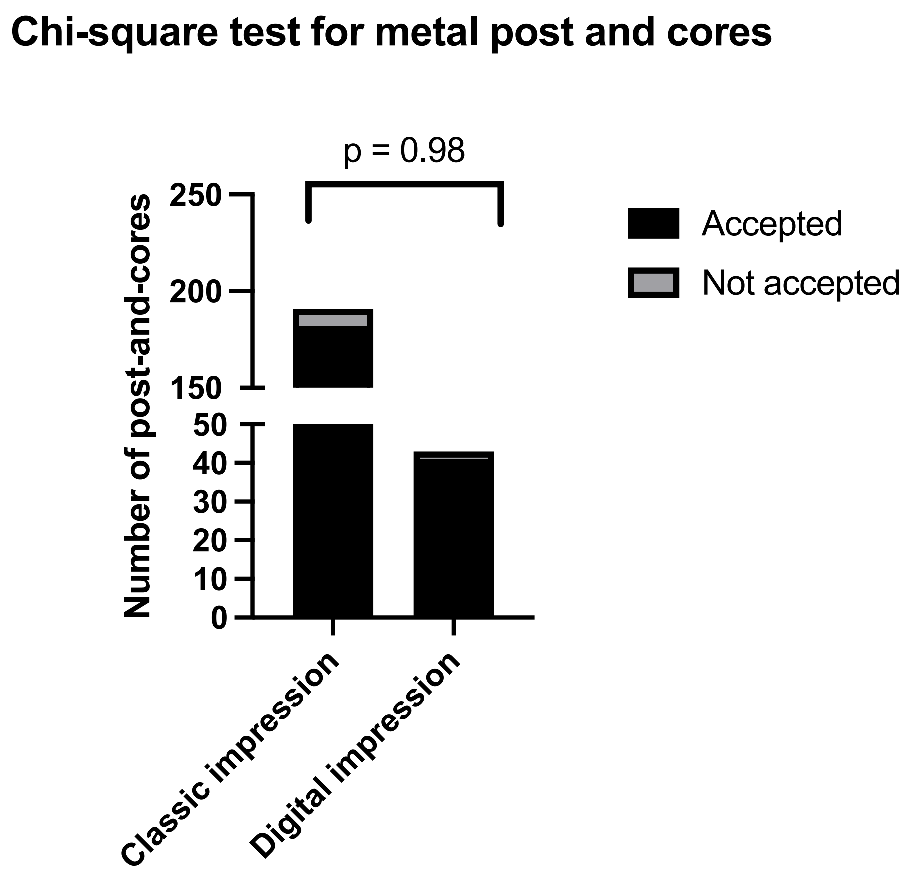

Figure 6.23. Chi-squared test for Cr-Co post and cores

Zirconia post and cores from conventional impressions had a 95% acceptance rate, while digital ones had 88%. Chi-squared test gave $p = 0.02$, indicating a statistically significant difference (Figure 6.24).

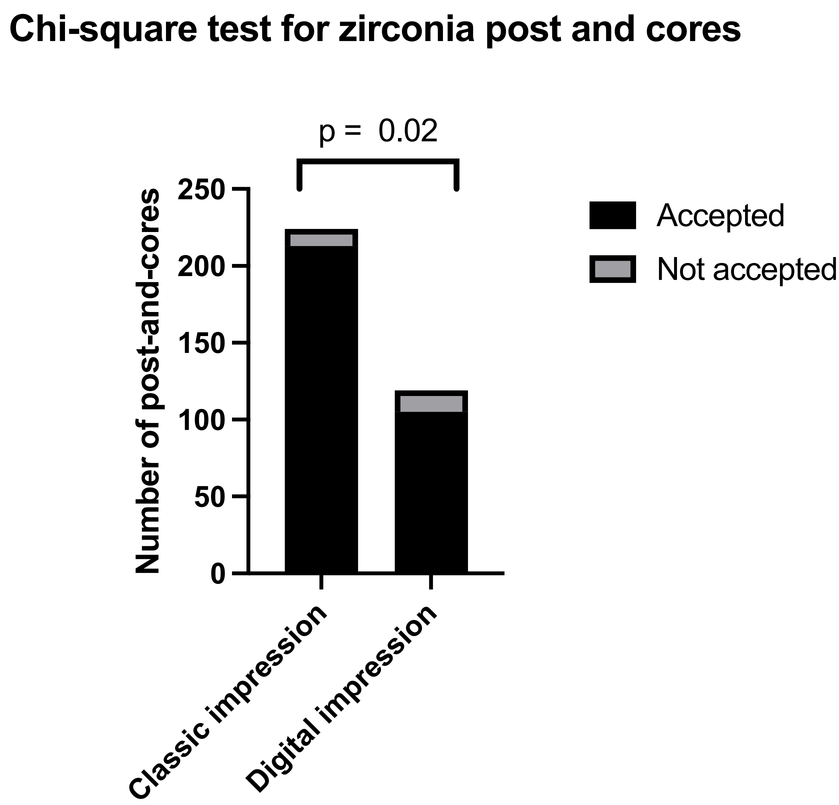

Figure 6.24. Chi-squared test for zirconia post and cores

6.4 Discussion

All current studies on "clinical acceptability" refer to crowns, not post and cores. A systematic review by Goujat et al.[6] found that most studies reported clinically acceptable marginal adaptation (<120 µm). Ferrairo et al.[7] showed that the four CAD/CAM systems tested produced lithium disilicate restorations with clinically acceptable marginal and internal fit. Farah RI et al.[8] also found acceptable fit in crowns fabricated by three CAD programs.

6.5 Conclusions

The null hypothesis was rejected only for zirconia post and cores, where conventional impressions had significantly higher clinical acceptability than digital ones. For Cr-Co post and cores, the null hypothesis was not rejected.

One limitation is the sample size. Future studies should investigate causes of rejection and marginal fit issues in post and cores, similar to those done for crowns.

CHAPTER 7 – A NEW ORIGINAL AND DIGITAL WORKFLOW FOR HYBRID POST AND CORE RESTORATIONS, APPLIED AFTER ENDODONTIC TREATMENT

7.1 Introduction

This in vitro study describes a new and simplified method for directly scanning a hybrid post and core preparation with a zirconia coronal part and a glass fiber radicular part—without using conventional impression material. A step-by-step workflow is described using Exocad (Exocad GmbH, Darmstadt, Germany), one of the most widely used CAD dental software applications. The study was conducted between 2019–2023 at the Department of Prosthodontics, Dental Ambulatory, Barajul Iezeru Alley no. 8.

7.2 Materials and Methods

1. After completing endodontic treatment under a microscope, the canal is prepared for the post and core using a standardized post drill from a dedicated fiberglass post kit. The coronal portion of the tooth is then prepared according to guidelines and working protocols for post and cores [9]. The preparation is finalized, checked, and cleaned.

2. A digital impression is recorded using the TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark). A patient scan file is created by selecting "New Case" and "In-house Lab" for the default connection with the dental lab. The specific tooth is selected in the software's patient chart, and then the options "Anatomy" and "Crown" are chosen to enable HD scanning for increased precision. Additionally, the "Pre-preparation" button on the right side of the screen is activated, allowing the software to scan a fourth STL file titled "Pre-preparation."

3. Scanning starts with the opposing arch, followed by the arch containing the tooth with the canal preparation drill in position, recorded as the "Lower Pre-preparation" (Figure 7.1) using the intraoral scanner. The digital impression should cover at least 2–3 adjacent teeth mesially and distally.

4. The software then prompts the marking of the target tooth. This allows the clinician to rescan the selected area. The calibrated drill is removed from the canal, and the tooth is scanned using a standard preparation technique. Re-scanning the entire arch is not necessary. Occlusion is then scanned as usual, with the patient in maximum intercuspation. The software will post-process four scans: "Lower," "Lower Pre-preparation," "Upper," and "Occlusion."

Figure 7.1. Tooth scanning with drill inserted in canal (personal archive)

5. From the patient chart, the scan is selected with a right-click and the "Export" > "Scans" option is used. A new folder is created for organizing the files. For better organization, a subfolder is created for each patient, the file type is changed from Digital Imaging and Communications in Medicine (DCM) to Standard Triangle Language (STL), and the files are renamed according to the folder name. The files will be saved as LowerJawScan.stl, LowerPrePreparationScan.stl, UpperJawScan.stl, and BiteScan.stl.

6. A CAD software (Exocad, Darmstadt, Germany) is used for designing the hybrid post and core. A client and a dental technician are selected for the restoration, and a case name is assigned (the same as the previously created folder). The prepared tooth is set as a "Telescopic Crown," the opposing arch as "Antagonist," and the occlusion scanning mode is selected as "Digital Impression Scan."

"Save and Design" is then selected. When the CAD window opens, LowerJawScan.stl is imported as the mandibular arch and UpperJawScan.stl as the maxillary arch. The scan data orientation is set, and then "Expert Mode" is selected, which enables the "Add/Remove" 3D file option. The scan named LowerPrePreparationScan.stl, which contains the tooth with the canal drill in place, is imported as a "Generic visualization mesh" and superimposed onto the identical scan showing only the post and core preparation without the drill. Both scans are now aligned in the same position (Figure 7.3).

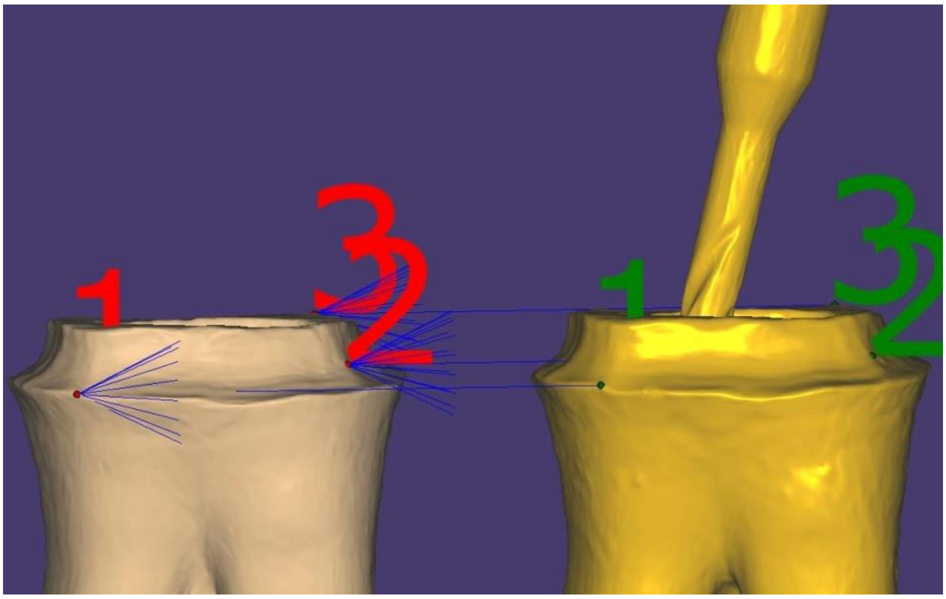

Figure 7.3. Superimposition of the two scans in CAD software (personal archive)

7. "Expert Mode" is exited, and the design of the coronal part of the post and core continues. The first step is margin detection on the preparation scan. A cement gap of 80 μm between the post and core and the preparation walls is recommended. The CAD software automatically generates an ideal tooth model from the library, which can be moved, resized, and rotated into the correct position. This ideal tooth is edited using "Free Forming" and then adapted to occlusion. The software generates a "Primary Telescope" according to the morphology of the future restoration and allows the operator to set the insertion axis. The geometry of the post and core will be modeled based on this corrected axis. Final form adjustments are made in the "Free Forming Telescope" step. At the final

step, all parts of the post and core are merged by the CAD software, resulting in the final restoration.

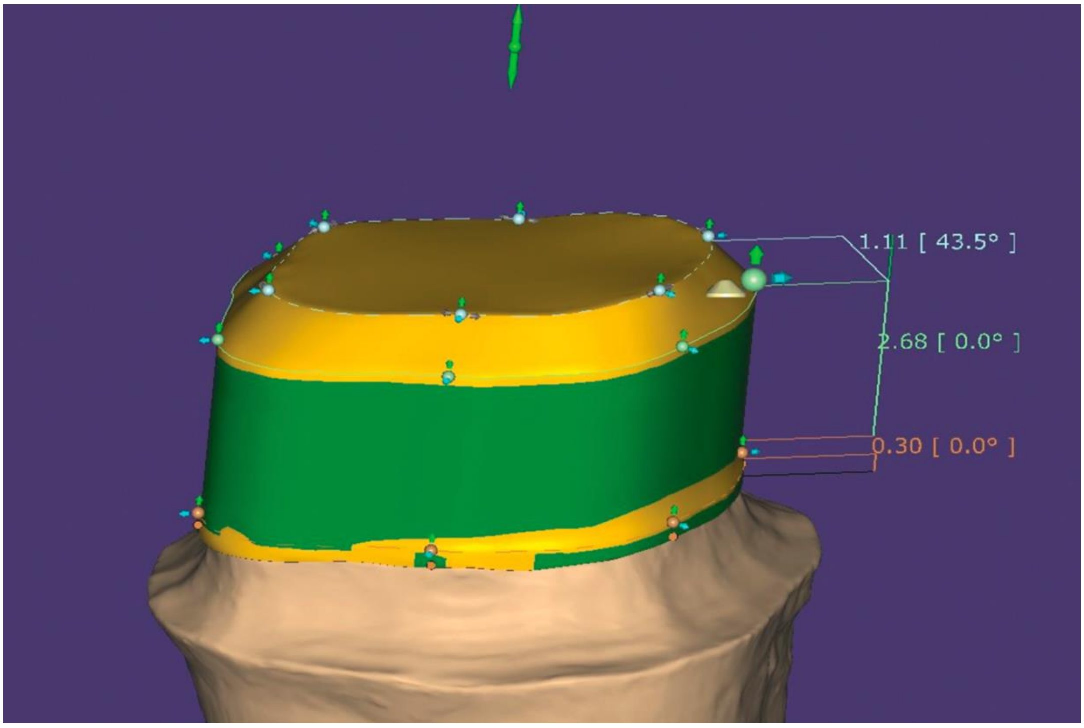

Figure 7.15. Design of the coronal component of the post and core in CAD software (personal archive)

8. The coronal portion generated by the software must be perforated according to the orientation axis of the fiberglass post representing the radicular component. To do this, the previously imported 3D file as "Generic Visualization Mesh" is activated and its transparency is reduced by 75%.

9. "Free Form Reconstruction" is accessed and "Attachments" > "Extrusion" > "Parametric Design" > "Circular" is selected. The cylinder radius is set according to the diameter of the fiberglass post plus 15 µm to allow space for the cement between the coronal and radicular parts. The orientation is set by clicking "Set from view" with the "Allow any modification" button activated. A channel is created in the coronal portion of the post and core, aligned with the post's orientation and diameter.

10. The CAD software automatically exports an STL file (Figure 7.21) into the designated folder. The STL file is sent to a 4-axis milling machine (CEREC MC XL, Dentsply Sirona, Germany), and a zirconia block (Katana Zirconia Block, Kuraray Noritake, Japan) is milled. The zirconia coronal part is then sintered in a fast-firing furnace (CEREC SpeedFire, Dentsply Sirona, Germany).

11. Intraorally, the fit of both components is evaluated individually and together.

12. The fiberglass post is passively guided through the channel created in the zirconia coronal portion. This coronal part is then placed separately into the preparation, respecting the insertion axis. The zirconia component seats passively due to the CAD software's ability to de-retentivize the restoration. No manual adjustments should be required.

13. Once the zirconia coronal part fits perfectly, the fiberglass post is inserted through the previously created channel, sliding into the preparation. An MDP-based primer for zirconia (Clearfil Ceramic Primer, Kuraray Noritake, Japan) is used.

14. Both components are simultaneously cemented with a dual-cure resin cement compatible with both zirconia and fiberglass posts, such as Panavia V5 (Kuraray Noritake, Tokyo, Japan). Resin is applied to the inner surface of the zirconia component, through the channel, and to the outer surface of the fiberglass post. The post is then inserted through the channel after placing the zirconia component in the preparation, and the resin is polymerized.

15. After cement curing, the fiberglass post is trimmed at the occlusal level of the zirconia restoration using a diamond bur.

7.3 Discussion

This method represents a quick and simple way to accurately design a hybrid post and core that includes a digitally created perforation aligned with the canal's angulation. This angulation is subject to an error of 5–10 microns depending on the superimposition of the two scans. The error is predictable and does not significantly impact the final restoration [10].

The described method is an innovative approach designed to overcome the shortcomings of direct scanning procedures at the canal level. Studies have shown that errors frequently occur when scanners attempt to capture narrow and deep surfaces inside previously prepared canals. It is challenging for the scanner's light to reach the deepest areas of the post and core preparation [11,12].

7.4 Conclusions

The third study of this doctoral thesis describes a pioneering technique aimed at in-office fabrication of hybrid post and core without the use of any conventional impression materials. The method is simple, straightforward, and fully digital, enhancing patient comfort compared to traditional impression techniques. Moreover, the main advantage lies in reducing the number of patient visits, as the restoration can be delivered on the same day.

CHAPTER 8 - CONCLUSIONS AND PERSONAL CONTRIBUTIONS

Based on the studies carried out within this doctoral thesis, the following conclusions can be outlined:

• Digital scanning of negative relief dental preparations intended for post and cores is more difficult than scanning positive relief surfaces such as prepared abutments, often resulting in errors with intraoral scanners.

• The analysis of 275 data sets obtained from scanning with the five intraoral scanners included in the study showed significant differences among the evaluated scanners.

• The accuracy of the intraoral scanners tested in this research was assessed according to ISO standards, by analyzing both trueness and precision.

• Trueness analysis revealed significant differences between scanners, with one-way ANOVA yielding a p-value < 0.05 (1.17×10^{-10}). The Medit i900 (Medit, Seoul, South Korea) exhibited the smallest deviations, followed by TRIOS 3 and TRIOS 4 (3Shape, Copenhagen, Denmark), and SIRIOS (Straumann, Basel, Switzerland).

• The intraoral scanner with the largest deviations from the reference was iTero Element 2 (Align, Tempe, USA); therefore, its use is discouraged for scanning negative relief surfaces such as post and core preparations for endodontically treated teeth.

• Precision analysis showed highly significant differences among scanners, with one-way ANOVA yielding a p-value < 0.05 (5.32×10^{-98}). TRIOS 4 showed the smallest deviations, followed by TRIOS 3, Medit i900, and iTero Element 2.

• The scanner with the lowest reproducibility (precision consistency) was SIRIOS (Straumann, Basel, Switzerland), hence its use is not recommended for scanning negative relief surfaces like post and cores.

• Post and cores made of metal alloy showed no significant difference in acceptability as evaluated by dentists, regardless of whether digital or conventional impressions were used. The sample size for metal alloy post and cores was 234.

• A significant difference was found between digital and conventional impressions in terms of dentist acceptability of zirconia post and cores; the sample size analyzed was 343.

• Hybrid post and cores, which combine the advantages of zirconia at the coronal level and fiberglass endodontic posts radicularly, can be fabricated using a novel, original technique proposed in this Doctoral Thesis.

• The new proposed technique does not require the use of any impression material, being 100% digital and thus sustainable.

• The CAD software required for designing the coronal portion can generate the channel in the zirconia mass, aligned similarly to the endodontic canal axis, thus allowing the fiberglass post to be inserted through the zirconia coronal part. The angulation is subject to an error of 5–10 microns, which is predictable and does not clinically affect the adaptation of the post and cores to dental tissues. This error results from the superimposition of the two scans.

• The cementation process of the proposed hybrid post and cores is simplified and does not require multiple cements despite the differences in material and chemical structure between zirconia, fiberglass, and dentin.

• The use of an MDP-based primer during cementation of hybrid post and cores is necessary to perform the procedure in a single step.

• The newly proposed technique compensates for the limitations of digital scanning in narrow root canals under 3 mm in diameter, where scanner light fails to penetrate the deepest preparation zones, particularly in deep preparations.

• The hybrid post and core can be achieved even in a dental practice equipped with the necessary technologies, in a very short time frame of 2–3 hours, without involving an external dental laboratory. In contrast, the fabrication time for a full zirconia post and core is at least 24 hours.

The obtained results confirm the effectiveness of using 3D applications in endodontics, both in terms of data acquisition during digital impression procedures and during the fabrication of new restorations for endodontically treated teeth, through both well-established methods and the innovative approach developed in this doctoral thesis.

The personal contributions of this doctoral thesis can be summarized as follows:

• Conducting a standardized comparison of the trueness and precision of five intraoral scanners in the context of scanning dental preparations for post and cores – Chapter 5, paragraphs 5.3 and 5.4.

• Performing a comparative study on 234 metal alloy post and cores to assess their acceptability based on the impression method – Chapter 6, paragraph 6.4.

• Conducting a comparative study on 343 zirconia post and cores analyzing differences in acceptability by dentists depending on the impression method used (digital or conventional) – Chapter 6, paragraphs 6.4 and 6.5.

• Proposing an original technique for digitally fabricating hybrid post and cores, applied after endodontic treatment – Chapter 7, paragraphs 7.2–7.3.

• Experimentally validating the proposed technique in a laboratory setting – Chapter 7, paragraphs 7.3–7.4.

• Optimizing the digital design (CAD) process for post and cores and integrating a fully digital workflow without the need for conventional impression techniques – Chapter 7, paragraph 7.2.

These personal contributions reflect an innovative approach to the integration of 3D applications in endodontics and may provide a solid foundation for future research in this field.

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