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In-vitro Comparison of Retention Among Contemporary and Conventional Post-and- Cores

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in conjunction with the
Faculty of Graduate Studies

In-vitro Comparison of Retention Among Contemporary and Conventional Post-and-Cores

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree
Master of Science in Prosthodontics

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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DEDICATION

This project is dedicated to my program director Dr. Mathew Kattadiyil who has been my constant source of inspiration and motivation, my research committee faculty Dr. Rami Jekki for his guidance, my parents especially my mother Aysha and my wife for being supportive during the hard times. Without their love and support this project would not have been possible.

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I would like to express my deepest appreciation to my family, especially my parents for believing and supporting me at every step in life. Challenging myself by coming to the United States and overcoming a lot of obstacles and moving forward to become a US graduate prosthodontist from a very well reputed program and ultimately working as a clinician and educator could not be reached without the hard work and constant support of my family. Without their tireless encouragement, love, support and prayers, this journey would have been extremely difficult, if not impossible. I would also like to express my deepest gratitude to my wife, Mona Alshahrani for her support and efforts, my brothers, Mahdi, Bader & Abdulsalam who continue to support me in my personal and professional life. They are one of the reasons that I could stay focused and pursue my goals.

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CONTENT

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ABBREVIATIONS

CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
CPC	Cast post-and-core
CCGPC	Custom cast gold post-and-core
CP-TI	Commercially Pure Titanium
CMTPC	Custom milled titanium post-and-core
CPTPC	Custom printed titanium post-and-core
CMZPC	Custom milled zirconia post-and-core
STL	Standard Tessellation Language
TI	Titanium
SD	Standard Deviation
NaOCl	Sodium Hypochloride
EDTA	Ethylene diaminetetraacetic acid

ABSTRACT OF THE THESIS

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by

Hatem Alqarni

Master of Science, Graduate Program in Prosthodontics
Loma Linda University, September 2019
Dr. Mathew Kattadiyil, Chairperson

Purpose: Computer-aided design/computer-aided manufacturing (CAD/CAM) technology is gaining popularity in dentistry, and more recently, used to fabricate custom post-and-cores (PC) for endodontically treated teeth. The purpose of this study was 1) to evaluate the overall retention of conventional cast gold post-and-cores compared to CAD/CAM fabricated printed, milled titanium post-and-core and milled zirconia post-and-cores based on load, time of dislodgement and 2) to evaluate the mode of failure of the post-and-cores.
Materials and Methods: A maxillary central incisor was selected. Root canal treatment was performed, and acrylic resin pattern was used to fabricate post-and-core. A total of 80 post-and-cores (20 conventional and 60 digital) were made and divided into 4 groups based on fabrication method: Group I, conventional method (lost-wax technique) and cast in type IV gold (CCGCP); group II, printed titanium (CPTPC); group III, milled zirconia (CMZPC) and; group IV, milled titanium (CMTPC). Acrylic resin pattern posts were scanned with 3Shape laboratory scanner and exported as STL files. Milled zirconia and milled and printed titanium post-and-cores were fabricated from the digital scans of acrylic resin patterns. The post-and-cores were cemented using Rely X Unicem resin cement after

surface treatment. A universal pull out test was used to measure retention at a crosshead speed of .5mm/min. The teeth and posts were evaluated under microscope and with scanning electron microscopy (SEM). The data were statistically analyzed using one-away ANOVA test, Post hoc tests and Tukey adjustment for multiple comparison. Mann-Whitney U test followed by the Bonferroni adjustment were used to compare medians of displacement scores of each group with the gold control group. Statistical analysis was performed using IBM SPSS Statistics (Version 25; IBM Corporation 1989, 2018.) ($\alpha = 0.05$).

Results: Pull out test revealed higher retention values for (CPTPC) and (CMTPC) among the groups. When compared to (CMZPC), conventional (CCGPC) revealed significantly better retention values ($P<0.05$) and time to failure. Cohesive failure was observed with groups I, II and IV. However, group III revealed a mixed type of failure.

Conclusions: Within the limitations of this study, although (CCGPC) revealed clinically acceptable values, (CPTPC) and (CMTPC) groups revealed better overall value for retention and time to failure. The titanium seems a promising choice for fabricating dental post-and-core restorations.

CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERATURE

Cast post-and-core (CPC) is commonly used to restore endodontically treated teeth with extensive coronal structural loss. Retention of CPC is a fundamental factor influencing definitive restoration longevity and success. Length, shape, diameter, and post surface, as well as the type of cement used, are associated factors that may affect CPC retention and stability.[1]

Custom CPC is documented to have superior adaptation and fit to the radicular post space walls when compared to prefabricated post.[2,3] Cast post-and-core provides the following advantages compared to others post-and-core systems; resistance to rotational movement forces[4], superior success rate[5,6], and ease of retrievability for endodontic retreatment.[5-7]

Currently, the material of choice for custom-made PC fabrication is high noble gold alloy.[8] This is attributed to its superior fracture resistance and retention.[7, 9] Moreover, gold alloy creates a layer of chromium oxide that resists tarnish.

Custom-made PC has been reported with some disadvantages, for example, most abutments break at a point beyond the half distance of the root length due to its high stiffness. If these teeth abutments fracture, usually they are unrestorable.[3,4]

Custom-made PC has also been reported to be fabricated out of zirconia to overcome esthetic limitation associated with metal CPC. This has been made possible due to the following properties of zirconia; high flexural strength, high fracture toughness, chemical stability, biocompatibility, favorable optical properties, greater toughness and maximum adaptability to the canal and appropriate esthetic characteristics.[10,11]However, the use of zirconia PC to restore endodontically treated teeth has limitations. In relation to its rigidity,[12,13] zirconia posts cause more catastrophic root fractures than fiber posts.[13] Also, the surface of zirconia posts does not bond to resin composite materials, leading to an inferior post retention. Another limitation of zirconia PC is the difficulty in retrievability when endodontic retreatment is required.[12,13]

Titanium has gained wide acceptance in dentistry due to its biocompatibility, excellent corrosion resistance, reduced cost, ease of fabrication (milling) and high mechanical properties. Titanium can be found in different combinations for use in dentistry. Pure titanium is composed by 99.5 % titanium and 0.5 % of interstitial elements (carbon, oxygen, nitrogen, hydrogen and iron) and the proportion of these elements directly affects the metallic properties. The ASTM (American Society of Testing and Materials) the standard of F1295 specifies titanium in different grades according to its purity, which is evaluated according to the amount of oxygen.[14] The titanium melted only from titanium sponge is known as titanium grade 1, which is considered the most-pure grade. When titanium sponge is mixed with titanium fragments, the amount of oxygen (O_2) and iron (Fe) increase and titanium becomes harder. The more fragments are added, the harder the titanium becomes (titanium grades 2, 3 and 4). Therefore, grade 1–4 refers to CP-Ti, but with different purity grades (Table 1).[14,15]

Table1. Components of commercially pure titanium (CP-Ti) grades 1-4.[14,15]

Components (%)	1	2	3	4
Fe max	.20	.30	.30	.50
C max	.10	.10	.10	.10
O max	.18	.25	.35	.40
N max	.03	.03	.05	.05
H max	.015	.015	.015	.015
Σ	.525	.695	.865	1.065
Ti (%)	99.470	99.300	99.130	98.930

Fe iron, C carbon, O oxygen, N nitrogen, H hydrogen, Ti titanium

To the best of our knowledge, there are no in-vitro studies assessing the relationship of the retention of custom cast post-and-core (Gold) and, custom milled post-and-core (Titanium) alloy, custom printed post-and-core (Titanium) alloy and custom milled post-and-core (Zirconia).

Aim

The aim of this study was to evaluate the difference in the retention between custom cast post-and-core (Gold), custom printed post-and-core (Titanium) alloy, custom milled post-and-core (Zirconia) and custom milled post-and-core (Titanium) alloy.

Null Hypothesis: There will be no difference in retention among custom milled post-and-cores (Titanium), custom printed post-and-cores (Titanium), custom milled post-and-cores (Zirconia) and conventional custom cast post-and-cores (Gold).

CHAPTER TWO

MATERIALS AND METHODS

Sample Collection and Storage

Eighty sound maxillary central incisors extracted for periodontal reasons were selected. Exclusion criteria included presence of caries, restoration, root canal treatment (RCT), crack/s, attrition, very long or very short teeth, and/or severe root curve, as shown in (figure 1). Teeth were thoroughly cleaned with a brush after the extraction and a sharp scalpel was used to remove any soft tissue from the root surfaces. Any remaining tissues were carefully removed by using a periodontal curette. Teeth were subsequently stored in 0.2 % sodium azide for at least 24 hours prior to the specimen's preparation (ISO 28399, 2011).[16]

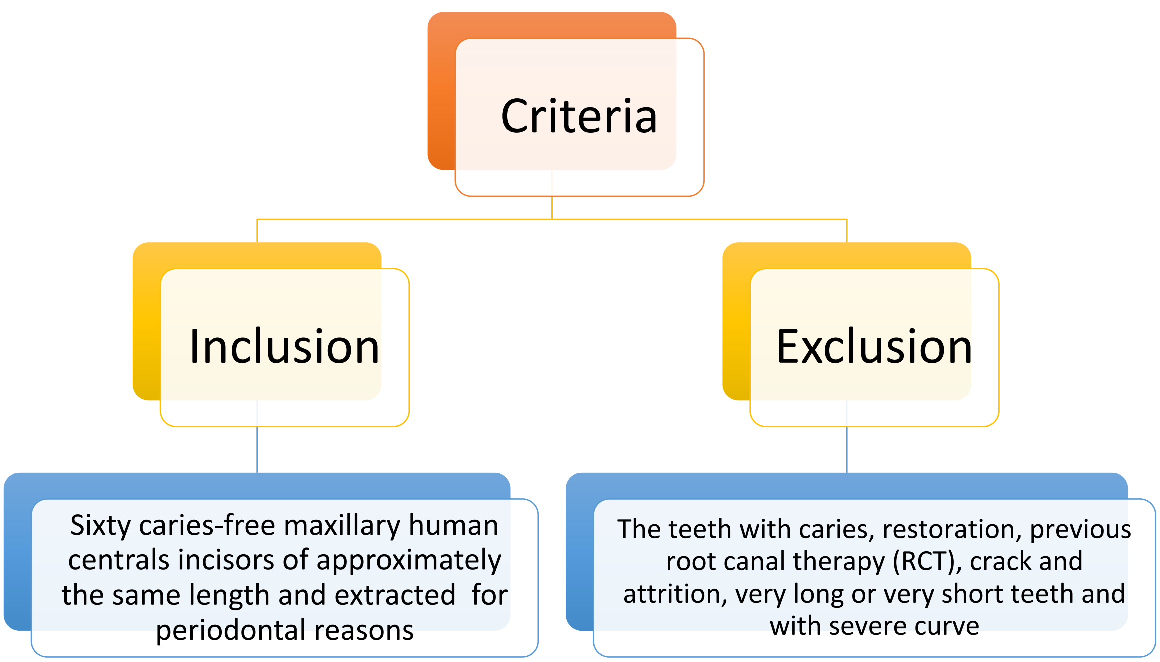

Figure 1. Flowchart depicting the criteria of the samples

Each tooth was randomly assigned by a number (from 1 to 80). Then the teeth were randomly allocated into four groups (n=20 each), group A was restored with custom cast post-and-core (Gold) and group B was restored with custom milled post-and-core (Titanium) alloy, group C was restored with custom printed post-and-core (Titanium) alloy and group D was restored with custom milled post-and-core (Zirconia). Each root length was measured from apex to the labial middle point of the cemento-enamal junction, together with labiolingual and mesiodistal dimensions at the level of the cervical margin with a digital caliper (Links Brand; Harbin Metering Instrument Works, Harbin, China). These measurements were recorded, and the average values calculated for statistical analysis.

Mounting Teeth in Acrylic Resin Blocks

The specimens were individually embedded (mounted) in special specimen holder by means of epoxy resin (Exakto-form, Bredent) with elasticity modulus of 12 GPa. which is similar to elastic modulus of human bone (18 GPa)[17] with the use of a test mount former, $2cm^3$ in dimension, 2-3 mm below the cemento-enamel junction (CEJ). A prefabricated printed jig made from Formlabs printer (Somerville, Massachusetts, United states) was used to position each tooth test mount former during immersion of the teeth in acrylic resin to standardize teeth position to be centralized within the test mounts. The mount test jig was used to standardize the teeth position while performing teeth preparation and RCTs (figure 2). During the polymerization of the acrylic resin, the acrylic resin block was cooled in water to avoid dehydration of the teeth. The teeth were prepared to have 2 mm ferrule and a 1mm shoulder finish line (figure 3).[18-20]

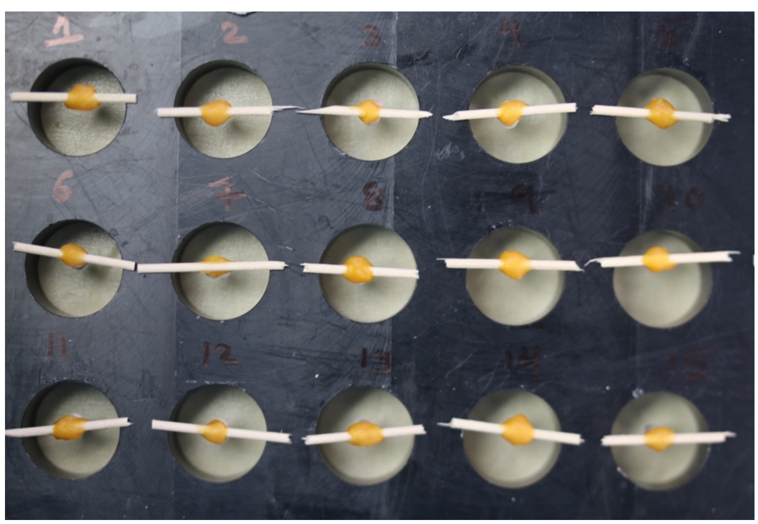

Figure 2. Teeth are mounted in acrylic resin blocks using test mount former

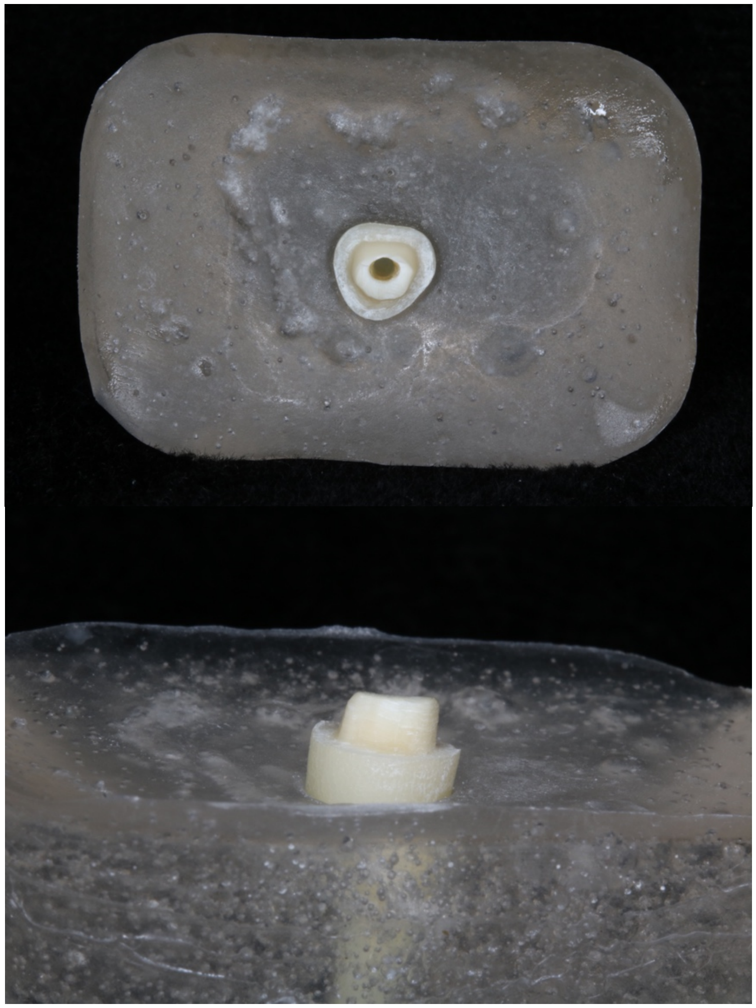

Figure 3. Preparation of tooth to have 2 mm ferrule and a 1mm shoulder finish line (Lateral-Occlusal view)

Root Canal Preparation and Obturation

Preparation of the access cavity was done using a size 2 diamond round bur mounted to a high-speed handpiece. The working length was established 1 mm shorter than the root apex. Root canal preparation for each tooth was performed up to file size 40 (Kerr/Sybron Corp). Flaring the coronal part of each root canal was performed using Gates Glidden burs number 2-4. Each root canal was irrigated with NaOCl 2.5% and EDTA 18% (chelating agent) (Ultradent Products, Inc) to remove the smear layers. Following irrigation, prepared root canals were dried with sterile paper points (Sure-endo, Gyeonngi-do, South Korea) before obturation. A size 40 gutta-percha master cone (Dentsply Maillefer) coated with AH Plus sealer (Dentsply DeTrey, Kontanz, Germany) was inserted into the canal. Root canals were obturated using lateral condensation technique with finger spreaders (Dentsply Maillefer). Finally, excess gutta-percha (Dentsply Maillefer) was removed and the remaining was condensed with a hot plugger.

Post-and-Core Preparation

Definitive post length was prepared and established with the use of peeso reamers (Maillefer S.A., Ballaigues, Switzer- land) up to size 3. To obtain a standardized length for the posts, the coronal portion of the gutta percha was removed with hot plugger until adequate length (11mm) was achieved.[21-24] Each root canal was cleaned by using air/water spray, EDTA and then dried by paper points.

Post-and-Core Fabrication Method

80 custom post-and-cores were fabricated with the use of auto polymerizing acrylic resin (Pattern Resin LS; GC) and serrated plastic post (M). Serrated plastic post was relined with acrylic resin then inserted in the root canal. Then the core was built up using GC pattern, and prepared using a diamond bur (diamond bur of head size ISO No. 010. to achieve a core with 4 mm height (Figure 4). A plastic loop was attached to the coronal part of the GC pattern core which was used to be attached to the instron machine (Instron Corp, Norwood, MA) during the pull out test.

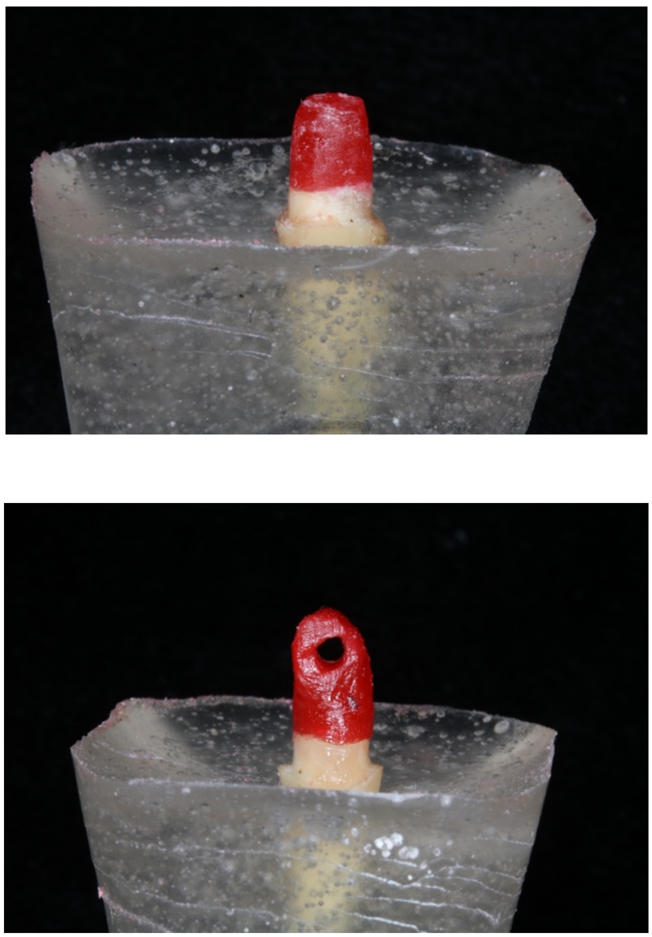

Figure 4. Acrylic resin post build up and the hole made to prepare the post for pull out test

Each post was randomly divided in to four groups as shown (Figure 5). Twenty acrylic resin pattern posts were cast with a Type IV gold alloy using the conventional lost wax casting technique (Figure 6). Sixty acrylic resin pattern posts were scanned in a desktop scanner (3Shape D900L, 3Shape Dental System). STL files for each scanned post-and-core as shown (Figure 7) was sent to Core 3D and Renovis for the fabrication of 20 milled titanium, 20 printed titanium and 20 milled zirconia post-and-cores each (Figure 8-10). The prepared specimens were stored in 100% humidity at room temperature to simulate the humidity in vivo until they were returned for testing.

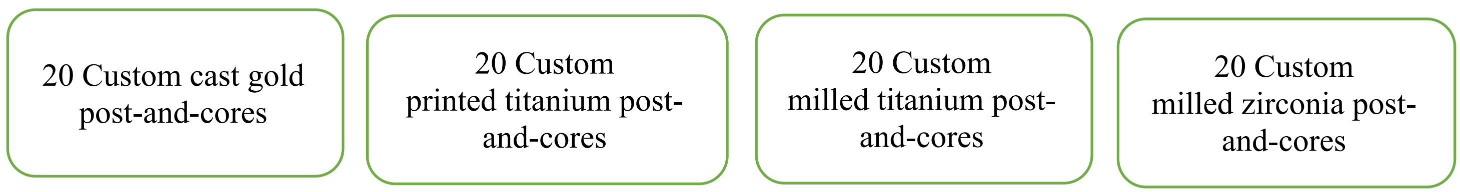

Figure 5. Four groups used in the study (Group 1 CCGPC, Group 2 CPTPC titanium, Group 3 CMZPC, Group 4 CMTPC).

Figure 6. Custom cast post-and-core (Gold) alloy with hole

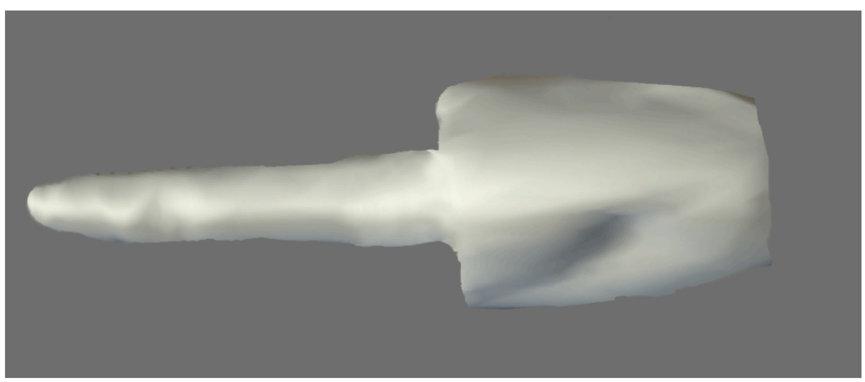

Figure 7. STL file for post-and-core scanned with a desktop scanner (3Shape D900L, 3Shape Dental System)

Figure 8. Custom printed post-and-core (Titanium) alloy with hole

Figure 9. Custom milled post-and-core (Zirconia) alloy with hole

Figure 10. Custom milled post-and-core (Titanium) alloy with hole

Post-and-Core Surface treatment

According to the manufacture recommendation, group 1 CPC gold, group 2 CPPC titanium, group 4 CMPC titanium were treated first using ultrasonic cleaning solution in 96% isopropyl (3 minutes) and then airborne-particle abraded (50 µm Al2o3 at 2.8 bar for 5 second). Group 3 CMPC zirconia was treated using ultrasonic cleaning in 96% isopropyl (3 minutes), Rocatec soft (30 µm airborne-particle abrasion at 2.8 bar for 12 second over entire zirconia surface and then, silane coupling agent (Espe-Sil) applied.[25]

Post-and-Core Cementation

The post-and-cores for all samples were coated with Rely X Unicem resin cement (3M ESPE, Seefeld, Germany) and mixed according to manufacturer's instructions (3M ESPE). Also, cement was applied into the root canals by using Elongation tip to the nozzle (3M ESPE). After that posts were inserted gently into the root canals to reduce hydrostatic pressure, they were positioned in place under firm finger pressure and the excess cement was removed (Figure 11). Then specimens of each group (n=20) were kept in normal saline for 24 hours in a refrigerator before testing.

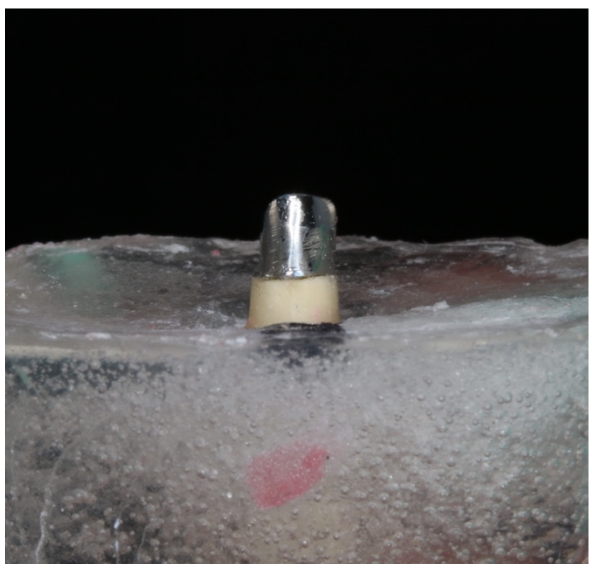

Figure 11. View of post-and-core post-cementation

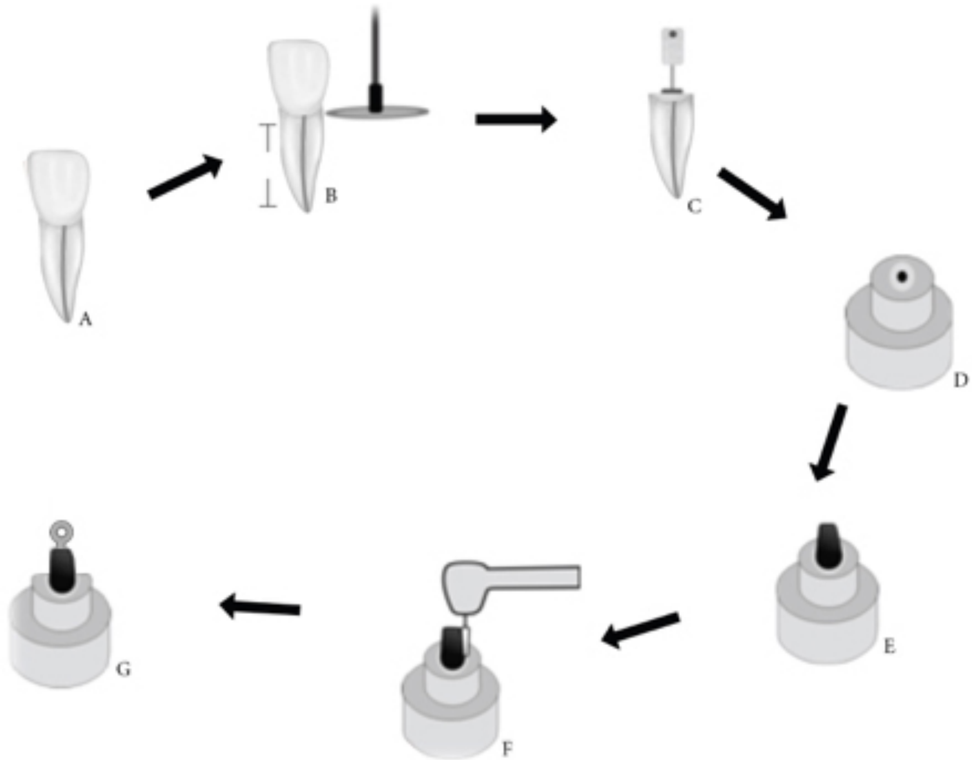

Figure 12. Schematic diagram of specimen preparation: (A) Extracted central incisor. (B) Section of tooth. (C) Sectioned specimen after endodontic treatment. (D) Embedded specimen in epoxy resin. (E) Cemented post-and-core. (F) Coronal preparation of core prior to fabrication in metal alloy. (G) Metal alloy specimen ready for retention test

Placing Specimens on the Measuring Machine (Instron Testing Machine)

Each tooth was subjected to a pull out test with a universal Instron Testing Machine (Instron Corp, Norwood, MA) at a crosshead speed of 0.5mm/min. The device was calibrated before placing each sample. The position and the direction of the samples in the machine were set by the device itself. The specimens were placed in a customized, self- aligning apparatus to standardize the position and the direction of the samples in the machine. The horizontal rod attached to the upper element of the Instron testing machine (ITM) was passed through the hole which was made in the CPC as hook attachment.

The acrylic holder allowed the teeth to be held firmly during retention testing (Figure 13). To measure the amount of retention, the force was applied until the post was dislodged from the canal. The force required to remove the post from the canal along its longitudinal axis was reported in Newtons to show the amount of retention. Test specimens were considered to have failed when the post-and-cores separated from the tooth.

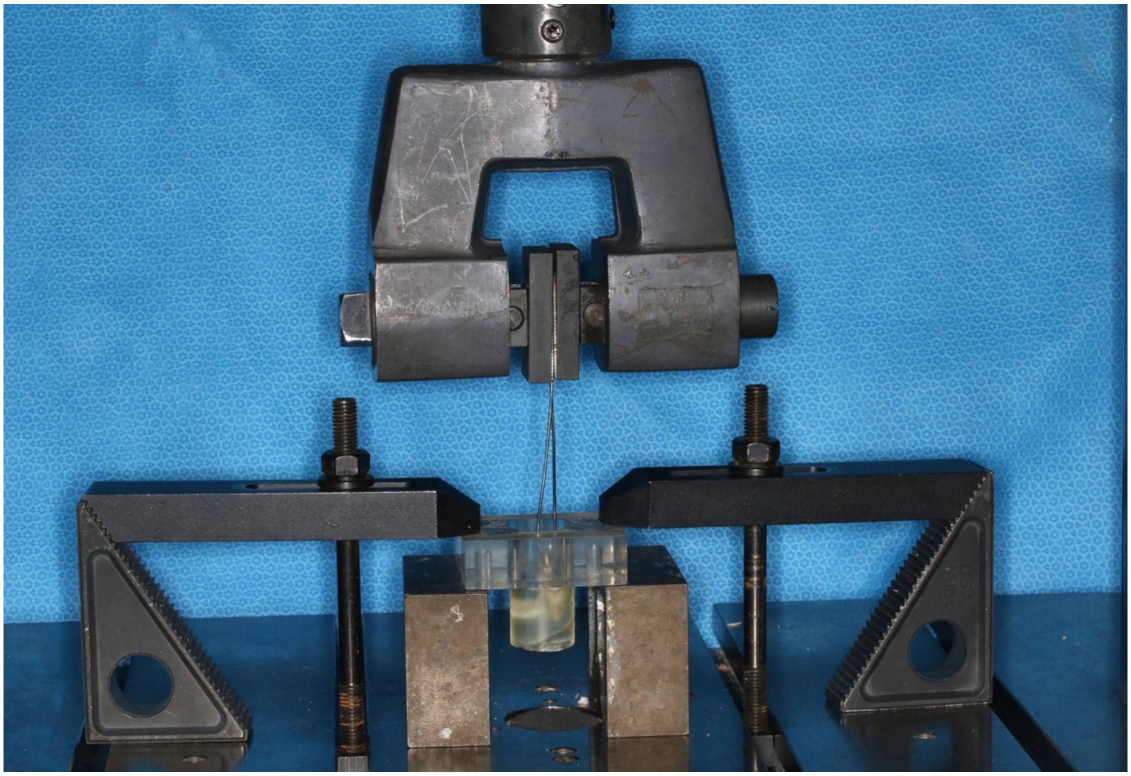

Figure 13. Specimen mounted on testing assembly for retention test

Adhesive and Cohesive Failure

Mode of failure was classified as following: (1) Adhesive (Clean break at the bond), (2) Cohesive (full break in the base material or tooth), (3) Mixed (combination of adhesive and cohesive failure) And to determine the failure mode, both dentin-luting agent and post-luting agent interfaces was investigated. The roots were cut along the long axis using Techcut 4tm precision low-speed saw (ALLIED High-Tech Product.Inc) under water irrigation. The root canal was inspected by means of a stereomicroscope at 50x magnification. The canal surface also was inspected by scanning electron microscopy (SEM). The dislodged posts were also surveyed by means of a stereomicroscope at the same magnification.

Statistical Analysis

Descriptive statistics are as mean ± standard deviation and median with minimum and maximum, for all variables by the dental material groups.

One-way ANOVA procedure was used to test if there is a difference in total time and average load between the treatment groups. Post hoc tests were done using Tukey adjustment for multiple comparisons. Games-Howell was used for multiple comparison instead of Tukey test if the assumption of equal variances was not assumed.

Independent Samples Mann-Whitney U test with Bonferroni adjustment was used to compare medians of displacement scores of each group with Gold control group. Statistical analyses were performed using IBM SPSS Statistics (Version 25; IBM Corporation 1989, 2018.).

CHAPTER THREE

RESULTS

The difference in retention for the different types of post-and-cores was evaluated. The mean and median values of retention for groups were calculated and are presented in Table II, III and IV. By using Mann-Whitney U test with Bonferroni adjustment to compare median of total time, average load and displacement variables of each group with gold control group, it was determined that retention between the custom printed titanium post-and-core (CPTPC), custom milled titanium post-and-core (CMTPC), custom cast gold post-and-core (CCGPC) and custom milled zirconia post-and-core (CMZPC) was significant ($P<0.05$), with higher values recorded for the CPTPC in comparison with all groups (Figure14). The mean values are shown in Table II and III. The load values necessary to create failure between CMZPC are lower compared to CPTPC, CMTPC and CCGPC and the standard deviation between the all groups showed different distribution in the time of failure and was statistically significant higher for the CPTPC and CMTPC groups ($P<0.05$). CPTPC when compared with the CCGPC group required a load of 361.5 N and 295.9 N respectively to fail and the difference statistically significant ($P<0.05$). When compared with the CMZPC group, the CPTPC required a load of 361.5N compared to 248.1 N for the CMZPC group and his difference was statistically significant ($P<0.05$) table II, III.

The failure mode varied among groups, as shown in scanning electron microscopy images. The majority of failures for all custom post-and-core systems tested were a cohesive failure, except for CMZPC which revealed a mixed type of failure (15-22).

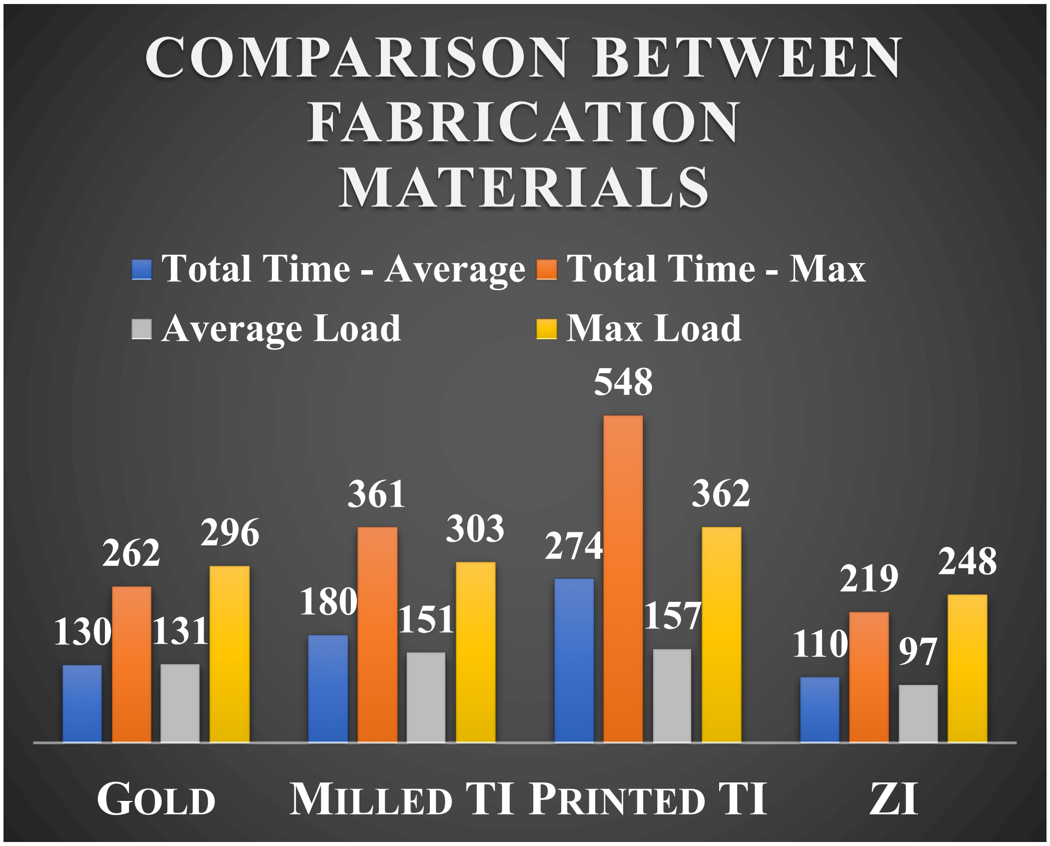

Figure 14. Comparison between fabrication materials with gold control group

Table 2. Differences in clinical factors by Group

Characteristic	*Gold vs. Milled TI*	*Gold vs. Printed TI*	*Gold vs. ZI*	*Milled TI vs. Printed TI*	*Milled TI vs. ZI*	*Printed TI vs. ZI*
	Mean Difference (95%CI)	***Mean Difference (95%CI)***	***Mean Difference (95%CI)***	***Mean Difference (95%CI)***	***Mean Difference (95%CI)***	***Mean Difference (95%CI)***
Total Time - Average*	**20.8 (-19.4, 61.0)**	**-143.6 (-222.2, -65.1) ¥**	**-50.0 (-98.3, -1.7) ¥**	**-164.4 (-245.8, -83.1) ¥**	**-70.8 (-124.2, -17.4) ¥**	**93.6 (8.8, 178.5) ¥**
Total Time - Max*	**42.5 (-37.9, 122.8)**	**-286.2 (-443.3, -129.2) ¥**	**-99.1 (-195.8, -2.4) ¥**	**-328.7 (-491.4, -166.0) ¥**	**-141.6 (-248.3, -34.8) ¥**	**187.1 (17.4, 356.8) ¥**
Average Load **	**-5.6 (-31.2, 20.1)**	**19.7 (-5.9, 45.4)**	**53.9 (28.3, 79.6)**	**25.3 (-0.30, 51.0)**	**59.5 (33.9, 85.2) ¥**	**34.2 (8.5, 59.8) ¥**
Max Load**	**-6.8 (-65.6, 52.0)**	**-65.6 (-146.2, 15.0)**	**47.8 (-25.8, 121.3)**	**-58.8 (-132.0, 14.5)**	**54.6 (-18.6, 127.8)**	**113.4 (40.1, 132.0) ¥**

*

Games-Howell / **Tukey adjusted post hoc test; ¥ P-value < 0.05

Table 3. Mean with 95% confidence interval of clinical factors by Group

Characteristic	Gold *Mean (95%CI)*	Milled TI *Mean (95%CI)*	Printed TI *Mean (95%CI)*	ZI *Mean (95%CI)*	*p*-Value
Total Time - Average	130.3 (112.6, 148.1)	180.4 (147.7, 213.0)	274.0 (217.3, 330.6)	109.6 (84.0, 135.2)	<0.001
Total Time - Max	261.6 (226.1, 297.1)	360.7 (295.4, 426.0)	547.9 (434.6, 661.1)	219.2 (168.0, 270.3)	<0.001
Average Load	131.1 (118.2, 144.0)	150.9 (133.5, 168.2)	156.5 (142.8, 170.1)	96.9 (83.4, 110.5)	<0.001
Max Load	295.9 (261.0, 330.8)	302.7 (273.1, 332.3)	361.5 (309.8, 413.2)	248.1 (202.9, 293.3)	<0.002

Table 4. * Comparison of different of the fabrication materials with gold control group

	Gold	**Milled TI**	**Printed TI**	**ZI**
	Median (Min - Max)	**Median (Min - Max)**	**Median (Min - Max)**	**Median (Min - Max)**
Displacement*	0.2 (0.1 - 1.0) ¥	0.5 (0.1 - 1.0) ¥	0.2 (0.1 - 0.8) ¥	0.1 (0.1 - 1.0) ¥

*Bonferroni adjusted; ¥non-significant compared with gold group

Custom casted gold post-and-core (CCGPC)

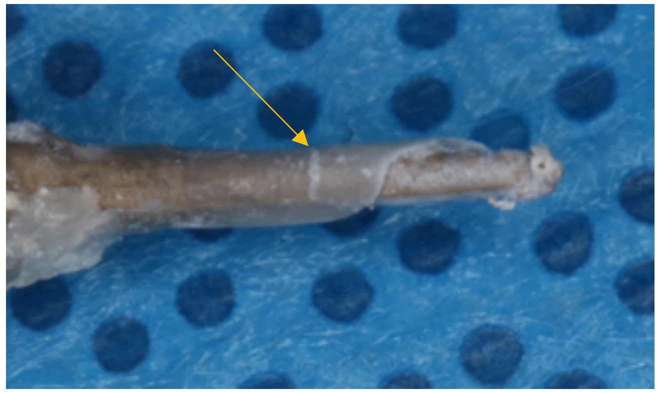

Figure 15. Cohesive failure at post/root interface in relined sample (Arrow)

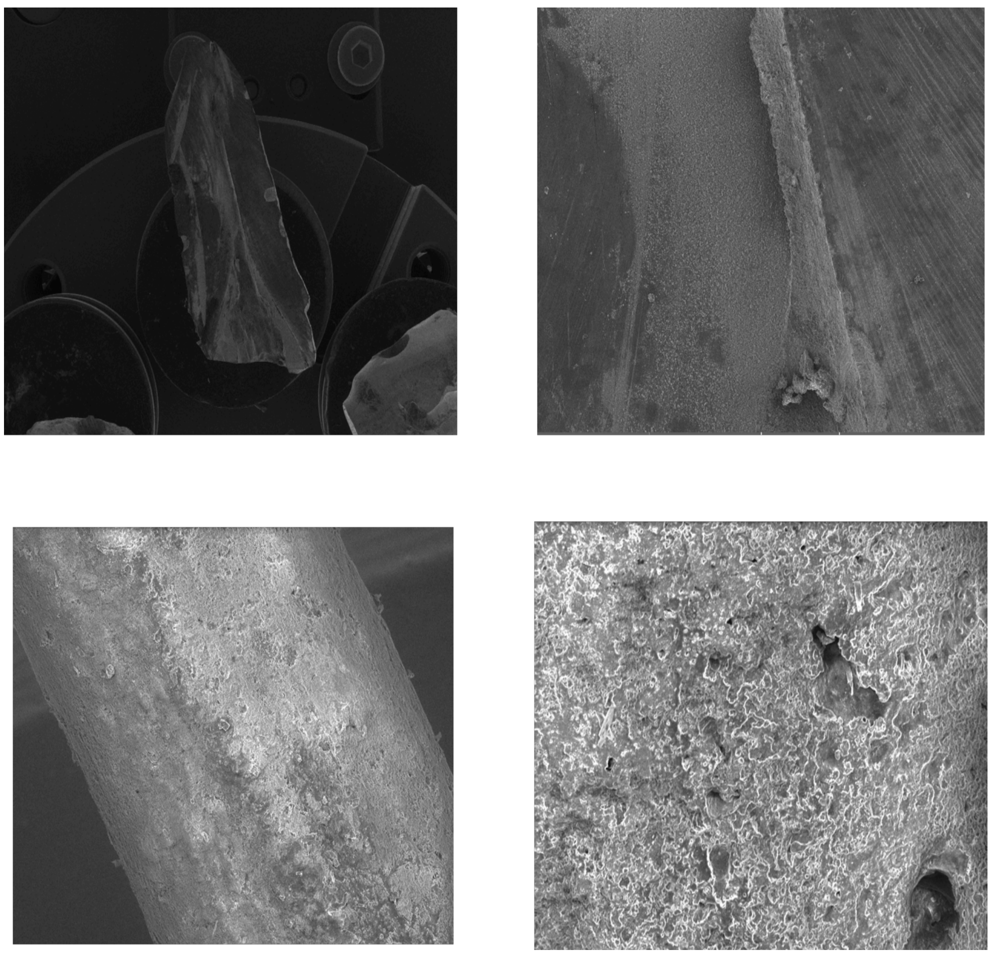

Figure 16. SEM of cohesive failure at root/post interface (Magnification X5, 50 and15)

Custom printed titanium post-and-core (CPTPC)

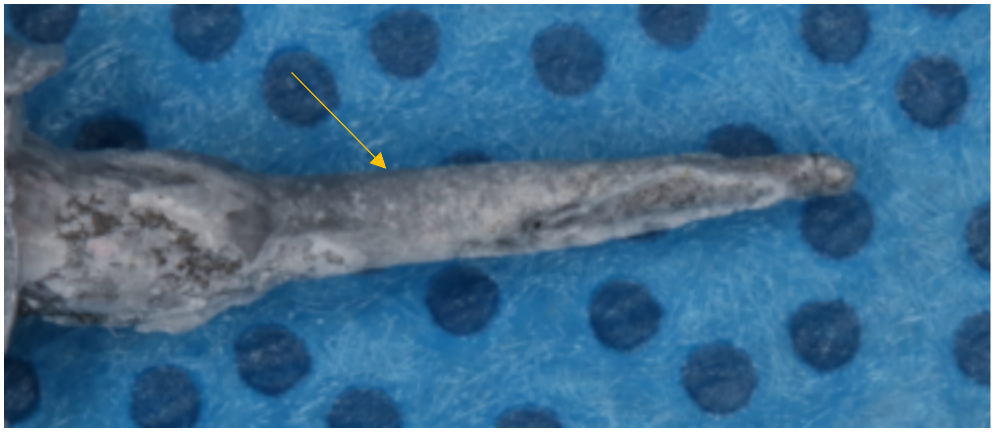

Figure 17. Cohesive failure at post/root interface in relined sample (Arrow)

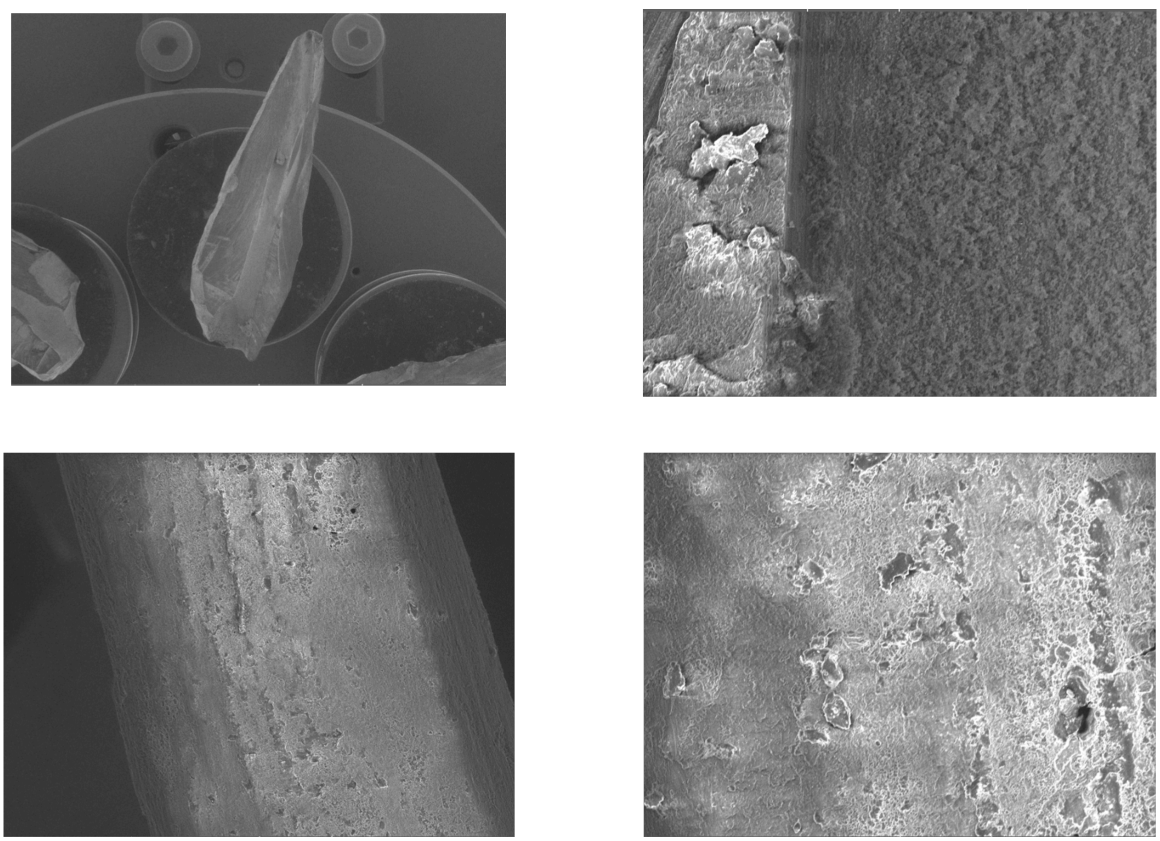

Figure 18. SEM of cohesive failure at root/post interface (Magnification X5, 50 and150)

Custom milled zirconia post-and-core (CMZPC)

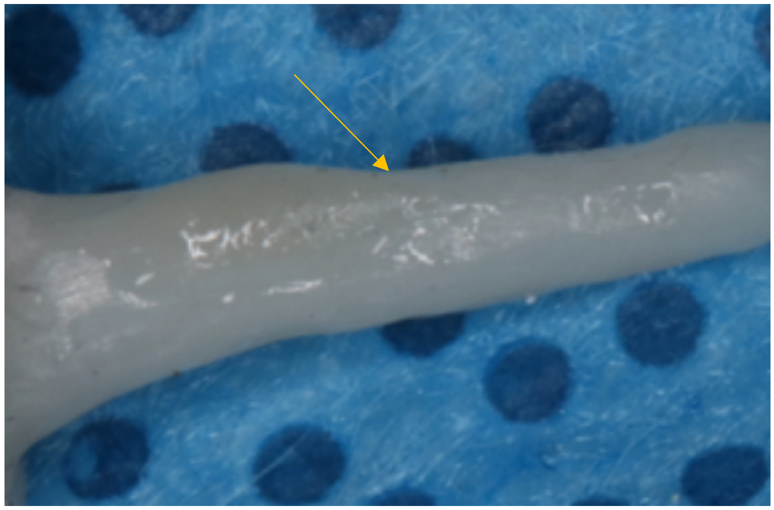

Figure 19. Mixed failure at post/root interface in relined sample (Arrow)

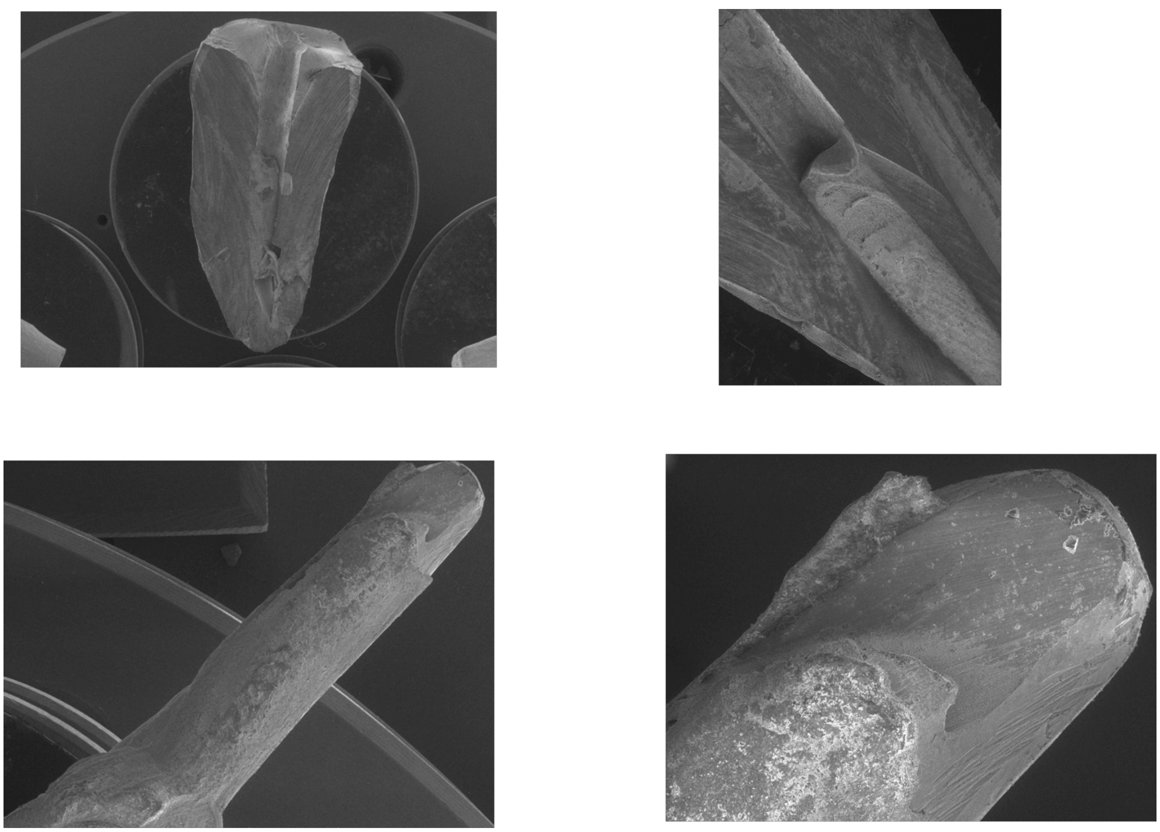

Figure 20. SEM of mixed failure at root/post interface (Magnification X5, 50 and 150)

Custom milled titanium post-and-core (CMTPC)

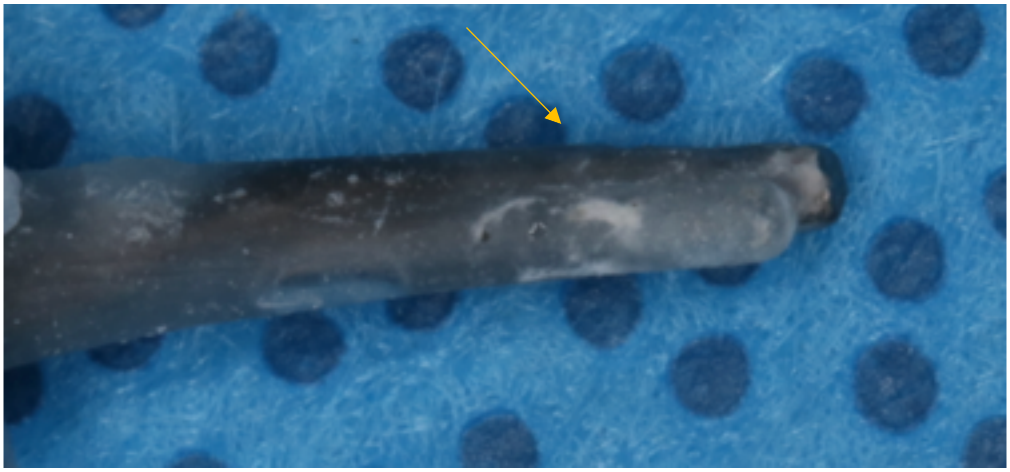

Figure 21. Cohesive failure at post/root interface in relined sample (Arrow)

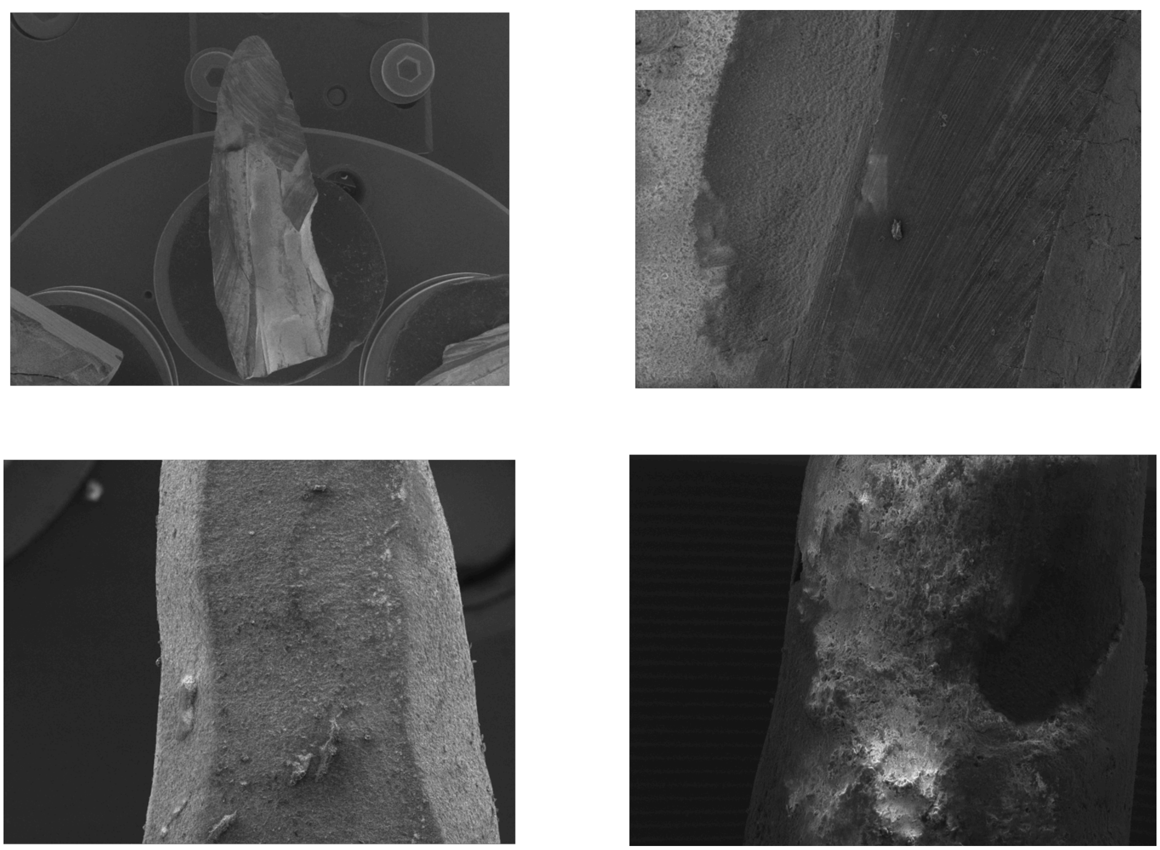

Figure 22. SEM of cohesive failure at root/post interface (Magnification X5, 50 and150)

CHAPTER FOUR

DISCUSSION

Several studies have reported acceptable clinical outcomes with custom cast gold post-and-cores and hence they are considered to be the 'gold standard' and was used as a control group in this study.[1,3-8] However, there is lack of strong evidence that printed/milled titanium technique post-and-core provides comparable retention and effectiveness.

Many investigators have reported that the material and design of cast post-and-core affect the success of endodontically treated teeth restored with post-and-cores.[5] The custom cast gold post-and-core as mentioned has been regarded as the gold standard for foundation restoration[5,6] due to its high biocompatibility, corrosion resistance and high rigidity and has been used extensively. Creugers et al. reviewed the literature and reported that the success and survival rates have varied in endodontically treated teeth restored with different post-and-core systems.[6] No consensus exists on which technique and materials are best suited for use.[6,26-28] Recently, Wei Liu et al. found that post-and-cores fabricated by CAD-CAM milled technique using cobalt-chromium alloy could be an alternative to conventional casting for metal post-and-core fabrication.[29] However, the retention of CAD-CAM milled or printed post-and-cores was not evaluated and tested in this study.

In this study, titanium custom post-and-cores (grad V titanium alloy) made from two different fabrication techniques milled/printed were evaluated and on the basis of the results of the present study, custom milled and printed titanium post-and cores revealed higher retention compared to custom cast gold and custom milled zirconia post-and-cores. Therefore, the null hypothesis was rejected.

The results of the present study showed that there was a significant difference ($P<0.05$) between the retention of the teeth restored with custom printed and milled titanium post-and-cores and those restored with custom cast gold and custom milled zirconia post-and-cores. The retention between the two groups with custom printed and milled titanium post-and-cores were not significant ($P>0.05$) and custom milled zirconia post-and-core group revealed significantly lower retention ($P<0.05$) The possible reason for the difference between custom post-and-core and the retention for the zirconia group could be the post surface configuration and roughness of the printed titanium post, which allows the post-and-core material to form micromechanical retention locks, whereas the smooth surface of the zirconia reduces mechanical retention. Maya et all reported similar results in that metal post (495.5 N-+75.9 N) had significantly greater retention than the zirconia post (241-+ 89.3 N).[30] In addition, study by Cohen et al reported that zirconia posts has extremely low retention values (104.5-+34.8).[31] These findings are consistent with the results from our study. Previous research has already demonstrated that resin cement can provide greater retention than non-resin cement.[32,33] This observation was not confirmed in this study as we did not evaluate post-and-cores cemented with non-resin cements. Several factors limit this in vitro study. For example, thermocycling was not used in this study and only one type of cement was tested. Simulated clinical situations might have affected the results and hence further studies that simulate the oral environment are recommended.

In order to increase the validity of the study and minimize the induced human error during manufacturing, the custom post-and-core surface were neither finished nor polished. Finishing and polishing of the post-and-core surfaces may improve the fit, however, this could affect the retention. It was noted that between custom post-and-core, those that were made from printed titanium required less adjustment and better fit when compared to other groups.

To date, due to the complexity of casting post-and-cores, and a wide range of available materials, few studies have evaluated the fit and accuracy of custom post-and-core quantitatively by micro CT scanning nor have they evaluated the fit and accuracy of CPC by visual inspection or direct measurements of the gap filled with cement material, as have been used to evaluate the internal fit and adaption of dental restorations.[34,35]

The authors recommend additional studies to evaluate fit accuracy of post-and-cores groups after final finishing and polishing procedures using different types of cements. Furthermore, because of the limitations with using one commercial laboratory for the fabrication of milling titanium, and another laboratory for printing titanium, the authors suggest future studies and further investigations to evaluate fit accuracy and internal adaptation of post-and-cores that are fabricated from different materials and manufacturers

CHAPTER FIVE

CONCLUSION

Within the limitations of the present study and based on the findings, the use of custom printed and milled titanium post-and-cores showed comparable results when compare to custom cast gold post-and-core. Custom milled zirconia post-and-cores revealed significantly lower retention compared to other groups. The use of titanium alloy fabrication of post-and-core is effective in retention and could be an alternative material of choice to gold alloy. Among 4 groups, the custom milled zirconia post-and-core showed least bond to resin cement materials, leading to significantly lower post retention. Further studies with in-vivo testing is required to confirm the conclusions from this study.

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